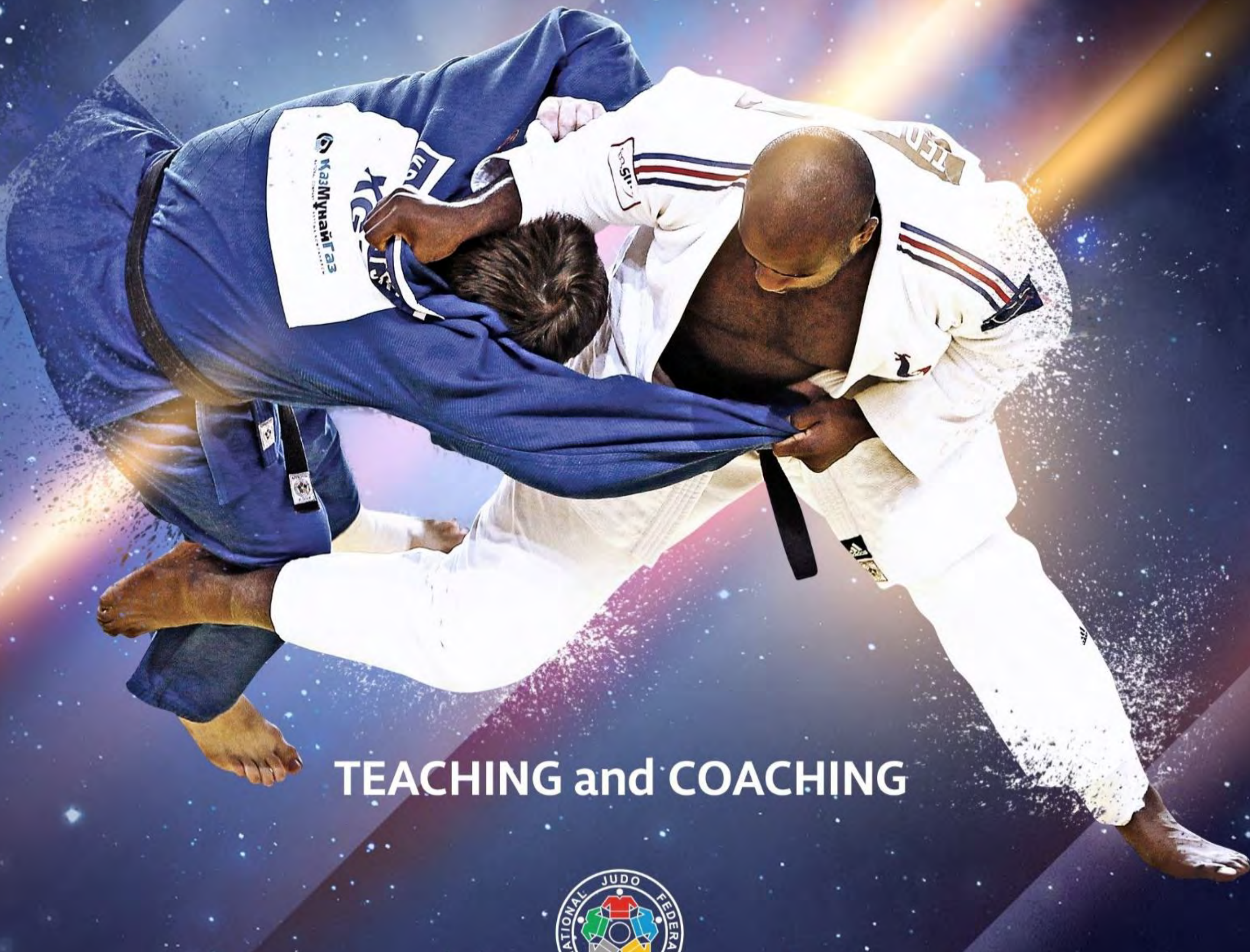
ATTILIO SACRIPANTI

JUDO
BIOMECHANICAL SCIENCE FOR IJF ACADEMY



TEACHING and COACHING

IJF
ACADEMY

Attilio Sacripanti

JUDO

Biomechanical Science For IJF Academy (Special Edition)

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The Author winner of the First European Scientific Award at European Senior Judo Championship (Lisbon 2021)

An annotated guide to ten different book's lectures

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And to my wife Valeria for her support.

Attilio Sacripanti

Foreword
By Mr Marius L. Vizer
President of the International Judo Federation IJF

The Academy was established in 2013 to serve our National Judo Federations in the professional development of Judo. We are always in search of the best experts in Judo and Sports Science. We would ask Professor Attilio Sacripanti, a foremost expert in Judo Biomechanics, to provide us with his research in this field of Sports Science.

Since 1988, Professor Sacripanti has been studying Judo in all forms of physics. So his review of his famous book, first published in Italian, would come in useful to our Coaches and Students.

In his last edition, we are happy that he has added some more exciting topics most useful for Judo's teaching, especially for our Academy.

We appreciate all the years that Dr Sacripanti has dedicated to our sport

Marius Vizer
President
International Judo Federation

Message from Envic Galea, Chair of the IJF Academy

I met Attilio in the ’80s during a National Italian Judo Refereeing Seminar in Rome at the Domus Maria, where both were National Referees. I was a guest of the Italian Judo Federation. We became friends, and I was immediately impressed with Attilio's depth of scientific knowledge in Judo Biomechanics and Sports Science.

We kept in contact throughout the years. We collaborated in many Judo Seminars, mainly when I was Education Director for the EJU. I had introduced the collaboration of the Medical Commission and the Judo Coaches. Attilio managed always to prepare outstanding, scientifically-backed presentations on all the topics we had.

Attilio’s love for Judo and Biomechanics' expertise contributed in no small way to our sport's scientific development.

Science and Judo studies are the basis of our IJF Academy. So, it was evident that sooner or later, his work would come in useful. I had already read his first book on Judo Biomechanics, first published in Italian. So I asked him if he would prepare a textbook on Biomechanics, especially for our IJF Academy students.

I believe he delivered an excellent collection. I am sure this book will be appreciated by our alumni and Judo coaches, and researchers worldwide.

Envic Galea
Chair
IJF Academy

Introduction to the Special Academy Edition 2021

"Branches grow due to the healthy roots."

Eleven years passed away from my second edition in English of my book on Judo Biomechanics. Here we are, with the third completely enlarged and revised Special edition.
Judo world is dramatically changed in the last years and more from the first Italian edition almost forty years ago.

Due to Mr Marius Vizer, IJF Presidents, the Olympic Judo now is the third Olympic Sport as Sponsors. Two hundred countries are under the Judo Olympic Flag, a splendid evolution from his Olympics born in 1964.

Nevertheless, thanks to Mr Envic Galea's dynamic vision and the EJU Committees, Judo's scientific part also grows in importance and application.

Japan has an active group of researchers, and eminent researchers are present in many countries, like Brazil with Francini, Miarka, Boscolo Del Vecchio, etc. Us with Imamura, and Matsumoto, Korea with Kwon, Kim and Cho, but it is Europe that showed the most dramatic increase in studies on Judo, with the development of exciting researches in many countries like Belgium, Bosnia-Herzegovina, Croatia, France, Germany, Italy, Poland, Portugal, Russia, Serbia, Spain, with renowned researchers such as, among others: Adam, Blais, Baudry, Busch, Callan, Carratala, Challis, Chalmet, De Blasis, Dopico Calvo, Garcia Garcia, Heinish, Kaijmovic, Monteiro, Paillard, Pierantozzi, Roux, Segedi, Sertic, Sterkowicz, Thiers, Trilles, Vieten.

All these researches were accompanied by an exciting project proposed by EJU Envic Galea from Malta, former EJU General Secretary. He organised a teaching facility for judo teachers and coaches based on six levels with Bath and Anglia Ruskin's English universities in Cambridge. In the Italian University of Roma Tor Vergata, an International Master's Degree, ISO 9001, the highest EJU structure title, was organised and directed by the author. Now all coach qualification has been transferred to the IJF Academy. During these years' science in the world changed abruptly. Scientists rose from an unsophisticated point of view in physics and biomechanics. They adopted an organic synthetic approach.

Today, many branches of science's synergetic influence converge in a complete athlete's knowledge, seen as a complex system.
However, this strong growth in Science was only possible because judo roots were healthy and deep in the world. Furthermore, today, the tree is significant, and branches help roots grow ever more deeply into the world.

Now it is time to grow the final aspect of judo that Jigoro Kano foresaw in its setting, educating young people through this sport as better citizens.

Introduction to the English Edition 2010

“Very strong roots for a big tree.”

Mystic understands Judo roots, but do not understand his branches; Scientist understands Judo branches but not his roots.
Science does not need mysticism, and Mysticism does not need science, but perfect Judoka needs both.
This sentence was in the first edition introduction.
After twenty years, it is possible to see that Judo Tree is massive, with powerful roots and branches covering the world.
However, why did a very strange “Pyjama Game” born in a small country gain considerable global diffusion?
At first, the imposing Kano action in the world to spread around his primitive “Pyjama Fight”, for a second the entrance into the Olympic (Tokyo 1964) in connection to the “*tragedy*” of the loss of Akio Kaminaga against Anton Geesink that changed the “fight” into “game” for the Monaco Olympic 1972.
“Judo Game” also fits the other Kano idea: the whole personal development of this sport is a tool to build not only physical capabilities but also mental resilience and self-discipline.
Also, Kano's forecasting by Jita Kyo Ei by (Mutual welfare and benefit for all) the second cornerstone of Judo; the first one was Maximum efficiency for expended efforts.
All this is about the right and powerful roots that this Japanese Man was able to give to his creation: Ju Do
Ok, we speak about the sturdy roots of this strange “Pyjama Game,” but what about his branches?
If you hear the speech of Japanese Judo experts, you could listen to only words about roots
But if you read Yokoyama, in his transcription of Dr Kano lessons in “Judo Kyohan”, you can read *“About physical training, Judo is important because the developing body also gives the technical ability to fight, …about fighting techniques. Judo is again superior because every part of the body works in agreement with the physiological laws. The application of forces agrees with the principles of mechanics. …finally, the mind works in agreement with psychology”.* In one other chapter about the body’s balance, Yokoyama wrote, “*Much erudite mathematical proof can be applied for the explication of this problem … but we prefer to explain it by the simple example of a stick motion in space...*”
It means that branches, or the metaphor: the scientific knowledge in judo were present among the founder and the first judo students.
After that, they omitted scientific knowledge for a long time. However, when Japan was preparing for the first Judo entry in the Olympic Games, the Japanese people, Kodokan Institute, and all the Japanese Universities made a considerable effort to revitalise the branches of the “Judo tree”. Starting officially in 1958 till 1963, the First and Second report of the “Bulletin of the Association for the Scientific Studies on Judo, Kodokan” contain a complete scientific biomechanical survey on Judo.
Under the direction of Risei Kano and scientific supervision of Dr Michio Ikai and Prof Yoshizo Matsumoto, it is possible to read about: Choking, Kinetics of Throws, Throws Energy Metabolism, Conditioning, Physical Fitness, Studies on Throws respect to the distribution of body weight, Throws electromyographic studies, studies on arm lock, etc.
After the Olympic preparation, not only knowing roots but also studying branches more in deep. These and other studies flowed in a fascinating Japanese Book of Y. Matsumoto. “Judo Coaching”, never translated in western countries.
Now Judo is an Olympic Sport, worldwide known. All countries bear original contributions to his branches to improve knowledge and coaching science at the service of athletes.
This book is my second little contribution to the loved Judo Sport: a massive and beautiful tree with strong roots.

Introduction to the Italian Edition 1988

Zen, Physics and Judo.

At first glance, these three "Ways" look very different, without a contact point, three other concepts …. with a huge abyss among them.
Nevertheless, suppose we study them more in-depth, at the bottom of their heart. In that case, we can find similarities and relationships not thought which relates them closely, more and more than it seems at a rushed sight.
Zen and Physics goal is to let know the life mystery through two very far ways: the first the" Mystic's" method or the form of the "Irrational Perception", the second one the "Scientist's" approach or the state of the "Rational Perception".
Zen is a "Liberation Way" that free man from frills and provisional transience, allowing him, by "Irrational Perception", to obtain the "Satori" (Illumination). A condition in which body and mind are melted in one complete harmonic unity with the whole universe.
After obtaining the illumination, life and daily actions flow in naturalness and simplicity, following the natural rules.
For this is the reason for which Po Chang defined Zen as "When you are hungry, eat; when you are tired, rest!" While the difficult task is to regain the loosen naturalness. The well-known Zen sentence indicates this: "before studying Zen, mountains are mountains, and rivers are rivers, while you are studying Zen, mountains are not more mountains, and rivers are not more rivers, but when you achieve the Satori, mountains are again mountains, and rivers are still rivers.
Physics is an "Intellectual Way" that freeing phenomena from frills of movements and parasitic forces. It lets men obtain a word's "conceptual map" using Rational intuition. Limited, schematic and approximated, the tool explains the mystery of reality that surrounds and encloses him.
They are overcoming the boundaries of the visible world and getting more and more into the heart of subatomic reality. Modern Physics today reaches a perplexing, similar vision obtained by mystics about two thousand years ago.
An "Organic" view absorbs the Newtonian mechanical theories and their associated determinism. The observer and phenomena of the universe must be a harmonious whole.
Judo "The gentle way" is an activity that, following the Zen experience, may be utilised to train the mind to grasp "Satori". By applying physics, knowledge may be used to obtain "Victory" in competition.
High-level Judo is an expression of simplicity and spontaneity; in other words, in it, the characteristics of Zen research inhabit. The judo mastery needs a perfection of execution that can be obtained only when the technique is not knowledge but joins spontaneity.
Can you grasp Judo Physical Knowledge? Like Mystics and Scientists starting from the opposite side of the knowledge, now they reached a similar point of view. It is possible to study from the scientific point of view Judo to know it more in-depth. If you read the book of Yokoyama and Oshima "Judo Kyohan" you can find these words in it:
"*About physical training, Judo is important, because developing body it also gives the technical ability to fight, …about fighting techniques, judo is again superior because every part of the body works in agreement to the physiological laws, the application of forces agrees with principles of mechanics, …finally the mind works in agreement with psychology".*
From these words, it is possible to declare: ***Mystics understands Judo roots but do not understand its branches. Scientist understands Judo branches but not its roots.***

Science does not need mysticism, and Mysticism does not need science, but perfect Judoka needs both.
For this reason, I try to give all judo lovers a scientific view of Judo to provide a small contribution to the scientific Judo knowledge.


WORLD
FRA

Part one

Biomechanics for modern Sport

Chapter 1 Biomechanics

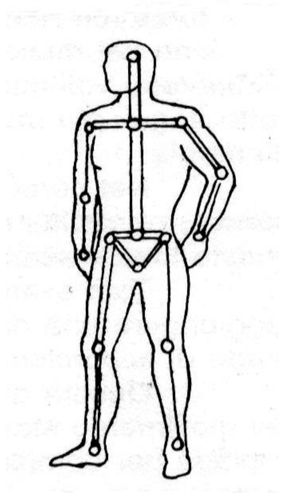
1.1 Classical Biomechanics

Biomechanics involves the precise description of human movement and the study of the causes of human movement.
The study of biomechanics is relevant to professional practice in many professions.
The coach teaching movement technique and the athletic trainer use biomechanics to qualitatively or quantitatively analyse movements.
Biomechanics' study requires an understanding of musculoskeletal systems' structure and their mechanical properties and their deep interconnection with the central nervous systems and the environmental influences on athletes.
Mechanics is the branch of physics that measures objects' motion, finds the forces and explains the causes of that motion.
Knowledge of the mechanics of judo movements allows professional coaches to understand those movements, develop specific training exercises, and change movement techniques to improve performance
Most sports biomechanics studies are based on rigid-body models of the skeletal system (see Biomechanical Athlete). Rigid-body mechanics can be divided into statics and dynamics: Statics study objects at rest or in uniform (constant) motion. Dynamics is the study of things being accelerated by the actions of forces.
Biomechanics in judo ranges from Newtonian Mechanics. If we study throws, choking, armlocks, holdings, and other "simple" technical motions, the Statistical Mechanics and Chaos theory must analyse the competition. (see Appendix I).
However, with a good approximation, most of the judo applications are bounded in the field of Classical Dynamics
Dynamics is concerned with determining the forces of motion.
Examples of kinetic variables in Judo are the forces between the feet and the mat or the grips' push-pull forces.
Understanding these variables gives the coaching knowledge of the good or bad judo performance of the causes (among others).

1.1.1 Biomechanical Athlete

In Biomechanics, the man's acting force is the force that he can apply to the external environment by the body's working points (for example the grips, or the feet on the mat)
The foreign bodies' contact points transmit both motion (linear momentum and kinetic momentum) and energy (translator and rotatory movements). The anatomic-physiological description of these motor actions, like bones and muscles activities, would be challenging. Consider that 200 bone segments form the skeleton, act more or less than 1000 muscles organised as single systems and groups.
This difficulty demands a simplification. We introduce at bone level rigid segments connected by hinges. At muscle action, the resultant for that abstraction is named "Biomechanical Athlete". It shall move only in terms of reciprocal rotation among his parts as the actual human body.

We define in this optics the *"Biomechanical Athlete*". We visualise it as "***A solid at variable geometry and cylindrical symmetry. This body can assume different postures, normally situated in unstable equilibrium into the gravitational field, over a plane surface with friction. This Biomechanical Athlete can produce by joints only defined rotations."***



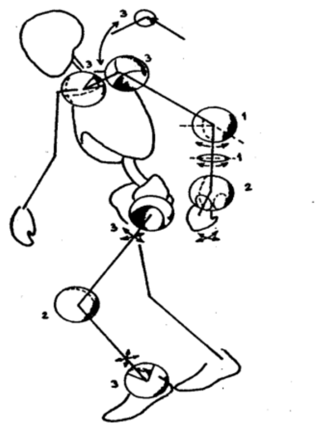


Fig 1.1.1.a, Biomechanical Athlete ***Fig.1.1.1.b, Articulations' degree of freedom***

From this definition, it is possible to state a simple consideration very easy but not worldwide known. The Biomechanical Athlete (like a man) can produce only defined joint rotations; it will translate from a well-known theorem:
"Necessary and Sufficient condition, so that a series of joint motion rotations will produce a translation will be that the relative angles addition should be zero to produce a rotation. The relative joint angles addition should be different from zero."

However, it is essential to know joints by their potential motion, by means their degree of freedom; in that function, it is possible to have:

1. Joints with one degree of freedom: all the diarthrosis can move in one plane, like only the elbow or the fingers' flection extension.
2. Joints with two degrees of freedom: all the diarthrosis can move in two orthogonal planes like the knee in the sagittal plane flexion-extension and rotation in the frontal plane. Alternatively, again, the elbow can produce flexion-extension and in the orthogonal plane pronation-supination.
3. Joints with three degrees of freedom: there are all the diarthrosis that can produce the maximum number of motions, two translations and one rotation; they are the neck, shoulder, hip, and ankle joints

Muscular contractions produce joint motions. Physically speaking, joints are hinges that are moved by a resultant of muscular forces. Whatever kind of muscles and tendons insertion on the bones, during movement (isotonic contraction), one of the tendons' inserts on the head of muscle is fixed, and the other is movable. The result is the movement of the bone on which is attached to the movable tendon insertion.
The lever mechanics regulate the different kinds of motion, with the connection joint as a fulcrum. However, we must remember that the sports gestures are complex motions of levers systems produced by muscular groups' synergic actions.
From Physiology, there is known that every motion came from the cooperation of three muscular functional categories.

1. Agonistic Muscles that fight against resistances and start motion
2. Antagonistic Muscles that balance and break the agonistic action
3. Fixing Muscles that guarantee the bones stabilisation is giving the right fixedness for the movement.

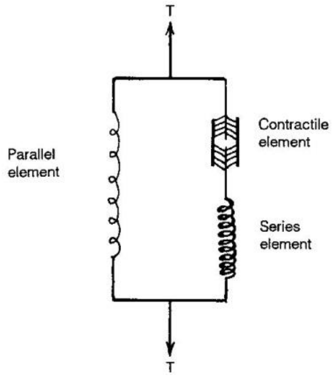
In practice, the peri-articular muscles can act both agonistic and antagonistic. Their tensile status can change the degree of freedom, from three to one degree of freedom producing motion in one specific direction and with the necessary speed.
In the joints with two or three degrees of freedom, the sportive technique is applied by the sequence of working muscles. Usually, the agonistic contraction gives the motion direction. The antagonistic provides speed, but in determining complex motion like judo throws, the muscles function could change over time. this role interchange is due by the reason that it is not possible a perfect balance of contractions in every muscle, unless after prolonged and constant conditioning and training that will flow in the most economical and practical application of the judo technique, following Kano thinking Maximum effort with minimum energy expenditure

1.1.2 Neuroscience of Muscular System.

The spinal mechanisms, which evolved in primitive vertebrates, are being studied to determine the degree to which spinal circuitry can recover primary postural and locomotor function after severe paralysis.
The most complex movements that we perform, including voluntary ones that require conscious planning, involve control of these basic spinal mechanisms by the brain.
Scientists are only beginning to understand the complex interactions among different brain regions during voluntary movements, mainly through careful animal experiments.
One important brain area responsible for voluntary movement is the motor cortex. This area of the brain exerts dominant control over the spinal cord through direct control of its alpha motor neurons.
Some neurons in the motor cortex specify the coordinated action of many muscles to produce the organised movement of a limb to a point in space.
Others appear to control only two or three functionally related muscles, such as those of the hand or arm, that are important for finely tuned, skilled movement. In addition to the motor cortex, movement control involves the interaction of many other brain regions. This area includes the basal ganglia, thalamus, cerebellum, and many neuron groups located within the midbrain and brainstem — regions that send axons to the spinal cord.
Scientists know that the basal ganglia and thalamus have extensive connections with the cerebral cortex's motor and sensory areas.
The cerebellum receives direct information from all the sensory receptors in the head and the limbs, and most areas of the cerebral cortex
The cerebellum acts to integrate all this information to ensure smooth muscle action coordination, enabling us to perform skilled movements as judo throwing techniques automatically.
Considerable evidence indicates that the cerebellum helps us adjust motor output to deal with changing conditions, such as growth, weight changes.
It tunes the motor output to be appropriate to the specific requirements of each new task.
The ability to adjust our strength, throwing an adult or a child, depends on the cerebellum.
However, both for simple and complex movements such as moving a finger or throwing an adversary, not only we can find neurons in that finger's area of the motor cortex active, but so were neurons in the cortical regions in other fingers. The entire hand's representation in the motor cortex participates even in simple acts, such as moving one finger. Furthermore, again, the total cortex will participate in a throwing motion.

1.1.2.1. Warm Up and Biomechanics of Muscular System

The most important part of the biomechanical athletes is their muscular-skeletal system because muscles are the engine of all actions applied during the fight.
These engines are very complex (see para. 1.2.1), but the macroscopic mechanical properties have been well known for a long time.
It is possible, for example, to remember the two Borelli experimental laws or the Rouvier laws. In short, we will follow both on muscles and the less recognised ligaments, also essential in joint mechanics during motor actions.
The mathematical model of muscle came from Maxwell. With this model, it is possible to build the constitutive equation of muscular mechanics and obtain isometric (constant length) and isotonic (constant tension) contraction.



$$T = P + S$$

$$dT/dt = dP/dt + dS/dt$$

$$\frac{dT}{dt} = \left(\frac{dP}{dL} + \frac{dS}{d\eta}\right)\frac{dL}{dt} + \frac{dS}{d\eta}\frac{d\delta}{dt}$$

$$L = \cos t \rightarrow \frac{dT}{dt} = \frac{dS}{d\eta}\frac{d\delta}{dt} e \frac{d\eta}{dt} = \frac{d\delta}{dt}$$

$$T = \cos t \rightarrow \frac{dL}{dt} = \frac{-\frac{dS}{d\eta}\frac{d\delta}{dt}}{\frac{dP}{dL} + \frac{dS}{d\eta}}$$

Fig 1.1.2 a Maxwell muscle model

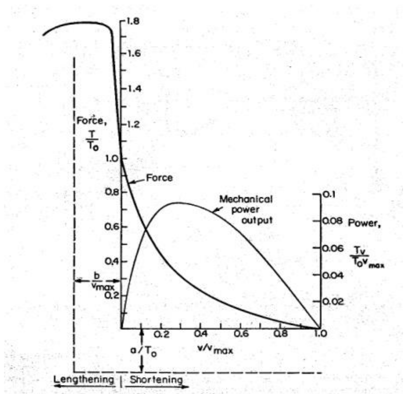
T= Tension; P= parallel contribution; S = Series contribution; L = Muscle length

Mechanical characteristic of muscles

The force of a muscle varies and can be described by three mechanical characteristics.
These characteristics deal with muscle force variations because of differences in velocity, length, and time relative to activation.

Force-Velocity Relationship

The well-known **Force-Velocity Relationship** (Hill) equation $(v+b)(F+a)=b(F_0+a)$ explains how fully activated muscle force varies with velocity. This activity is the most crucial mechanical characteristic because all three muscle actions (eccentric, isometric, concentric) are reflected in the Judo actions.



v =contraction velocity.
F = Muscular Force
F_0= Maximum Isometric Force
a, b= constant.

Fig 1.1.2.b Hill F/v curve

Force–Length Relationship

The **Force–Length Relationship** documents how muscle tension varies at different muscle lengths. The variation in potential muscle tension at different muscle lengths also affects how movement is created.

Force–Time Relationship

The **Force–Time Relationship** refers to the delay in muscle tension development and can be expressed as the time from the motor action potential to the rise or peak in muscle tension. The Force–Time Relationship is often referred to as the **electromechanical delay** in electromyographic (EMG) studies. This delay in the development of muscle tension has implications for the coordination and regulation of movement. Tendons make the connection between muscles and bones. Their elastic properties are connected to muscle contraction transfer and optimisation of torque, but the guide of joint motion are based on the ligament's properties

Ligaments are tough connective tissues that connect bones to guide and limit joint movement

Most joints are not perfect hinges with a constant rotation axis. They tend to have small accessory motions and moving axes of rotation that stress ligaments in several directions.

The collagen fibres within ligaments are not arranged in parallel like in tendons but in various directions. As bone, ligaments and tendons remodel according to the stresses they are subjected to. The musculoskeletal system's ability to adapt tissue mechanical properties to loads of physical activity required by judo guarantees a low risk of injury for conditioned people. But when a trained individual pushes himself beyond the tissue's physiological ability, the accident is ever-present

We see that a similar attitude is current in Sports before the pilots warm the engines from the car racing. The muscular engine needs to be warmed.

Warm-Up

The warm-up will improve the effectiveness of training and should be done before every training session. This is fundamental to safe practice.

- ***Direct physiological effects:***
    1. *Release of adrenaline*
        - Increased heart rate
            - Enables oxygen in the blood to travel with greater speed
            - Increased production of synovial fluid located between the joints to reduce friction, allowing joints to move more efficiently
        - Dilatation of capillaries, enabling oxygen in the blood to travel at a higher volume, increasing his washing task (lactic acid and carbon dioxide)
    2. *The increase of temperature in the muscles*
        - Decreased viscosity of blood, enabling oxygen in the blood to travel with greater speed
        - Facilitates enzyme activity
        - helps the dissociation of oxygen from haemoglobin
        - Decreased viscosity within the muscle, increasing both. extensibility and elasticity of muscle fibres and force and rate of contraction
    3. *The increase in muscle metabolism*
        - Supply of energy through the breakdown of glycogen
    4. *Increase in rate of nerve impulse conduction.*

- ***Direct psychological effects***. The most critical phases for judo players are:

    1. *Breaking off the environmental interferences.*
    2. *Cooling down the anxiety and other emotional disturbances*
    3. *Remembering the learnt motor task*

Saito, Kimura, Matuzaki, Masaki and Shinohara, performed a specific study on the effectiveness of warm-up intensity in judo practice. The purpose of the study was to investigate the optimum intensity of Warm-up for intermittent exercise in judo.
The Warm-up load was 30%, 60% and 75% of the maximum oxygen uptake.
The results were as follows. The 60% condition was the best for the highest power value from the performance test. On the contrary, the 75% condition was the lowest.
It was also indicated that the load of the warm-up of the interval motion was not effective in 30% or less of oxygen uptake. This research showed that the intermittent exercise's warm-up's optimum intensity was 60% of maximum oxygen uptake. A final consideration suggests that, as a general rule, a medium intensity warm-up should be helpful in competition. On the contrary, hard warm-up and lower intensity warm-up could be not valuable.

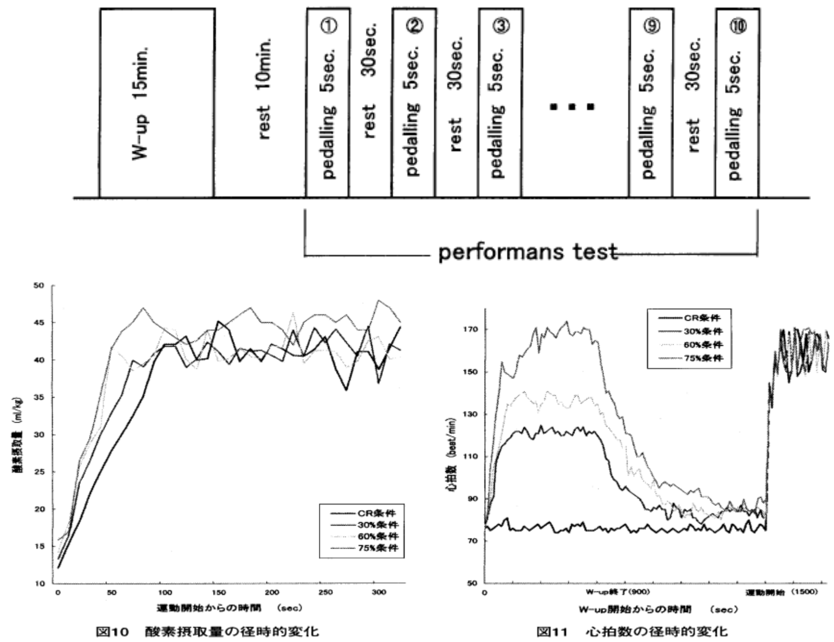


Fig 1.1.2.b,c Saito experiences on judo warm-up results.

1.1.3 Deformation of Biomechanical Athlete, Energy and Fatigue.

Deformations of Biomechanical Athlete

During an actual judo performance, the Biomechanical Athlete cannot be considered a rigid body. The complexity of movement must be analysed to evaluate the energy consumption.
The athlete's body undergoes some deformations that could be classified into three families:

1. **Postural Deformations**
   The kinetics chains' positional variations, under external and internal forces
2. **Muscular Deformations**
   The muscular variation in length, diameter, and tension under nervous stimuli activation using internal chemical energy stored.
3. **Internal Deformations**
   The passive displacement of the organic fluids and soft tissues under the body's accelerations and decelerations, which yield internal and passive friction forces

Postural Deformations are born by movements finalised to judo techniques. Motion energy will waste into improper motions during kinetic chains by internal frictions, viscosities, inertia, etc. Biomechanical Athletes will develop mechanical energy by the transformation of chemical energy in muscles.

Because the internal energy sources are not endless, the Biomechanical Athlete cannot be seen as an isolated system. However, we must consider the energy exchanges between man and the environment (respiration, sweat evaporation, thermal emission and so on).
All these are indirectly evaluated by oxygen consumption. Fuel gives us the gross energy consumption connected to the movements' efficiency.

Energy

The last advanced research in biochemical and biomechanics shows us that the glycolytic system is non-linear (see Appendix II). Nevertheless, the treatment shown in this paragraph will be classical.
Energy stored in the chemical bonds of adenosine triphosphate (ATP) is used for muscular power activity. Three basic energy systems accomplish the replenishment of ATP in human skeletal muscle: (1) phosphagen, (2) glycolytic, and (3) oxidative.
All the processes are interconnected, and their evolution in time is complicated.
The better way to have a clear overview of the energy systems activation is to show them in a concise analytical way.

- **Phosphagen System**
  - Provides ATP primarily for short-term, high-intensity activities (e.g., sprinting) and is active at the start of all exercise regardless of intensity
  - ATP Stores, about that there are essential some remarks on the argument
    - The body does not store enough ATP for judo practice.
    - Some ATP is needed for primary cellular function.
  - The Phosphagen System uses the creatine kinase reaction to maintain the concentration of ATP.
  - The Phosphagen System replenishes ATP rapidly
- **Glycolysis**
  - Glycolysis is the breakdown of carbohydrates—glycogen stored in the muscle or glucose delivered in the blood—to synthesise ATP. The result of Glycolysis (pyruvate) may proceed in one of two following directions:

  1) Pyruvate can be converted to lactate.
      - ATP resynthesis occurs at a faster rate but is limited in duration.
      - This process is sometimes called anaerobic Glycolysis (or fast Glycolysis).

  2) Pyruvate can be shuttled into the mitochondria.
      - When pyruvate is shuttled into the mitochondria to undergo the Krebs cycle, the ATP resynthesis rate is slower. However, it can occur for a longer duration if the exercise intensity is low enough.
      - This process is often referred to as aerobic Glycolysis (or slow Glycolysis).
- **The Oxidative (Aerobic) System**
  - This system is the primary source of ATP at rest and during low-intensity activities
  - It uses carbohydrates and fats primarily as substrates
  - Interconnected to the Glycolysis is the Glucose and Glycogen Oxidation (aerobic Glycolysis)
    - The oxidative metabolism of blood glucose and muscle glycogen, which begins with glycolysis, leads to the Krebs cycle. (Recall: If oxygen is present in sufficient quantities, the end product of Glycolysis, pyruvate, is not converted to lactate but is transported to the mitochondria, where it is taken up and enters the Krebs cycle.)
    - ATP is produced from ADP.

It is also interesting to remark, for completeness of information, the energy Yield of Glycolysis processes both from blood glucose and muscular glycogen:

- Glycolysis from one molecule of blood glucose statistically yields a net of two ATP molecules.
- Glycolysis from muscle glycogen statistically yields a net of three ATP molecules.

•

As a result, the phosphagen energy system primarily supplies ATP for high-intensity activities of short duration, the glycolytic system for moderate- to high-intensity activities of short to medium length, and the oxidative system for low-intensity activities in the long term. The extent to which each of the three energy systems contributes to ATP production depends primarily on muscular activity intensity and secondarily on the duration.

Some short remarks about the Lactate and Glycolysis process.

Glycolysis leads to the Formation of Lactate

- The result is *not* lactic acid.
- Remember that Lactate is *not* the cause of fatigue
- Lactate can be transported in the blood to the liver, where it is converted to glucose. This process is referred to as the Cori cycle.

– Glycolysis also leads to the Krebs cycle in the case of Oxidative Glycolysis.
  - Pyruvate that enters the mitochondria is converted to acetyl-CoA.
  - Acetyl-CoA can then enter the Krebs cycle.
  - The NADH molecules enter the electron transport system, where they can also be used to synthesise ATP.

– Lactate Threshold and Onset of Blood Lactate
  - Lactate Threshold begins at 50% to 60% of maximal oxygen uptake in untrained individuals, and at 70% to 80% in trained athletes.
  - The onset of blood lactate is a second increase in the rate of lactate accumulation. It occurs at higher relative intensities of exercise and when blood lactate concentration reaches four mmol/L.

Fatigue

Can be the lactate be connected to muscular fatigue?

Today, scientists seem more dubious about that.

In every part of the sports' world, lactate is utilised to indicate the athletes' fatigue state. However, on the boundaries of the researches, every day, there are indications that the lactate capability, as a fatigue indicator, is not correct. Lactate has traditionally been blamed for almost all muscle fatigue.

However, recent scientific evidence has demonstrated this to be highly unlikely.

The second evidence was that muscles' inability to contract after repeated contractions resulted from maintaining potassium balance. The mechanism proposed was: Muscle cells release potassium as part of the contraction process, but the cells try to recover all the potassium afterwards. Very rapid repetitive contractions cause the muscle cell to release so much potassium so quickly that the re-uptake mechanism cannot keep up.

Our understanding of fatigue has advanced tremendously during the past several years. The last findings are that the real reason is not merely metabolic. However, one of the first actors is the SR Ca^{2+}. One argument against purely metabolic mechanisms of muscle fatigue and in favour of an essential role for defects in SR Ca^{2+} release is the finding that after strenuous exercise, human muscle exhibits a sustained depression in force generation that can persist for up to several days.

This period corresponds to the period over which prolonged inhibition of SR Ca^{2+} release is observed.

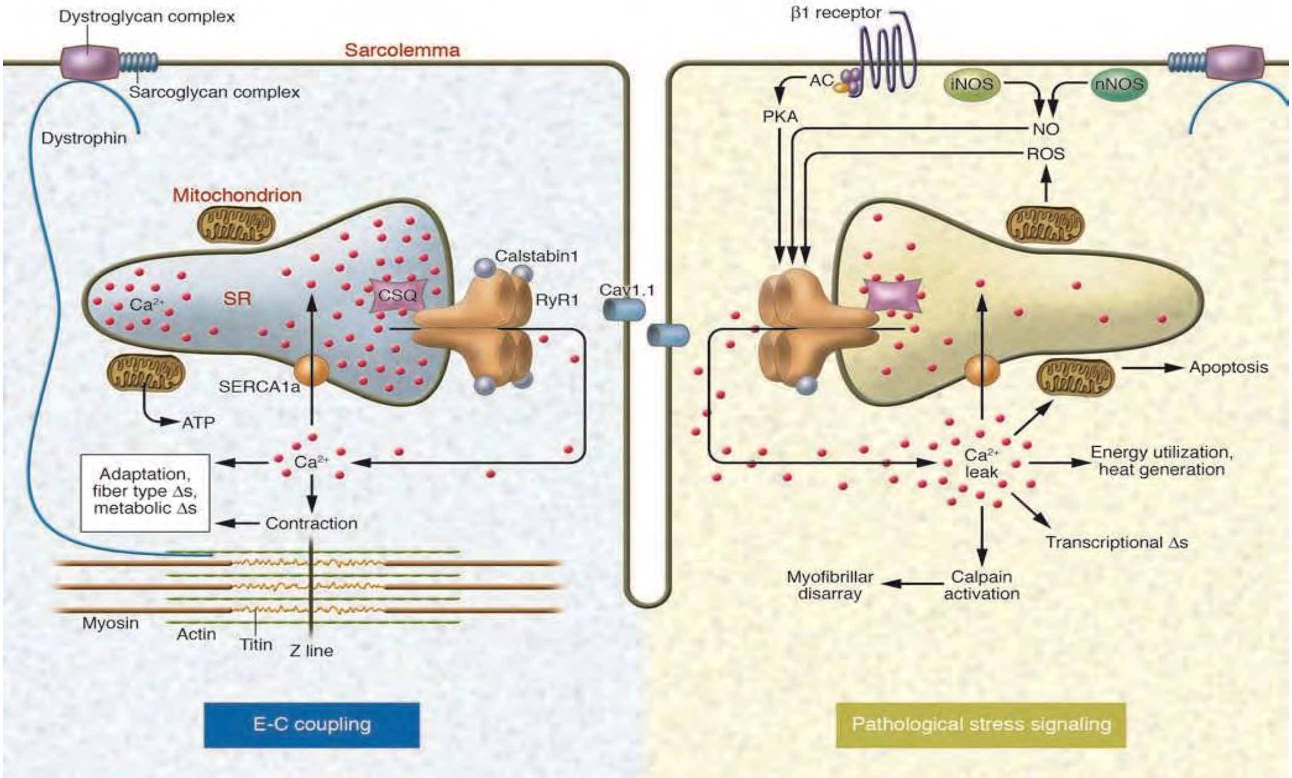


Fig 1.1.3. The stress response in skeletal muscle during E-C coupling. Depolarisation of the T-tubule membrane activates Cav1.1, triggering SR Ca2+2+ release through R y R 1 and leading to sarcomere contraction, a process is known as E – C coupling. Intercellular signalling pathways activated in skeletal muscle by pathological stress affect RyR1 function and alter E-C coupling. Stress-induced RyR1 dysfunction can result in SR Ca2+ leak, which potentially enables numerous Ca-dependent cellular damage mechanisms. AC adenylate cyclase.

From Bellinger and co-workers. Stressed out: the skeletal muscle ryanodine receptor as a target of stress The Journal of Clinical Investigation Volume 118 Number 2 February 2008

We know that fatigue arises from several potential causes: energy fatigue, pain and mental fatigue, and dehydration.

Energy fatigue is the principal cause of fatigue in most athletes. This occurs when our muscles cannot generate energy fast enough to sustain muscular contractions' desired power.

Coaches and Athletes have long been taught that lactate accumulation causes fatigue but has recently shown the reason is the defects of SR Ca^{2+} release.

If scientific experimentation indicates the SR Ca^{2+} release as a primary cause of Fatigue, what is lactate's function? According to the last few years of experience: Lactate is:

A valuable energy source within working muscles and non-working muscles are subject to training-induced improvements in fuel use. Quantitatively, it is the most critical contributor to the making of glucose in the liver

-

1.1.4 Biomechanics of Motor Actions

Dynamical non-linear systems theory has emerged in science as a viable framework for modelling athletic performance. From a dynamic systems perspective, the human movement is a highly non-linear network of co-dependent sub-systems (e.g. respiratory, circulatory, nervous, skeleton-muscular, and perceptual). These are composed of many interacting components (e.g. blood cells, oxygen molecules, muscle tissue, metabolic enzymes, connective tissue and bone). (See 1.2) A critical theoretical concept - yet fully explored in judo throws – is the kinetic chain theorem. This theorem defines the kinetic chain as a proximal-to-distal linkage system through which energy is not conserved. However, momentum is transferred sequentially and achieving maximum magnitude in the terminal segment. It is still unclear how body segments are coordinated to optimise energy and momentum transfer. To understand better how body segments are organised in fast throwing movements. Sports bio-mechanists should refrain from reducing time-series data to discrete kinematic measurements and their corresponding time histories. Because this is in the linear theory of motion, optimisation and coordination are usually not linear processes. This simplifying procedure fails to capture the essential profound dynamic nature of the fast throwing movements. In conclusion, the non-linear theory applied to motor control seems to be a relevant framework for actual performance-oriented sports biomechanics research.

Motor Actions

Activities with a motor objective are those in which the intentionality focuses on aspects associated with the motor activity itself: throwing the competitor, holding, gripping, shifting, etc.

In all of these practices, the final goal has to do with or is focused on motor activity.

Continuing with the previous example, walking to fight against an adversary does have a motor objective to grips the competitor

Motor Action Science studies it as a fundamental and unitary aspect by the non-linear systems theory. It is a scientific discipline whose field of study is precisely these situations: complex (non-linear) physical activities of sports nature.

Its object of study is precisely the motor action; thus, it studies the conditions, modes of operation, and results of carrying out this type of move like throws, holds, arm lock, etc.

In the first approximation, it is possible to use a linear simplifying theory of motor actions. However, if we can understand the system's effective inner dynamic, we need to use non-linear theories.

Motor Actions are the basic unit of analysis because they are what we can see and observe in the course of a fight.

Motor actions can be studied independently of the specific individuals carrying out the activity. The bio-mechanist may understand the basic steps that are invariant in every action (see Action Invariants). To single out these fundamental components of Motor actions, there is a better understanding of the Non-linear System "*man*" acting in the Couple System during the dynamics fight process.

1.1.4.1. Study on Motor Action: Gripping

Grip fighting is one crucial part of the judo competition. If a judo athlete reaches an optimum grip position, he considers psychologically ahead with a clear benefit to its competition.
The multijointed action present in a judo grip movement is studied intensely in neuro-mechanics for general purposes.
A significant role of the motor system is to interact with the environment.
As expressed in Newton's third law, this interaction is two-way: action and reaction are equal, opposite, and simultaneous.
The resistance characterises the mechanical interaction with the environment modulated by the neural input to imposed motion (mechanical impedance Hogan, 1985),
A significant component of mechanical impedance resisting human movement arises from the viscoelastic tissue properties.
Although the slow response of neural processes limits voluntary movements, impedance responds instantaneously.
Thus, it is fundamental to tasks involving fast dynamic changes such as during impact with the adversary's body during grip fighting.
The mechanical behaviour at the endpoint of the limb is generally the most important because most interactions occur there.
In principle, impedance depends on the position, velocity, and muscle activation.
To examine how impedance varies with movement direction, one can measure the restoring elastic force to small displacements of the hand in different directions (Burdet et al., 2000).
Most movements of the joints can be performed using various muscle combinations, which is called *muscle redundancy*. On the other hand, in reaching movements, infinitely many paths can reach the target. The muscles can theoretically be activated with infinitely many different temporal activation profiles to produce different velocity profiles, referred to as *trajectory redundancy.*
Despite an infinite number of possible ways of grasping an object, observations suggest that humans consistently employ similar postures and paths. The hand trajectory is usually quite straight with a Gaussian velocity profile *v* which a fourth-order polynomial can model. Then the final hand velocity takes the following form:

$$\text{v(t)}=(t_n^2 - t_n + 1)\frac{30At_n^2}{T} \;; \qquad t_n = \frac{t}{T}$$

Where *t* is the time, *A* is the movement amplitude, and *T* the duration of movement (Flash & Hogan 1985).
Usually, impedance is a nonlinear function of the three primary parameters. However, in a linear model, the impedance can be represented by three components — stiffness, viscosity, and inertia — which depend on body geometry.
Naturally, subjects tend to take a position where the final impedance is adapted to the task performed.
See the following figure 1.1.4.1a. This means that body position must be studied to perform one adequate grip in judo; this is true even for grip fighting. A wrong body position can drive in breaking symmetry that could be disadvantageous for the athlete.

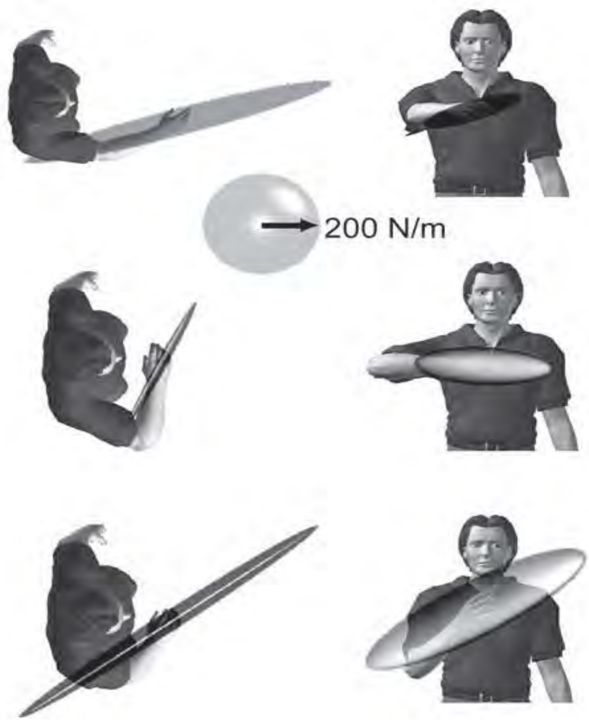


Fig.1.1.4.1a Man tends to select a posture adapted to the task (Trumbower 2009)

Many studies have been performed during these last five years in the world on grips; for example, Endel increases maximum grip force during power grip (2010).
In neuroscience, a fascinating work performed by Hadjiosi and Smith (2015) has found much in-depth information about the adaptation of grip to environmental changes. In the following figure, some of the most important results.

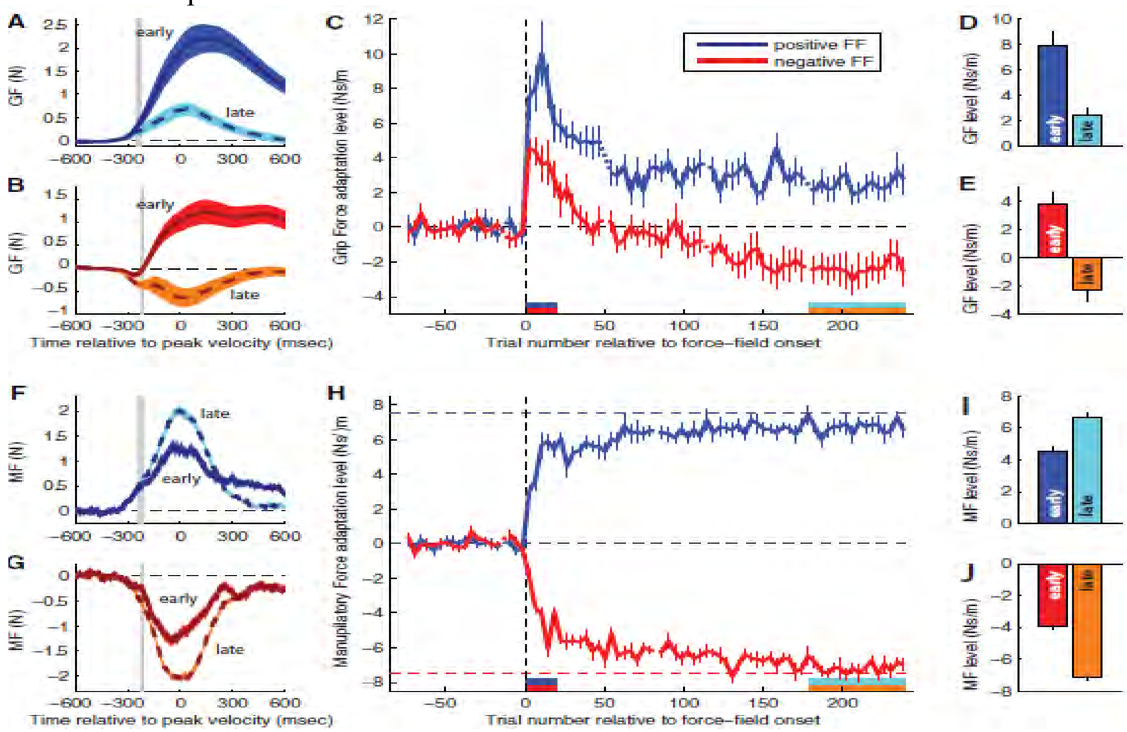
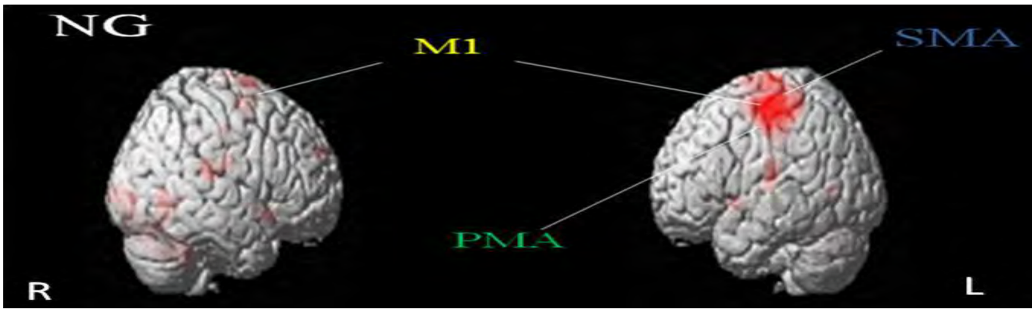


Fig. 1.1.4.1.b Grip Force (GF) shows an asymmetric non-monotonic adaptation curve following opposite perturbations. However, Manipulative Force (MF) shows a different adaptation curve.

In neuroscience, grips the last time are also studied using Magnetic Resonance Imaging (MRI). Some results show that strong grips present a higher activation area concerning regular grips in both brain hemispheres.



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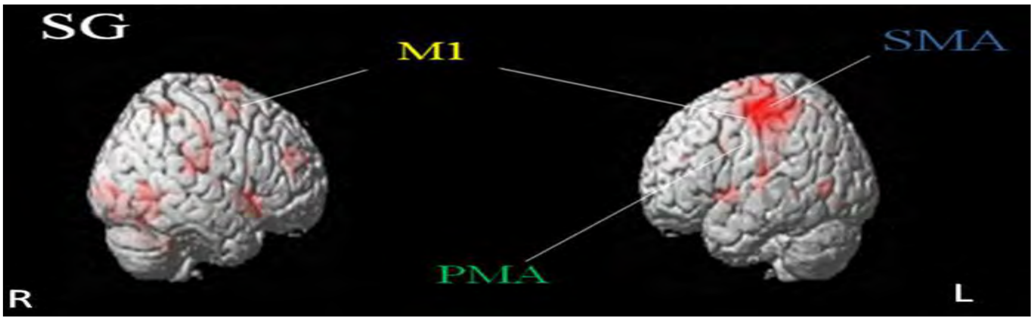

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Fig. 1.1.4.1.c, d. Regular Grip (NG) versus Strong Grip (SG) activation areas.

Both images show the activation of the Primary Motor Area (MI) of the Supplementary motor area (SMA), Premotor Cortex areas, both dorsal and ventral (PMA). However, the intensity of the signal was more substantial in SG than in NG.
Different information comes from Power Grip (PG) and Precision Grip (PRG). In this case, the activation area is stronger in precision than in Power grip execution.

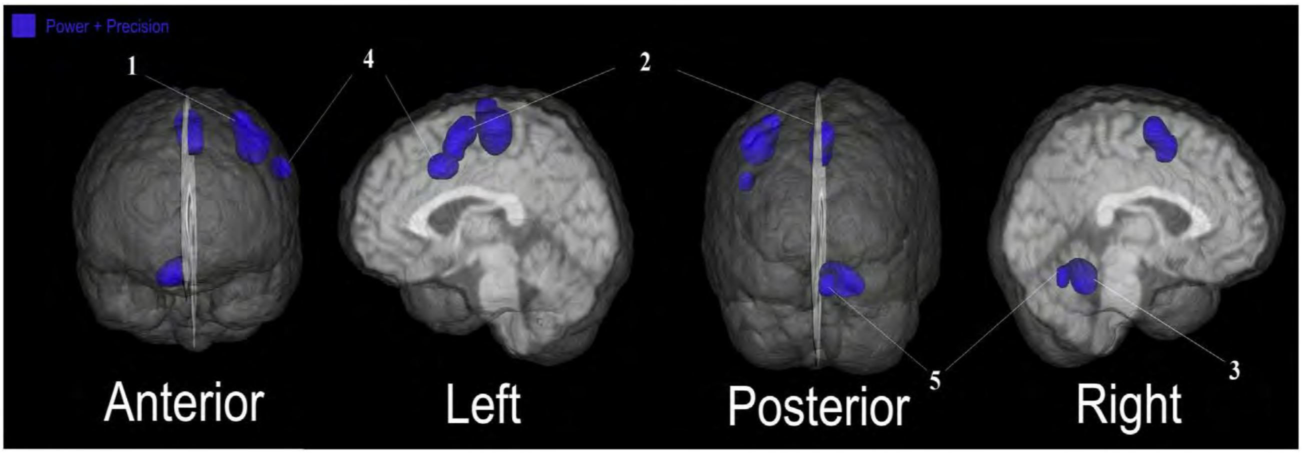

Fig.1.1.4.1. e Common activation areas between Power Grip and Precision Grip

1.1.5 Human Body Equilibrium and Stability

The human body cannot be assimilated to a rigid body, assembled by mobile segments connected by joints. It is better to show it as a deformable system of geometric solids (see Biomechanical Athlete). Such a system is balanced when all the external forces and torques are balanced. In the kinetic chains between two bone segments, there is equilibrium or if the upper element lays on the under elements by the joint, or the muscles fight against external forces to save the balance

For two bones connected by joints, the mechanical condition of balance are:

1. All the segments' centres of mass must be lined up along the gravity line.
2. All the segments' rotation axes must be lined up
3. The gravity line must pass through the polygonal base called "Trapezoidal Optimal Surface "or "Support Base".

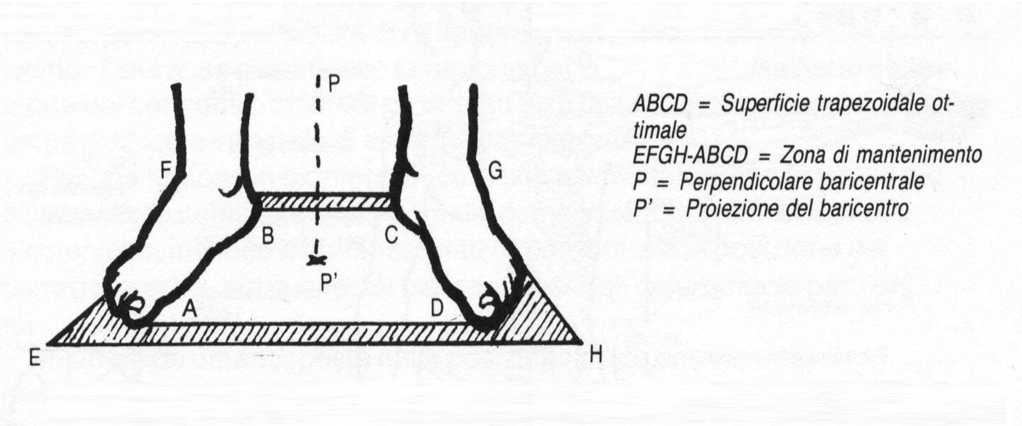

Fig 1.1.5.a = Support base and preservation zone

After the right conditioning time, all the postural reactions can be considered first detected at the cortical level by proprioceptive sensors, after obtaining by not conscious muscular contractions at the spinal level.

An Athlete increases his stability by many different pseudo-static methods, for example, when his line of gravity is centralised within his optimal trapezoidal surface. He increases his support base's size when he lowers the height of his centre of gravity.

Some other systems to obtain better stability are connected to the body's motion itself; for example, an increase in Friction can improve an athlete's stability. Rotation can improve an athlete's stability. Shifting the line of gravity toward oncoming forces can improve stability.

Bidimensional Equilibrium relies on three conditions:

$$Static\ 1)\sum_{i=1}^{n} F_v = 0 \quad 2)\sum_{i=1}^{n} F_i h_i = 0 \quad 3)\sum_{i=1}^{n} T_i = 0$$

$$Dynamic\ \ 1)\sum_{i=1}^{n} F_x - m\bar{a}_x = 0 \quad 2)\sum_{i=1}^{n} F_y - m\bar{a}_y = 0 \quad 3)\sum_{i=1}^{n} T_g - I_g\alpha = 0$$

F= forces T = torques h = centre of mass height I= Inertial moment a,α= linear and angular acceleration.

1.1.6 Human Body Centre of Mass (Shizentai, Jigotai, Tanden)

The centre of mass of the human body is the application point of the resultant of weight forces; the centre of mass of the body accelerates in response to the gravitational and contact forces acting on it. Generally, in every homogeneous body, the centre of mass is determined by its geometrical shape and mass distribution in space.

However, the human body is a composite body that can change shape when not in contact with other bodies (like a couple of athletes), the human body is in free fall (unstable equilibrium)

The Centre of gravity is when the mass can be imagined acting by a well-known theorem. In formulas, the previous sentence can be written:

$$x_{com} = \frac{m_1x_1 + m_2x_2 + m_3x_3 + \ldots}{m_1 + m_2 + m_3 + \ldots} = \frac{\sum_i m_i x_i}{\sum_i m_i}$$

$$y_{com} = \frac{m_1y_1 + m_2y_2 + m_3y_3 + \ldots}{m_1 + m_2 + m_3 + \ldots} = \frac{\sum_i m_i y_i}{\sum_i m_i}$$

$$\vec{r}_{com} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2 + m_3\vec{r}_3 + \ldots}{m_1 + m_2 + m_3 + \ldots} = \frac{\sum_i m_i \vec{r}_i}{\sum_i m_i}$$

Deriving

$$v_{x,com} = \frac{m_1v_{x,1} + m_2v_{x,2} + m_3v_{x,3} + \ldots}{m_1 + m_2 + m_3 + \ldots} = \frac{\sum_i m_i v_{x,i}}{\sum_i m_i}$$

$$v_{y,com} = \frac{m_1v_{y,1} + m_2v_{y,2} + m_3v_{y,3} + \ldots}{m_1 + m_2 + m_3 + \ldots} = \frac{\sum_i m_i v_{y,i}}{\sum_i m_i}$$

$$\vec{v}_{com} = \frac{\sum_i \vec{p}_i}{M} = \frac{\vec{p}}{M}$$

With x_{com}, y_{com}, r_{com}= coordinate of the centre of mass x,y,r =coordinate of the mass particle of the body
v_{com} = velocity of Centre of mass v_i = velocity of a mass particle of the body

In athletes in a standing position, it is in the pelvic region near the spine's base. The centre of gravity is standing still in the abdominal cavity, about 12 cm above the pubis symphysis.

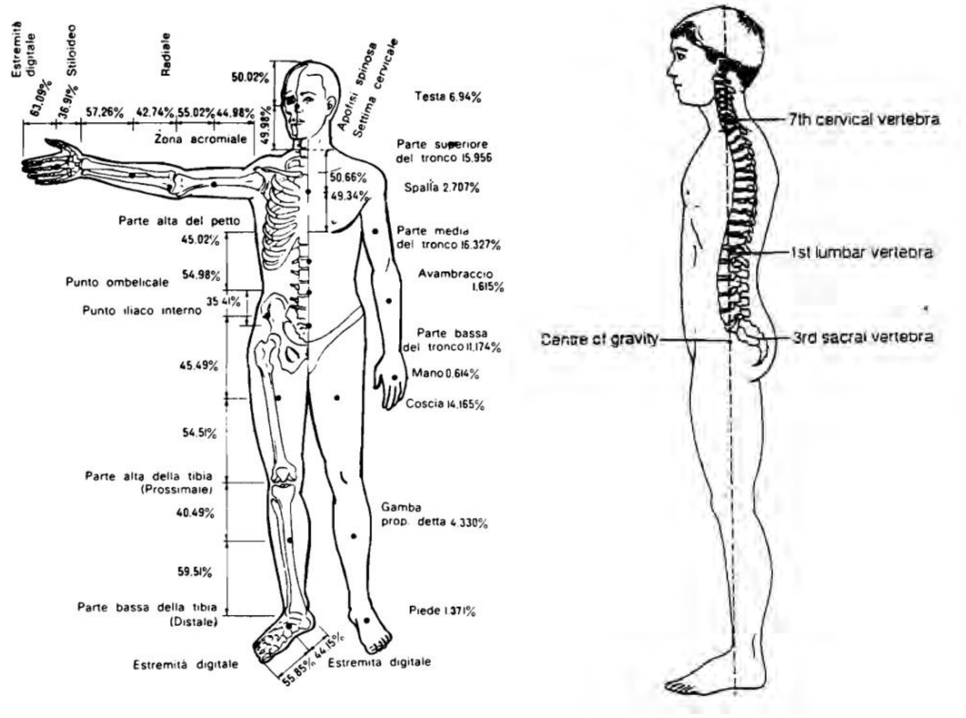

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Fig. 1.1.6 a,b= Centre of Mass of the human body and its constituent parts.

The Centre of Mass, however, is a theoretical point inside the body. ***It is not fixed*** and depends on the human body's case from its limbs' relative position.
As the athlete’s position changes, so do its centre of gravity. In male athletes in a standing position, the CM is near the second sacral vertebra; for the female Athletes, its position is 1-2% lower if we take 100 the body height. The intersection point between CM perpendicular and support base is into the Optimal Trapezoidal Surface in a standing still position.
Studies performed at Kodokan on these arguments showed that the position of the intercept point (Counted 100 the foot length) changed from 46.5% to 43-42%, considering both the judo position of the natural Shizen Tai and the defensive Jigo Tai.
Comparative studies on interception point position, like stability, among judoka, kendoka and kyudoka showed that the judo posture was more stable than the others, around 1.2-1.4%.
The previous studies performed on the Tanden positioning. Specifically, Saika Tanden (Kinesiological Analysis of Shizentai) with the dr Hasekagwa method (Shintai Kinsei no Kagaku) showed that CM and Tanden were not coincident. Because the Tanden is lower than 1% for CM and the support base's interception point is advanced about 1.6%.
From that point, it shall be correct in biomechanics to referee at the body’s Centre of Mass and not at Tanden.

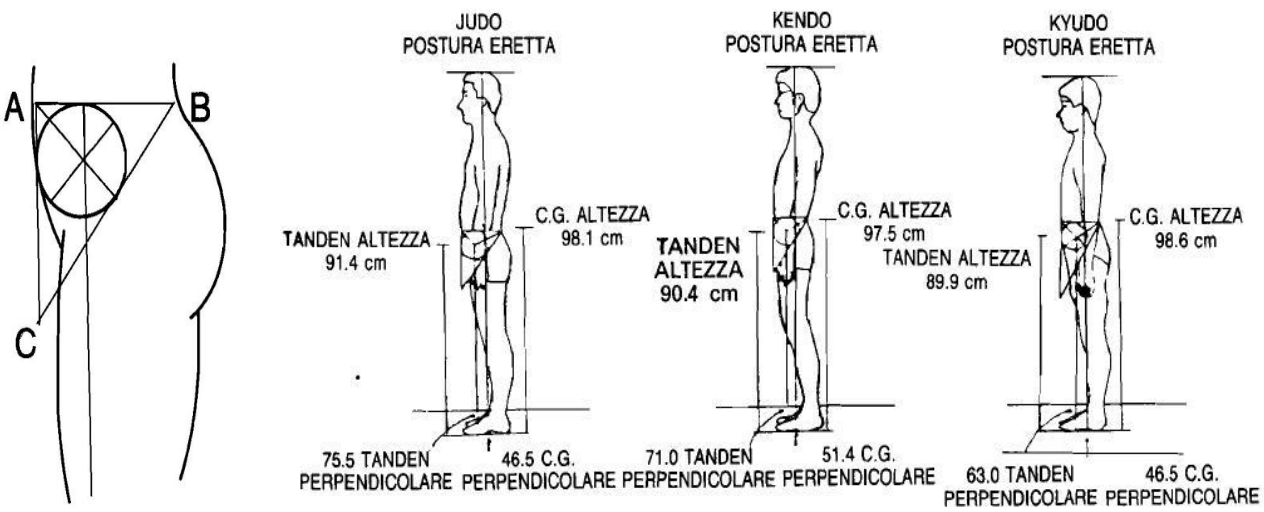


Fig 1.1.6.b,c= Tanden and centre of mass positions in different martial art basic posture

1.1.7 On-Site Body's Rotation (Tai Sabaki)

The rotatory motion on-site and the rototraslatory movements are called in judo: Tai Sabaki.
From a biomechanical point of view, they can be classified as rotatory movements with the conservation of angular momentum or variation of angular momentum.
In the first case, there will be only internal forces to the systems (roughly isolated). In the second one, there are external forces that will produce the rotation.
To obtain a specific rotation velocity, ω (t^{-1}) shall depend on the difference between agonistic muscles' action and the break of antagonistic muscles connected to the time application of force.
Remembering that $s = r\theta$ it is possible to obtain:

$$F = \frac{mv^2}{r} = mr\omega^2 = \frac{mr^2\omega^2}{r} = \frac{I\omega^2}{r} \quad (mlt^{-2})$$

Physiologic mechanics means to increase the rotation velocity. An increase in the tension produces a torque of agonistic muscles. Antagonistic muscles have a simultaneous decrease in torque. In the training term, if we increase rotation velocity, we must also train the antagonistic muscles. For example, training on the right side means also applying some techniques of the same biomechanical group on the left. This exercise increases the rotatory capability of the athlete.
The conservation principle of angular momentum makes it possible to increase the angular velocity, decreasing inertia's momentum. For example, applying Tai Sabaki with the arms extended. After using the same Tai Sabaki with tightly shut arms, the decrease of the radius of gyration will produce the increase of angular velocity of the athlete, in formulas:

$$\begin{aligned}
&if\ \ I_1 = m_1 r_1^2 > I_2 = m_2 r_2^2 \\
&the\, conservation\ \ principle\ \ gives \\
&I_1\omega_1 = I_2\omega_2\ \ then \rightarrow \omega_1 < \omega_2
\end{aligned}$$

All Judo Throws based on a Tai Sabaki to gain contact with the Uke body will be faster if the Tai Sabaki happens in a curled up position. Furthermore, suppose these techniques belong to the physical lever group. In that case, they shall also be energetically more convenient because the lever arm increases and the force applied for throwing decreases. Consequently, it should also decrease the energy expenditure (as the overall conditions do not change). See the following figure for the application

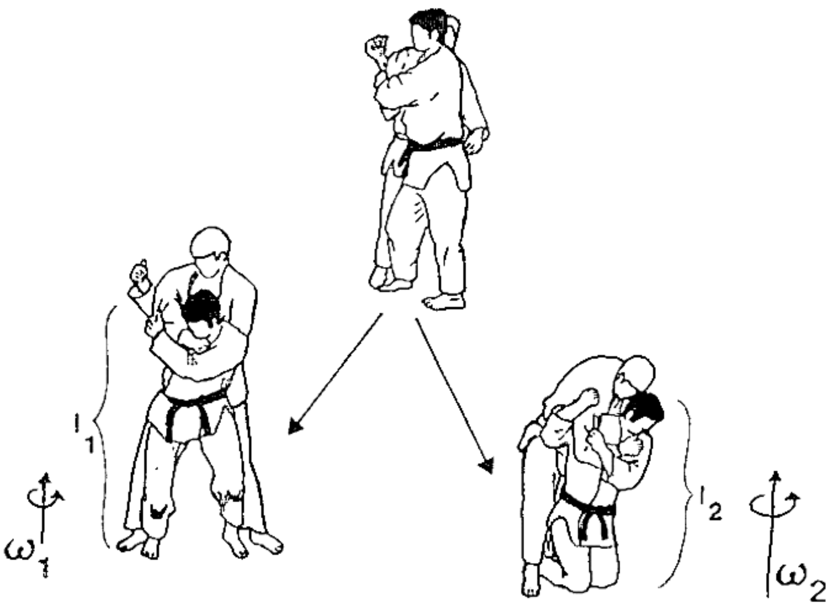


Fig 1.1.7. a = Conservation of momentum in standing and suwari seoi produces a decrease in energy expenditure

1.1.8 Locomotion (Ayumi Ashi, Tsugi Ashi)

The Judo locomotion in the competition (Aruki Kata) can be divided into two groups Ayumi Ashi (normal locomotion) and Tsugi Ashi formally (foot follows foot)

Human walking biomechanics is a very complex branch of Kinesiology. The actual knowledge on walking mechanics came from many types of research, the first ones at the start of the previous millennium.

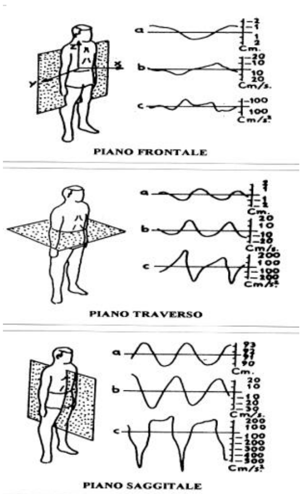
As we demonstrate in the first edition (Biomeccanica del Judo), the Tsugi Ashi is energetically convenient for Ayumi Ashi and more stable concerning external disturbance through push/pull forces.

Walking is a cyclic activity in which one stride follows another in a continuous pattern.

We define a walking stride as being from a touchdown of one foot to the next touchdown of the same foot or from toe-off to toe-off. There is a single support phase in walking when one foot is on the ground and a double-support phase when both are touching the ground. The single-support phase starts with the toe-off of one foot, and the double-support phase begins with the touchdown of the same foot.

The coordinated human walking movements are generated not from an explicit representation of each anatomical segment's precise trajectories as in bipedal robotics but by dynamic interactions between the nervous system, the musculoskeletal system, and the environment. Different types of movement exist and are associated with different kinds of commands. (1) Voluntary movements are integrated at the cortical level and can be initiated without any external stimulus. (2) Automatic movements are memorised strategies that are elicited by internal commands or external stimuli. (3) Spinal reflexes are genetically programmed responses to external stimuli, modulated by superior centres. A primary concern of the CNS is to maintain dynamic stability during locomotion in competition. Dynamic stability during movement is the control of the centre of mass (COM) within a changing base of support and requires effective proactive and reactive recovery response strategies when exposed to perturbations

The motion of COM is not a simple motion for the athlete's dynamic stability, as it is possible to see in the following figures in the symmetry planes of the human body.



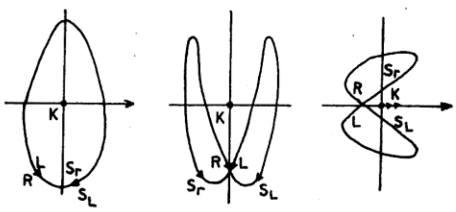


Fig 1.1.8. a,b Motion of COM in the three symmetry planes of the human body and relative curves

The mean interactions in judo competition are push and pull forces applied into a couple of athlete’s systems.

Few studies have been applied to this particular part of the competition and the human body's response to perturbation during walking.

During maintenance of postural equilibrium, COM is kept within the support base by activating appropriate muscles that move the centre of pressure (COP). During locomotion, the same principle for COM control applies, with one crucial difference: foot placement at the end of each swing phase provides the primary method of moving COP in the sagittal and frontal planes.
The results from a recent study on locomotion illustrate this clearly.
In this study, individuals were walking on a treadmill. At the same time, unexpected mechanical perturbation (push) to the upper body in the frontal plane was applied during the two single support phases. A push to the right when the left foot is in the single support phase produces the right swing limb's abduction and subsequent increase in step width.
In contrast, a push to the right given when the right foot is in the single support phase produces adduction of the left swing limb and a subsequent decrease in step width see the following figure

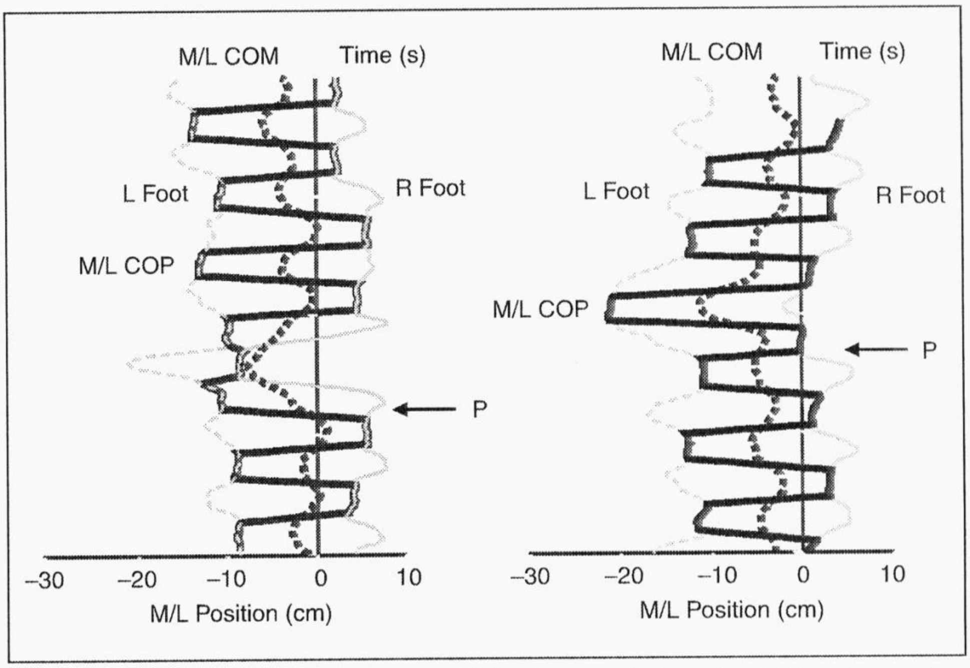


Fig. 3. COM and COP profiles before and following a push from the right at the shoulder level while the person was walking on a treadmill are shown. COP profiles are estimated from foot marker profiles. The left panel shows response when the left foot is on the ground: note how the right foot crosses over to be placed ahead of COM. The right panel shows response when the right foot is on the ground. Perturbation onset (P) is indicated by an arrow.

Fig 1.1.8.c From A.E. Patla, N. Wijneberg, and S.W.D. Hill, "Control of COM by COP explains The response reversal observed during medio-lateral perturbations applied during Human locomotion," Gait & Posture, vol. 9 (suppl. 1): S4, 1999.

1.1.9 Reflexes and Motor Control

Motor control is a broad term that describes the general ability to initiate and direct muscle function and voluntary movements. A related expression, "motor skills," refers to performing specific physical movements, like judo throws or groundwork techniques. Motor control is divided into two subsets. Gross motor control and Fine motor control is the ability to manipulate precise movement. The voluntary motor system, also known as the somatic nervous system, is the structure that permits and creates motor control. Sports performance is a complex mixture of biomechanical function, emotional factors, and training techniques. This action is most accurate in demanding situational sports like Judo. Sports performance has four distinct aspects, each of which is highly variable. The four areas include neuromuscular factors, the relationship between the nervous system and its dimensions and the musculoskeletal system; mental control and psychological factors; environmental conditions; and coaching and external support for the athlete

A **simple reflex** is entirely automatic and involves no learning. Examples of such reflexes include the sudden giving up by hand kick in response to a painful arm lock stimulus. The simple reflex can be modified by the brain's involvement – for instance. Humans can override the automatic reflex to giving up by the hand.

A **conditioned reflex** involves the modification of reflex action in response to experience (learning). Classical conditioning (also called Pavlovian conditioning after its discoverer Ivan Pavlov) consists of the creation of a conditioned reflex; conditioned responses are probably adaptive because they prepare the organism for the forthcoming unconditioned stimulus

Operant Conditioning

The second type of conditioning, operant conditioning, does not involve reflexes at all.
Instead, certain kinds of voluntary behaviour, usually skilled motor behaviour, are affected by the following consequences.
Stimuli associated with contingencies do not force response, as in the case of reflexes. Instead, such stimuli alter the likelihood that behaviour will occur. For example, the "open" sign on a restaurant's door makes it likely that someone ready for a meal will open the door because of experience.
The new behaviour can be created through operant conditioning using a procedure called shaping or reinforcing successive approximations of the target behaviour. for example, a dog can learn to roll over if a skilful trainer provides it with food and praise (the reinforcement) for closer and closer approximations of rolling over during a training session

1.1.10 Skill, Reaction Time and Anticipation

Skill

Skill is a consistent part of judo practice that is applied in competition.

There are many definitions of skill. In the sportive area, the following general description can be accepted as sufficiently acceptable. ***Skill is the effective production of goal-oriented motor actions, which are learned and specific to the sportive task.***

Generally, the sports area's skills are classified as a function variable between closed and open skills. In our definition, skill is a goal-oriented activity.

The nature of the goal will determine how we evaluate the level of its performance. Typically there are many kinds of skill classifications.

One classification of skill is *'fine motor* versus *gross motor* skills. Fine motor skills are rarely found in sport and require the use of few limbs and are undertaken in limited space.

On the other hand, most sports skills are gross motor skills. They require the use of several Limbs, often the whole body, and tend to take place in a comparatively large amount of space. Even though sports skills are gross motor skills, much that has been written about skill acquisition comes from research using fine motor skills.

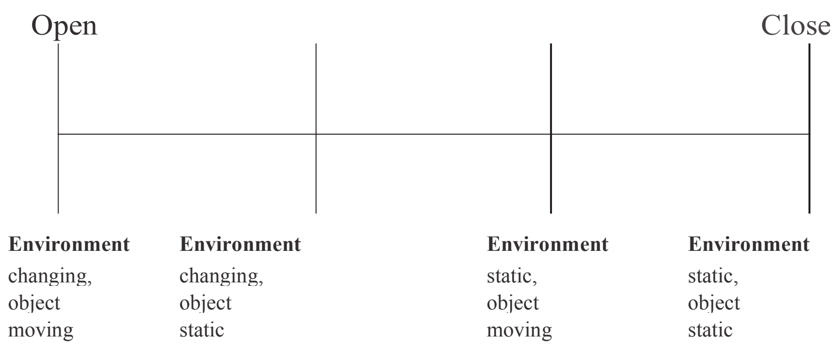
Whether delicate or gross, skills have been divided into *discrete, serial* and *continuous.* Discrete skills are definable beginning and end, such as a set shot in basketball, a free-kick in soccer, or a throw in any sport.

Discrete skills concern the performance of *one* action in isolation from other movements. On the other hand, serial skills are when we join together two or more discrete skills. This classification can be helpful to us when examining some aspects of practice and learning. One of the most used categories of skill is *simple* versus *complex* skills.

The British psychologist Poulton (1957) did not use complex and straightforward terms but was relatively *open* and *closed* to distinguish between these skills. According to Poulton, open skills require much information processing and take place in environments rarely, if ever, wholly repeated.

The change in the environment means that every time the skill is performed, the performer must modify their technique to achieve the same goal. Or even use a different method to achieve the goal. Closed skills, on the other hand, take place in the same or very similar environments. Therefore the same technique can be used repeatedly.

In the following diagram, it is possible to understand the skill classification proposed by Poulton and refined by Gentile (1975)



Diag. 1.1.10.a from Open to Closed Skill Classification by Diagram (Gentile 1975)

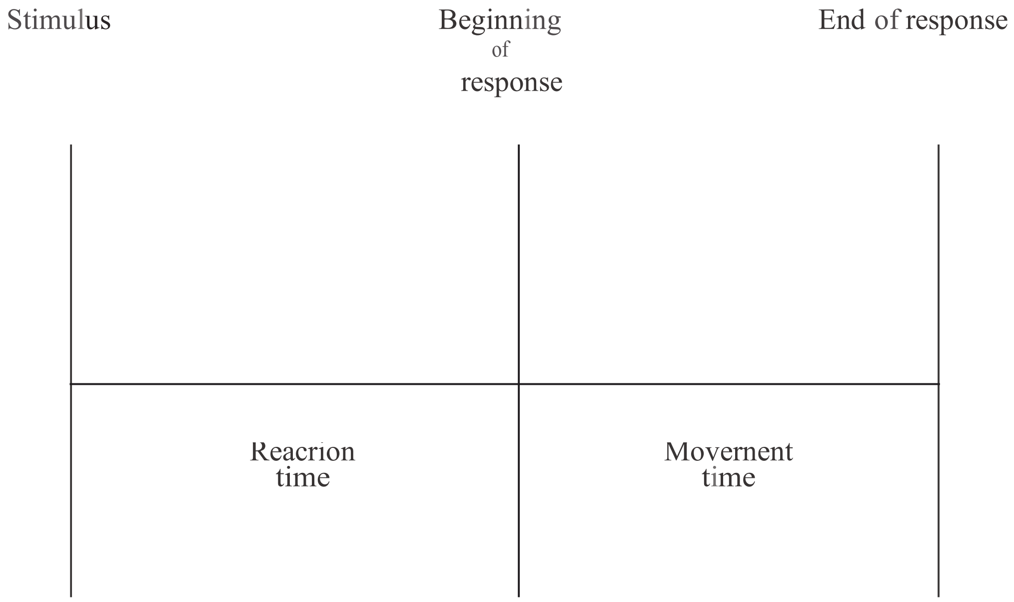
The performance of judo skills needs to be carried out very quickly if the athlete is successful. To find the right moment to apply the throw and avoid the attack and apply kaeshi waza, all need to respond quickly.

It is also evident that there are limitations in how quickly individuals can respond. Sometimes, what is required of us is beyond our capabilities.

Before examining how theory attempts to explain this, we need to be fully aware of what we mean by reaction time.

People often use the term 'reaction time' when, in fact, they are talking about response time. *Response time* is the time from starting *a stimulus to completing the action required to deal with the problem.*

In effect, response time is produced by two parts “reaction time” and “movement time”. See the following Diagram.



Diag. 1.1.10b ***Response time composed by (Reaction time + Movement time)***

The two concepts are different and separate entities
A judo athlete can have a fast reaction time but slow movement time or vice versa.
While movement time describes the actual physical activity, reaction time attempts to explain the invisible CNS activity. *Reaction time elapses from the sudden onset of a stimulus to the beginning of a movement response* (Oxendine, 1968).
The critical point here is that, like response time, it starts with introducing the stimulus but ends at the *beginning* of the response, *before the motor act* begins.

Anticipation

Anticipation allows us to determine what is going to happen before it does happen.
Anticipation could be classified into two areas *perceptual anticipation* and *interceptive actions.* Generally, Judo is utilised at 90% perceptual anticipation, defined as the athlete’s ability to predict upcoming movement based on partial information. It depends on selective attention, pattern recognition and working memory. It could be enhanced by the use of video analysis and motor imagery.

1.1.11 Biomechanical Classification of Sports

There are several sports classifications:

1. Referring to the energetic expenditure (physiological and biomechanical classification, Dal Monte A., (1983)
2. Referring to the complexity of the motion (physical and biomechanical classification)
3. Referring to the kind of motion needed to perform: refined by A. Sacripanti (2004)

- ***Cyclic Sports*** (with a basic repeated motion): namely those whose performances are based on a specific cyclic motion or movement repeated over time. Thus the performance could be investigated through the analysis of these repeated motions or actions.

- ***Not Cyclic*** or ***Acyclic Sports*** (the basic movement is performed just once). Namely, those whose performances are strictly related to a specific movement or gesture performed only once; motions and performances could be investigated by analysing these particular motions or actions.

- ***Alternated-Cyclic Sports*** (several basic repeated and alternated motions or movements): namely those whose performances are defined by two or more basic motions or gestures, repeated alternatively over time, so that performances could be analysed investigating individually each movement or gesture, thanks to the theorem of the independence of simultaneous actions.

- ***The situation or Contest Sports*** (movements without repeatability patterns): namely those whose performances are not characterised by repetitive and straightforward temporal patterns of the performed activities due to the presence of one or more opponents. So, there is no fixed pattern over time, and the theorem of independence of simultaneous actions may not be applied. These sports may not be investigated by analysing summed or linked simple actions. Because of the presence of opponent/s that tries/try to counteract the performed skills and make the ongoing situation not repeatable but classifiable only statistically speaking. Therefore, if studying the motion, in this case, is meaningful on a statistical basis only. It makes no sense to analyse it by Newtonian physics. However, more efficient and less approximate methods are required, such as Statistical Physics and, being these dynamic systems, the Chaos Theory.

The Situation Sports could be classified as:

- Dual Sports
- Team Sports.

Each class has two sub-classes:

- No contact (with the opponent/s)
- With contact (with the opponent/s).

Situation's Dual Sports		Situation's Team Sports	
No Contact	With Contact	No Contact	With Contact
Badminton Squash Table Tennis Tennis	Boxing Exrimia Fencing Lucha Canaria Lucha Leonesa Judo Karate Kick-box Koresh Sambo Savate Sumo Taekwondo Wrestling	Baseball Cricket Softball Table tennis Dou Tennis Doubles Volleyball	American Football Basketball Football or Soccer Handball Hockey (Field, Ice, Skate) Polo Rugby Water polo

Tab 1.1.11.a General classification of Situation's Sports
Sacripanti (2004)

	Situation's Dual Sports		Situation's Team Sports	
	No Contact	With Contact	No Contact	With Contact
General aims of the biomechanical analysis:	Motion tracking Specific conditions Interactions	More complex motion tracking Interactions	Motion tracking Specific standard conditions Interactions, both strategic and dynamic	Extremely complex motion tracking Interactions, both strategic and dynamic
Basic Methodological Analysis	Serve +Motion + interaction	Motion +interaction	Serve + motion + passing + interaction	Motion passing+interaction

Tab 1.1.11.b General biomechanical Aims and Methodological Approach to Situation's Sports
(Sacripanti 2004)

1.1.12 How to find a good judoka? With a multi-regression equation!

A very severe problem is growing in the judo world in these few decades related to talent individuation. They are borrowing from other sports to find talent with a well-defined performance indicator or set of hands. Also, judo tried this way. Some studies and articles were born in the scientific literature during the time. The last time, an absorbing state of the art relative to judo was presented by Mr Challis for the English judo Association (2006). Where about the anthropometric tests, there are explicitly written these words:

Anthropometric testing-Reilly et al., 2000 used anthropometry to assess soccer players and found that three of their measures - namely skin folds, percentage body fat, and endomorphy - successfully discriminated between sub-elite and elite players. However, the age group studied was older than judo TID (mean age= 16.4, range 16.2-16.6). Judo has a far more diverse population in terms of body composition. Despite this, Claessens, Beunen, Wellens & Geldof (1987) stated that outstanding judo players could be characterised as robustly built athletes with a rather "thick-set". Anthropometry-based on current top-level judo players will potentially be of little use in modern TID due to the potentially diverse nature of the sport and the multitude of different somatotypes

A different approach can be found in Bangladesh about the Bangladesh National Judo Team (2005 and 2006). Fifteen members of the national judo squad (7 female and 8 male) of Bangladesh were measured for somatotype. Body composition evaluation from 14th to 18th Dec 2005 and 1st June to 5th June 2006, and from India, wherein 1995 a paper was presented by Dhananjoy and Kavanal.

Extrapolating from other sports fields, the two authors stated that the anthropometric characteristics could be used as a rationale to give information and prediction on performance as indicators. They built a multi-regression equation to predict judo performance. The multi-regression equation approach is well known in Statistics.

The multi-regression is always built by some standard logical steps. The steps in multiple regressions are the same.

1. State the research hypothesis.
2. State the null hypothesis
3. Gather the data
4. Assess each variable separately first (obtain central tendency and dispersion; frequency distributions; graphs).
5. Assess each independent variable's relationship, one at a time, with the dependent variable (calculate the correlation coefficient; obtain a scatter plot).
6. Assess the relationships between all of the independent variables with each other (obtain a correlation coefficient matrix for all the independent variables)
7. Calculate the regression equation from the data
8. Calculate and examine appropriate measures of association and tests of statistical significance for each coefficient and the equation as a whole
9. Accept or reject the null hypothesis
10. Reject or accept the research hypothesis

Just as a vital remark on limitations of this mathematical approach, like the simple regression. Multiple regressions will not explain the relationship of the independent variables to the dependent variables if those relationships are not linear. Remember that the human body is non-linear (see Appendix II). It shall be not linear also judo performance and athletes' capabilities. The primary rationale for the equation was that judo is subjected to dynamics and mechanics related to the human body and the mind's function. To save ***time and money*** (?) in finding and help in predicting individuals who are especially suited for judo and "*…the performance of judo player may be predicted by selected structural and body composition variables more objectively, to assist Judo experts* (coaches) *along with their subjective assessment."* A multi-regression equation was drawn based on 46 male first category judo players collecting 14 Anthropometric variables. Among them, the "judo performance" ***Y,*** for prediction of judo performance. The equation was drawn based on the three most contributing predictors with the mean value's help by eliminating the less contributing variables. The equation is:

$$Y = 0.514(LBM) + 0.182(UFAR) + 0.496(SH) + 18.297$$
$$LBM = Lean\ Body\ Mass$$
$$UFAR = Upper\ and\ forearm\ ratio$$
$$SH = sitting\ height$$

However, although talent identification and development programmes have gained popularity in recent decades, there remains a lack of consensus about how talent should be defined or identified. There is no uniform acceptance of theoretical frameworks to guide current practice. There is a growing consensus between the Scientific and Sports worlds that traditional cross-sectional talent identification models are likely to exclude many. Those late maturing, promising children from development programmes. Due to the non-linear dynamic and multidimensional nature of sports talent. The optimal framework advocates that talent identification and development programmes should be dynamic and interconnected (challenging tasks to accomplish) considering maturity status and development's potential capabilities. However, the multi-regression equation presented is connected to judo performance with significant prediction efficiency (under the paper authors' commitment).

1.2 Advances in Biomechanics

Biomechanics is the study of movement and forces in living organisms and of how living tissues react to these forces or apply them.
Judo Biomechanics, as already seen, applies particularly to those aspects of human biomec+hanics that relate to this sports practice.
Also included are the mechanical properties and design of sports equipment (Tatami) and clothing (Judo-gi).
However, the growing scientific knowledge presses for an in-depth revision of well-established achievements in the ordinary Judo world.
Non-linearity in Biomechanics, today in the light of modern knowledge, becomes every year more important in its applications such as rehabilitation, sport, ergonomics.
As computer resources become powerful and data handling and algorithms become more sophisticated, finite element analysis is becoming an increasingly important part of biomechanical orthopaedic research.
Until recently, tools with sufficient power did not exist today. There are resources to model fully three-dimensional, nonlinear, multi-tissue, and even multi-joint systems.
With the rapid development of efficient computer hardware and sophisticated software packages, the computerized optimization of sports motions has become a viable goal. The subject-specific data are fed into a general computer program that permits the simulation of any sports motion.
In particular, the optimal form of a specific motion can be found for the athlete under consideration.
Nonlinear theory, in recent times, has emerged as a viable framework in modelling athletic performance, owing to its emphasis on processes of coordination and control in human body movements.
From a dynamical perspective, the human movement system is a highly intricate network of inter-dependent nonlinear sub-systems. (e.g. respiratory, circulatory, nervous, skeleton-muscular, and perceptual) that is composed of many interacting components (e.g. blood cells, oxygen molecules, muscle tissue, metabolic enzymes, connective tissues and bones).
In nonlinear theory, movement patterns emerge through self-organisation today in modern physical and biological approaches to living systems.
The significant problem is that nonlinearity is a worldwide presence in the human body. From microscopic states to macroscopic motion patterns (see Appendix II for a more in-depth analysis of this modern vision evolution).
Suppose this scientific evidence shows us that simple classical thinking is not a viable tool for simple cyclic sports like running, cycling, or rowing. In that case, it becomes self-evident that the error associated with this "simple thinking" to complex dual situation sports, like judo, boxing and taekwondo, will be more significant.

1.2.1 Astonishing Information in Muscular Contraction

To understand human movement, the biological motor that powers this movement: the skeletal muscle, must be understood.
Ideally, one would like a constitutive law for muscle. This equation describes muscle work output and chemical energy input as a function of the system's state variables.
Unless we consider the study of Aristotle in "De Incessu Animalium or the first muscular model proposed by Alfonso Borelli in his work "De Motu Animalium", the foundations of the theory of muscle contraction were laid only over 50 years ago by Hill.
After that, it was realized that force and motion in striated muscle were not generated by the filaments but by Myosin 'cross-bridges linking; adjacent Myosin and Actin filaments.
This idea is embedded in the pioneering quantitative model of Huxley.

Since then, a prolonged period of experimentation and debate has yielded a host of insights into the molecular mechanism,
Molecular models of contractility in striated muscle require an integrated description of Myosin motors' action, firstly in the filament lattice of the half-sarcomere.
The Brownian ratchet theory illustrates such behaviour but imposes anisotropic constraints on the geometry of the system. Feynman conceived the first system of this nature.
Feynman's example achieved two goals: First, it showed the subtlety of the second law of thermodynamics, and second, it demonstrated how it was possible to extract work without a macroscopic gradient force from a system that is far from equilibrium.
Feynman's example became the paradigm for molecular motors. It led to extensive theoretical and experimental research in noise-induced transport and biologic molecular motors.
Feynman's example consists of a ratchet that is wheel-shaped like a circular saw with asymmetric Teeth (i.e., one face of each tooth is oriented orthogonal to the wheel's circumference, whereas the other face is at an angle of inclination smaller than $\pi/2$). A spring is attached to a pawl that prevents the free rotation of the ratchet. The ratchet is connected to a vane using a rod. A load is attached to the vane. We assume that all machine elements are perfect isolators. The vane and spring are in two separated, isolated boxes filled with a temperature T1 and T2 gas, respectively (Fig. 1.2.1). We further assume that the device is microscopic.
In the absence of a load, no directed movement of the ratchet can be induced if the vane and spring are embedded in thermal baths of equal temperature, despite the system's asymmetry.
However, suppose the spring is embedded in a thermal bath with a temperature T2 lower than T1. In that case, the ratchet will move counter-clockwise (Fig. 1.2.1). Conversely, if temperature $T2$ is greater than $T1$, the ratchet will move clockwise. Therefore, thermal gradients can drive the ratchet in a directed motion or perform work against a load.

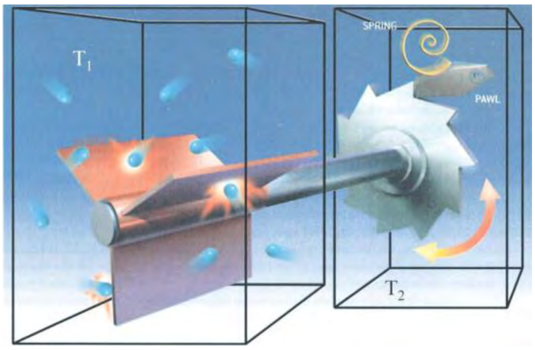


Fig. 1.2.1. A Feynman's ratchet and pawl. The vane and spring are in two separated, isolated boxes filled with a temperature T1 and T2 gas. The Brownian particles hit against the vane providing enough energy to move the ratchet to the next tooth. The fluctuation of the spring attached to the pawl allows for a backward rotation of the wheel. If the temperatures T1 and T2 are equal, there can be no net movement of the ratchet. If T1 is greater than T2, the ratchet will move counter-clockwise, while if T1 is smaller than T2, the ratchet will move clockwise. Feynman's ratchet and pawl illustrate how random noise from non-equilibrium fluctuations can induce directed motion in conjunction with the anisotropy of the system. (Adapted from ref. 66 with permission.) **Astumian, R. D. (2001) Making molecules into motors. *Sci. Am.* 285, 57–64.**
Feynman, R. P., Leighton, R. B., and Sand, M. *The Feynman Lectures on Physics.* Addison-Wesley Reading, MA, 1966.

The principal molecular participants in the process of muscular contraction have been identified as myosin II, actin filaments (G-actin, tropomyosin, troponin), ATP (adenosine triphosphate), water, Mg++ and Ca++. A crucial first step in understanding the mechanism of muscle contraction was the discovery of the geometric arrangement of actin and myosin within the sarcomere

Muscle contraction is thought to occur as follows: the myosin head is believed to bind ATP and detach from actin. The myosin motor's functioning can be understood as follows: In the detached state, the myosin head is at a position *x* and is subjected to free Brownian motion.
The probability distribution of the myosin head's position follows a Gaussian function that spreads out over time. Once the chemical reaction has advanced the myosin head to the attached state, because of the asymmetry of the potential in this state, the myosin head is more likely to be located in the possibility with a negative slope than the part with a positive slope. Therefore, the myosin head is more likely to exert a positive force (which would shorten the sarcomere) than a negative force. All this means that each myosin head does not accomplish a deterministic traction movement in only one direction (increasing the contraction). However, randomly each head can attach the actin filament in both directions forward and backwards. However, the resultant motion will be statistically in the contraction direction.

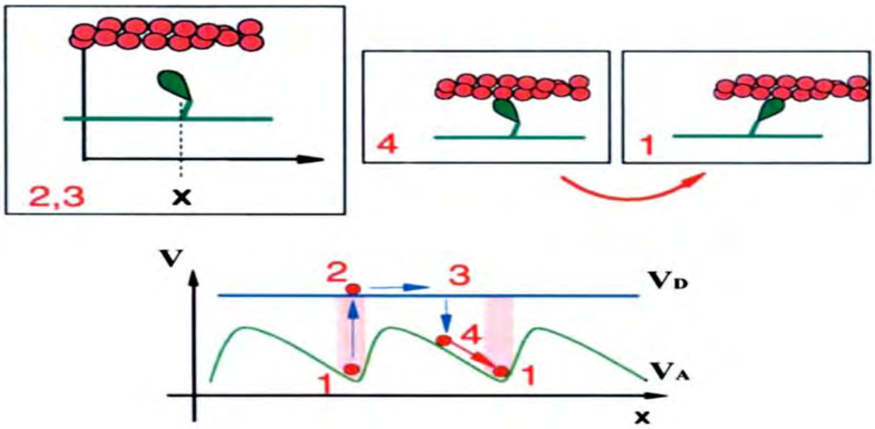


Fig. 1.2.1.b. Ratchet model for muscle contraction. In the attached state, the myosin head is located in a local minimum of the potential of interaction between actin and myosin filament (potential VA(x)) (1). Once the ATP attaches to the myosin head, the myosin head detaches from the actin filament. It undergoes a free Brownian motion (2 and 3). After ATP hydrolysis, and because of the asymmetry of the potential once the myosin head is attached to the actin filament, the myosin head is mostly found in a region of negative slope on the potential VA(x), allowing the fibre to shorten and produce force (4). (Reprinted from with permission.)
***Julicher, F. Force and motion generation in molecular* motors:**
A generic description. In: *Transport and Structure in Biophysical and Chemical Phenomena.* Muller, S. C., Parisi, J., and Zimmermann, W., (eds.). Lecture Notes in Physics, Springer, Berlin, 1999.

1.2.2 Fractals in Heart Rate

Not only the human body but also human life activity is nonlinear.
From the viewpoint of the system, human beings are the most complex system in nature. For such a physiological system with the uttermost complexity in tissue, structure, and function, even if people already know it, there is still much unknown information.
For instance, we are unaware of the quantity of the independent variables that control it, making it challenging to constitute a valuable model of its dynamical action.
For a long time, biomechanical people used to simplify and abstract this complex system by establishing an ideal linear model, and giving the model linear analysis and processing in the time domain, frequency domain, time-frequency transform; this model was beneficial especially in Sports conditioning, as we can see in chapter 4
Practice in the late half-century demonstrated that it is not enough to use simply the linear analysis methods to study the essentially nonlinear activities
A distinguishing feature of the nonlinear human system is that there exist interactions among the composing parts; thus, the system's output is not directly proportional to the input, and the principle of linear superposition is not applicable.
Nonlinearity is today a focal point of natural science research. Understanding nonlinearity has deepened our knowledge of many concepts such as determinism and randomness, simplicity and complexity, noise and order, which will profoundly influence the development of all life sciences applications, including Sports.
The last two decades have seen intensive research on the theory of nonlinear dynamics, fractal and chaos; ideas and methods from the theory have been applied to almost all branches of sciences and, in particular, to human physiology.
In the field of cardiovascular dynamics, several reports on nonlinearity, fractal, and chaos have been focused on the structures of the heart tissues, nerves distribution, and heart rate control.
Nonlinear analysis of cardiac electric activities is an attractive research field and a front research subject abroad. Especially in the last 20 years, researchers in this field have done a lot of exciting works.
We need to extend and deepen the traditional arithmetic methods and raise the calculation speed to analyse the nonlinear information.
It is then possible to introduce some existing cardiac electric signal analysis methods, such as multifractality, entropy, etc.
Finally, finding some nonlinear parameters suitable for short time series, fast calculable, and sensitive to physiological state and variations like conditioning in Sports.
For example, physical activity, as well, may provide a more relevant analysis of cardiac autonomic function.

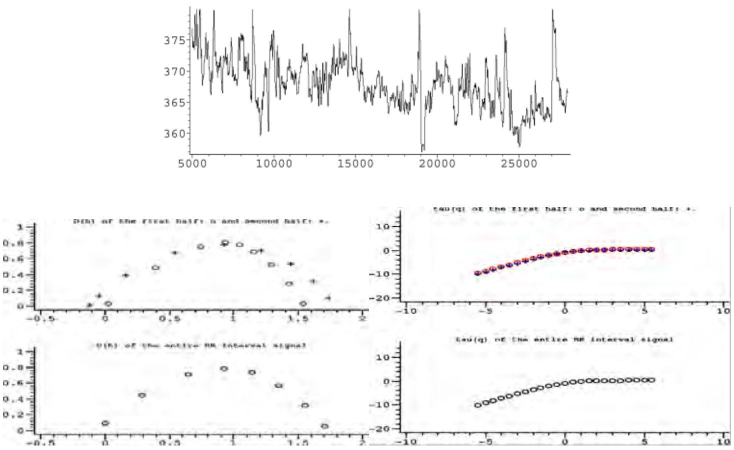


Fig 1.2.2. a,b,c= heart rate time series, and their fractal evaluation

1.2.3 Fractals in Breathing Patterns

In adult humans and Athletes, respiration is characterized by considerable variability in the frequency, duration, and amplitude of breaths.

Usually, the basis for the variability of these respiratory parameters is founded on two possibilities.

First, except for some short-range correlations, the fluctuations in respiration might be random, i.e., uncorrelated. Although influenced by events (breaths) in the recent past, the present value of the measured parameter would not be related to events in the far history.

The second possibility is that long-range correlations also exist among the fluctuations in one or more of the respiratory parameters. If so, it would be essential to define the duration of the memory in the system.

The term "memory" is used in the time frame when over a series of breaths are correlated. If the memory extends across more than a one-time scale, the fluctuations would be best modelled as arising from a fractal (time-scale-invariant) process in which the present value of the measured property is related to events in the distant past.

The term "time scale" refers to the temporal resolution used to measure the parameters of interest. The following figure shows the fractal correlation in the breathing pattern of an adult man.

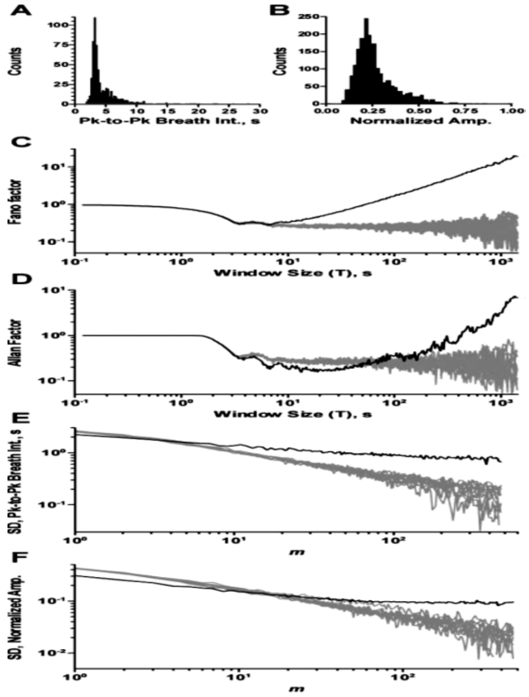


Fig 1.2.3. A breathing time series and their fractal evidence.

Fig.1.2.3.a. Shows a fractal analysis, of breathing pattern, in a subject in whom fluctuations: several breaths, respiratory period, and breath amplitude were fractal. A: distribution of 1,884 peak-to-peak breath intervals (Pk-to-Pk Breath Int.). B: distribution of 1,885 normalised breath amplitudes (Amp.). At least one count is at a normalised amplitude of 1.0 in this and all subsequent amplitude distributions. C: Fano factor curves for original time series (black trace) and ten surrogates (grey traces). D: Allan factor curves for original time series (black trace) and ten surrogates (grey traces). E: dispersion analysis of the original time series of peak-to-peak breath intervals (black trace) and ten surrogates (grey traces). SD: standard deviation. F: Dispersion analysis of original time series of breath amplitudes and ten surrogates

1.2.4 Multifractals in Human Gait

As already said, human actions lie in spatial-temporal patterns generated by a complex and time-varying non-linear dynamical system. A complete description of this system will require enumeration of all independent variables, their complex interdependencies, the knowledge of differential equations controlling their evolution and a set of boundary conditions satisfied by the system itself.
Ideally, every bio-mechanist would like to obtain a complete description so that it can be used to control, predict, and extract features of the dynamical system in a deterministic fashion.
However, in practical scenarios obtaining a complete analytic description is practically impossible.
Walking is a complex process that we have only recently begun to understand by applying nonlinear data processing techniques to stride interval time series.
As well known, walking consists of a sequence of steps partitioned into two phases: a stance phase and a swing phase. The stance phase is initiated when a foot strikes the ground and ends when it is lifted. The swing phase is triggered when the foot is lifted and ends when it hits the ground again. The stride interval is the time to complete each cycle.
Typical stride interval time series for an adult subject in both free and metronome constrained walking at regular, fast and slow regimes are shown in Fig. 1.2.4a

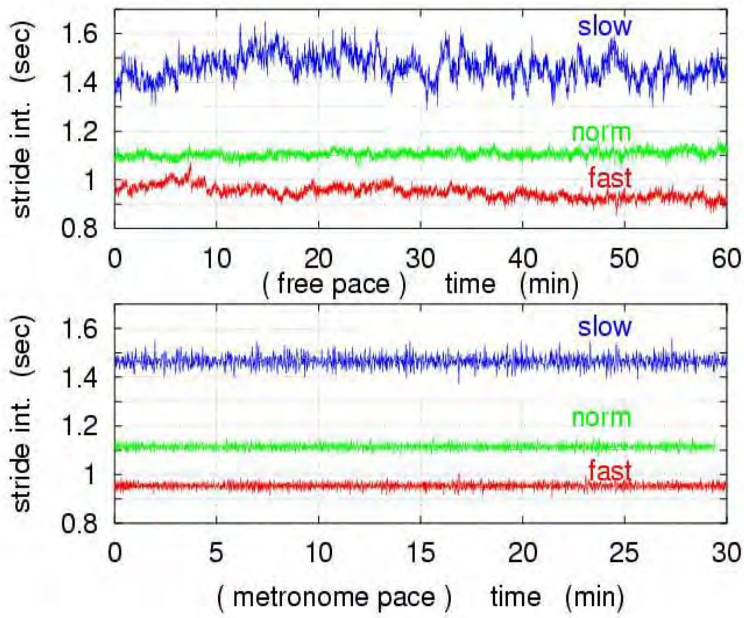


Fig1.2.4a: Typical stride interval time series in the free and metronome-paced conditions for normal, slow and fast paces.

By estimating Hölder exponents' distribution, it has been shown that the stride interval time series for normal gait shows fractal properties like 1/*f*-noise and is weakly multifractal. The time series may be non-stationary, and its fractal variability changes in different gait mode regimes. In particular, the persistence and the multifractality of the stride interval time series tend to increase slightly for both slow and fast paces above that of the average pace.

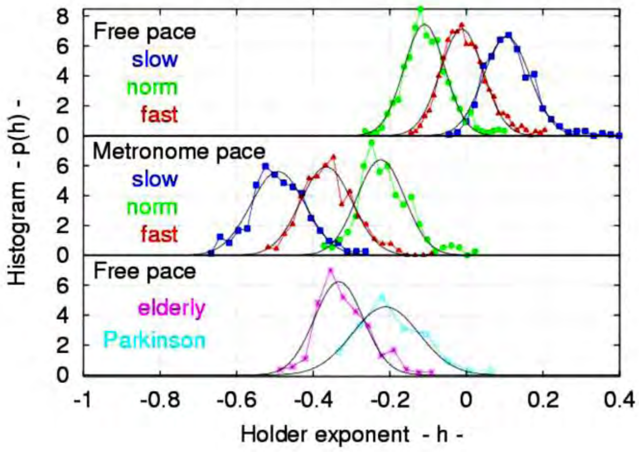


Fig1.2.4.b: Typical Hölder exponent histograms for the stride interval series in the free walking and metronome conditions for normal, slow and fast paces and the elderly and a subject with Parkinson's disease. The data are reported using the average over the subjects.
The average histograms are fitted with Gaussian functions. (from Scafetta)

Then, as we see before, today, biomechanics and physiology, physics, biology, and a lot of scientific disciplines connected to life are faced with the complexity associated with the non-linearity present in the Human body, which shows self-organization and fractals pattern both static and dynamic, (see Appendix II) in many microscopic and macroscopic or internal and external manifestations.
This constant non-linear behaviour under suspicion the linear approximation until today utilised in biomechanics or conditioning, especially for complex sports like judo.
However, in the first approximation, the linear perspective can be acceptable in explaining the basic judo concepts and movements.
This statement, astonishingly, guarantees that the Kano's foundations are scientifically correct in first approximation, or more pictorially, the judo's Japanese roots are deep and powerful.

1.2.5 Hot News: shorten Reaction Time by Visual Training.

Visual training

The reaction time depends on the CNS activity. *Reaction time elapses from the sudden onset of a stimulus to the beginning of a movement response* (Oxendine, 1968).
The critical point here is that, like response time, it starts with introducing the stimulus but ends at the *beginning* of the response, *before the motor act* begins.
In athletes, as in people, it is possible to identify two main kinds of reaction times: acoustic reaction time, like start in sprinters and visual reaction time like, for example, tennis serves.
In judo, considering that acoustic, vestibular, tactile and kinaesthetic stimuli could also be involved in making quick decisions during the judo fights, reaction time is connected to reacting at one actual attack. Usually, this specific characteristic could be evaluated as 5% acoustic, 90% visual, 5% others.
The following two figures figure out the research layout utilised by Kubota and coworkers (2013) to perform exciting research on judo visual reaction time for defensive action connected with increasing grip strength.

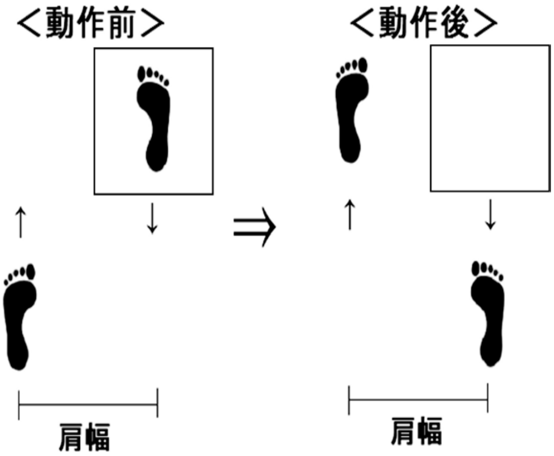


Fig 1.2.5.a,b. Layout and motion performed during Kuroda research.

The results showed that increasing holding strength, reaction time increases
As shown in the following table

Grip force	0%	20%	50%	80%
Reaction time	0.341	0.354	0.361	0.370

Tab. 1.2.5a Increase of reaction time with the strength of grip.

Different results were founded by Cojocariu and Abalasei (2014), probably because they utilised for research a more classical set-up, far from the judo competition situation. In their study, Judo athletes always showed a shorter visual reaction time than the control group, but the differences were not statistically significant. In the following tab, there are presented the results of this research.

Test	***Group 1 students (n = 20)***	***Group 2 judo (n = 8)***
Simple reaction time [ms] (Test 1)	***238,7 (6.8)***	***233.6 (5.0)***
Choice reaction time [ms] dominant hand (Test2)	***421.3 (9.5)***	***404.1 (11.0)***
Choice reaction time [ms] non-dominant hand (Test3)	***425.9 (10.2)***	***409.0 (13.6)***
Choice reaction time [ms] dominant hand (Test4)	***407.8 (8.1)***	***391.0 (11.9)***
Choice reaction time [ms] non-dominant hand (Test4)	***418.5 (16.2)***	***395.3 (18.6)***

Tab.1.2.5.b Simple and choice reaction times

However, both research results were in accord with the experimental Hik-Hayman law (1952-53), which states that reaction time increases by about 150ms every time the stimulus-response groupings are doubled.
Sometimes low concentration is a result of poor eye control. With visual training, one can learn to concentrate and ignore distractions.
In judo, one's visual attention must shift rapidly and fluidly, with continuous eye movement.
Right concentration with a clear mind is increased with the ability to move only the eyes, not the head. The head and neck's movement increases stress upon the balance system with the likely result of visual misjudgement.
The secret of right concentration is keeping both eyes on the stimulus without being distracted by the background, peripheral images, shadows, colour changes, and extraneous sounds and movements.
But what are the visual skill crucial for judo success?

Dynamic Visual Acuity; Seeing sharply and clearly when an adversary is in motion.
Focus Flexibility: The ability to quickly refocus at different distances, adversary movements
Eye-Hand/Foot/Body Coordination: Controlling muscular movements to match a visual stimulus
Binocularity/Stereopsis: Coordinated use of both eyes to see depth and distance accurately
Peripheral Awareness: The ability to concentrate on one particular while maintaining awareness of others
Visualisation: The skill of mentally reviewing a situation and guiding the body to react efficiently
Visual Tracking: accurately fixating and following moving parts of the adversary body.

One interesting PhD thesis from Bologna University, " Visual scanning in sports action comparison between soccer goalkeepers and judo fighters" (2010), analyzes in-depth this area not so studied about judo.

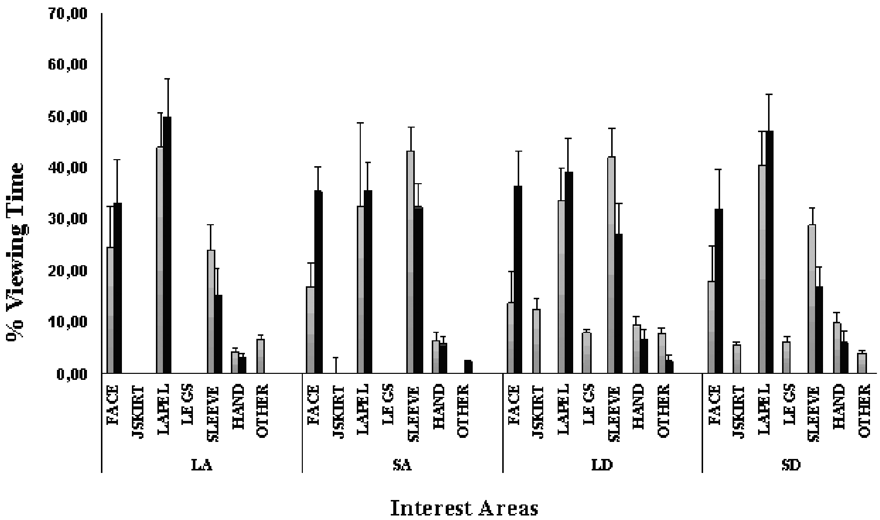
Figure 4. EyeLink II eye movements system consists of two miniature cameras (A) mounted on a leather-padded headband computing the relative positions of the pupil in relation to the image recorded by a scene camera (B).

Fig.1.2.5 c EyeLink analyzer

Figure 5. Procedure of Judo study showing gaze image (A), motor image (B) and gaze cursor (C). In the motor image, with Blue Judogi Emanuela Pierantozzi, and with White Judogi the participant who is wearing the silicon swim red cap and the EyeLink II.

Fig. 1.2.5.d,e. A layout of judo research

Some of the main results about judo are shown in the next Diagram



Diag-1.2.5.a Percentage of time fixation in slave/lapel Attack and Defence

Judo is not different from other sports; the eyes fixations are target-directed. But the athletes used a gaze strategy to anticipate the opponent's movement to reach the correct target or avoid its action at the proper instant. Novices, making more fixations of short duration, make this prediction mainly look at the moving body segments. However, experts analyze the central body area that gives information about the attack intention as "dangerous" or not.

Last Hot News on Visual Training

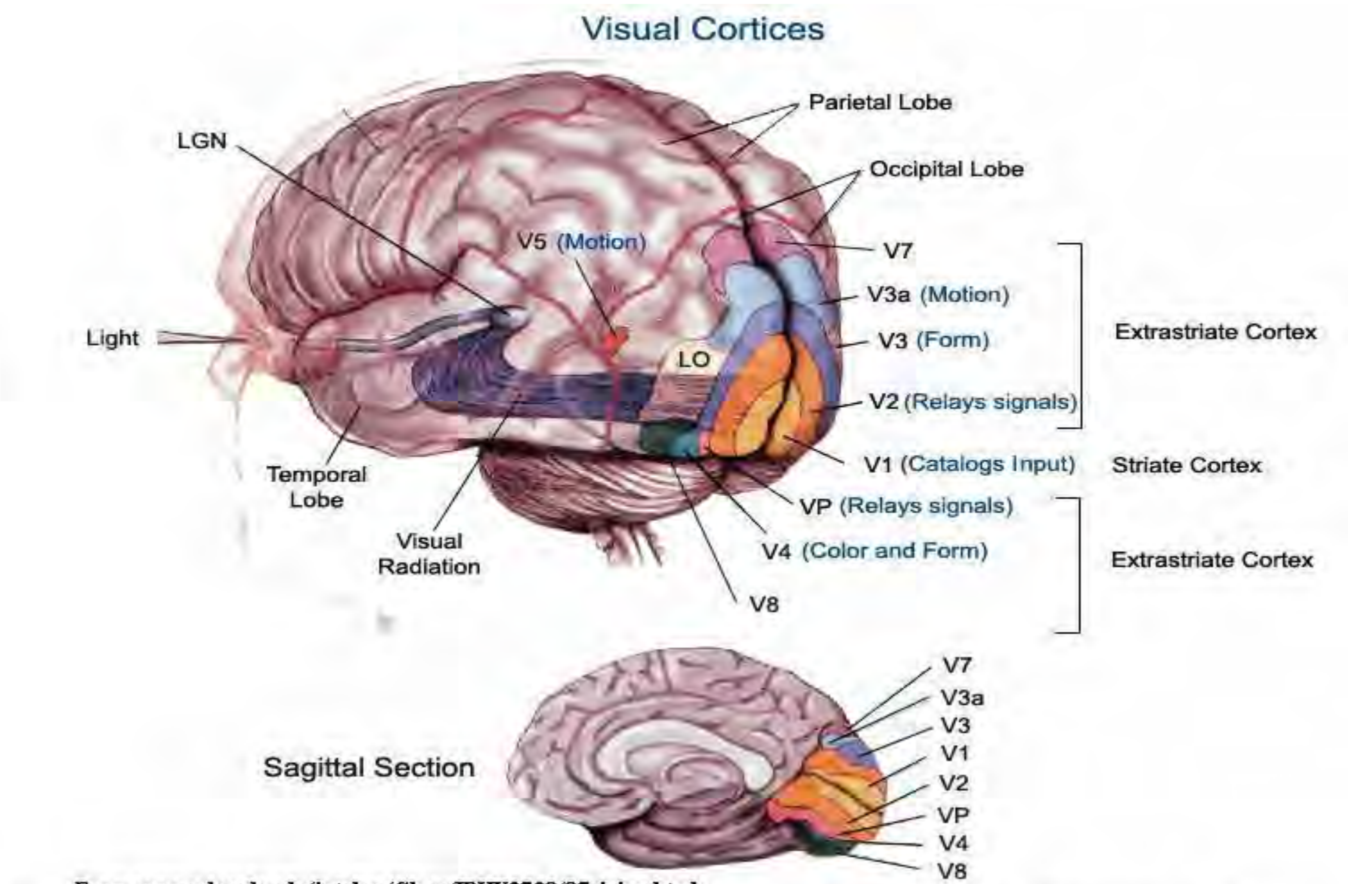
As we can see in the previous paragraph, visual training is essential for judo athletes. However, it is today not recognized by the big part of National Federations.
The importance of this training was recognized at first by Professional baseball Teams in the US. Starting from 1984 with the International Academy of Sports Vision foundation, the visual training techniques were also applied to all US Olympic athletes.
In the last time, visual training was applied in Raquet's sports. It is crucial to increase the speed of visual engagement and the coordination eye-arm.
The scientific base is the CNS plasticity (the capability of the Central Nervous System to change and adapt himself at the enhanced performance), with biofeedback application and Cortical Response Training CRT.
In short terms, the most relevant result with the CRT is that athletes with this kind of neuronal training can enhance and increase the cortical response putting it under their voluntary control.
In the study, about 15 tennis athletes (Segnalini and co-workers 2015), for 14, there were evaluated impressive improvements; for one, there were no improvements.
For the 14 sensible to this training, the results are shown in the following table.

Visual acuity	Pre-mean Dioptres 12/10	Post-mean Dioptres 18,5/10
Contrast Sensitivity	Pre 1,4%	Post 0,4%
Reaction Velocity (PEV)	Pre 106 mm/s (P100)	Post 101 mm/s (P100)
Eidomorphometry	Pre 0.4 mm	Post 0.2 mm

Fig.1.2.5.f Results of visual training for tennis.

It is essential for our information that the cortex signal speed with this training is enhanced from a transmission time of 600 ms to 400 ms, with an apparent increase in athletes' reaction time.
All the subjects show the same subjective reaction "After this training; we have the feeling that everything is moving in slow motion. "
A shorter transmission time from the eye to the visual cortex automatically decreases reaction time to adversary movements, with the critical enhancement of both defensive and attacking attitudes.

The following figures are shown the visual cortex pathways.



From www.colorado.edu/intphys/Class/IPHY3730/07vision.html

Figure 3. The primary visual cortex, V1, is located in and around the calcarine fissure in the occipital lobe. Each hemisphere's V1 receives information directly from its ipsilateral lateral geniculate nucleus. Each V1 transmits information to two primary pathways, called the dorsal stream and the ventral stream. The dorsal stream begins with V1, goes through visual area V2, then to the dorso-medial area and visual area MT (also known as V5) and to the posterior parietal cortex. The dorsal stream, sometimes called the "Where Pathway" or "How Pathway", is associated with motion, representation of object locations, and control of the eyes and arms, especially when visual information is used to guide saccades or reaching. The ventral stream begins with V1, goes through visual area V2, then through visual area V4, and to the inferior temporal cortex. The ventral stream, sometimes called the "What Pathway", is associated with form recognition and object representation.

Fig 1.2.5.g Visual Cortex pathways

GWAK
KOR
FRA

Part two

Judo

Chapter 2 Basic Judo Principles

2.1 Straight line unbalances (*Happo No Kuzushi*)

Previously, we tested the physical concept and mathematics definition of rigid body's balance placed on a horizontal level and biomechanical aspects of the human body's balance. In this paragraph, we will discuss human body Unbalance, considering Jigoro Kano's most important rudiments about this concept and Kudo's increasing; under those circumstances, examining it closely from a biomechanical and physical point of view.

Kano, who was a student of an ancient Jujitsu school-*Kito Ryu,* during the training of *randori* with Ikubo, focalized the concept of *rival's balance break,* to get better throwing techniques; an efficacious execution of this technique, between two fighters with the same physique and force, is founded on the way to put on unbalancing one of the competitors.

The old-school jujutsu consists of breaking the condition of the body, which has lost equilibrium.

It is called kuzure-no-jotai (state of broken balance). Sometimes the opponent himself loses the balance. At other times you positively destroy the opponent's balance, leading him to a vulnerable posture. In Judo, each technique was first analyzed into tsukuri (preparatory action) and kake (attack). The preliminary action is further divided into aite-no-tsukuri (preparing the opponent) and jibun-no-tsukuri (preparing oneself). Preparing the opponent consists of destroying the opponent's balance before performing a technique and putting him in a posture where it will be easy to apply it. Simultaneously, the contestant himself must be in a stance and position in which it is easy to use a technique. This is the preparation of self.

These remarks, about unbalance concept, produce the elaboration of the principle "***roppo no kuzushi***", *six fundamental directions of unbalance"* that became under Kodokan, **"*happo no kuzushi*",** *eight precise directions of straight unbalance.*

The word *kuzushi* (unbalance) was associated with Kano with the concept of

'maximum power in a throwing technique with minimum muscular energy'.

This notion was already developed by jujitsu school *Kito-Ryu*, even if in a warning sign way; considering the specific dynamic phase of fighting, the main question was the opponent's imbalance, surely more complex and articulate the imbalance of a passive and still body.

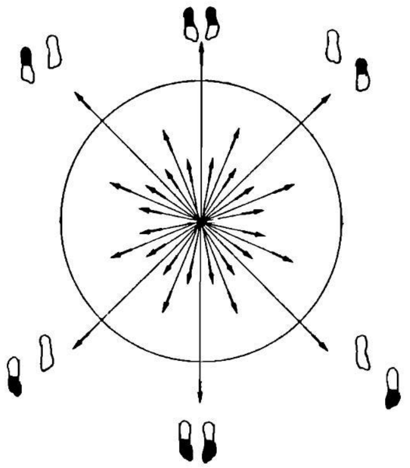


Fig 2.1.a Roppo No Kuzushi

The biodynamic solution of such question needs meticulous studies about forces into action; right direction to unbalance rival's body; right moving to prepare an efficacious throwing technique; a way to effect grips; direction change or gears, etc.
Jigoro Kano tested scientifically, first still rival throwing, *go-kyo,* (static phase) in *uchi-komi*. Then he studied the principles about throwing in dynamic movement, *nage- no- kata* (dynamic phase).
According to their evolution biomechanical analyses, Kano and his assistants were realised during the years ante litteram three different phases in the throwing dynamic and static action: *Tsukuri, Kuzushi, Kake*.
The last word *Tsukuri* (construction), included the whole of the innumerable movements that the competitor can realise to prepare a throwing technique's realisation.
With Yokoyama and Oshima, Kano used *Kuzushi* to synthesise the action transferring in biomechanical elements the barycentric pulling of the rival's body, outside the optimal trapezoid surface the support base.
In 1908, Yokoyama wrote: "We could explain these unbalances through wise mathematics proofs, but we are afraid that they are so much complex…."!
The action of *kuzushi* takes advantage of the human body's erect position, 'a physic position of unstable equilibrium', all that permits precisely to effect throwing body, after an unbalance, through an appropriate barrier (*tai otoshi; hiza guruma*) or only to cause hyperextension of the body in space (*uki otoshi; sumi otoshi)*
The nicety of judo techniques lies not in performing techniques but rather in the skill with which the preparing is done as a preliminary. The clear-sighted and original idea of the founder of the Kodokan Judo analysed the technique applied instantly and attached importance to the study and practice of preparatory action. In preparing the opponent, the theory and practice of breaking the balance must be studied, while as regards preparing of self, it is necessary to check the natural posture and the theory and practice of ma-ai (space condition).
*Kake (*application) refers to various movements of an ending technique part, to global control and to put on a barrier or a hyper-extension, causing an unbalance's competitor.
All this permits an efficacious rival throwing on the tatami.
A natural temporal division doesn't exist between these phases; it's an only explicative artificiality to teach a single, fluent and continuous movement.
The controversial matter about the priority of one of these phases, Kodokan's old scientific research (*Analysis of the kuzushi in the nage waza)* has proved, through electromyographic check-up of the competitors' fundamental musculature, that two phases are both connected.
For this reason, we can declare that three phases, *kuzushi/tsukuri/kake*, are precisely a single movement because they start at the same time; and so, doesn't exist priority.
The question about the direction of forces and their use drove Kano to consider the development of the dynamic actions with a purely straight and two-dimensional symmetry—"…if a rival push, you must pull in the same direction; if he pulls, you push him in the same direction". He and his assistants affirmed the principle of maximum efficiency that, in biomechanics words, means the principle of minimum application of muscular energy.
This concept about linearity, a fundamental aspect at the beginning of the years of Judo, was the basis in the laying notion of *happo no kuzushi* or 'of the eight basic unbalance directions', all these one proposes a linear and straight symmetry compared to a parallel plane to the tatami.
Nowadays, Kano's last pupil, Mr Kudo, decided to increase the directional principle of *kuzushi;* he talks about fourteen fundamental unbalance directions with the exact linear symmetry.
"I'd like if you considered my principle about fourteen directions to unbalance the rival, thinking it like a going over of the old rudiments': this new principle arises from the evolution of technique and more and more mastery, in a throwing, of many masters." (Dynamic Judo vol. I)

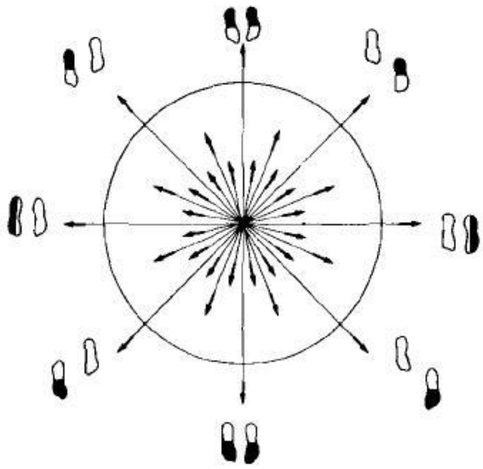


Fig2.1.b Happo no kuzushi

This effort, from the scientific point of view, results in useless cause some simple geometric considerations (even if we consider only two-dimensional linear symmetry excluding the three-dimensional question too, because of its complexity) show us that the number of unbalance directions is infinity, with precision '*an infinity of the power of continuum'.*

Happo no kuzushi directional principle is therefore satisfactory entirely. On condition, to consider the eight fundamental and straight directions, discovered by Kano, one after the other and like *Representative Vector* of a whole or more precisely of a *class of directions.*

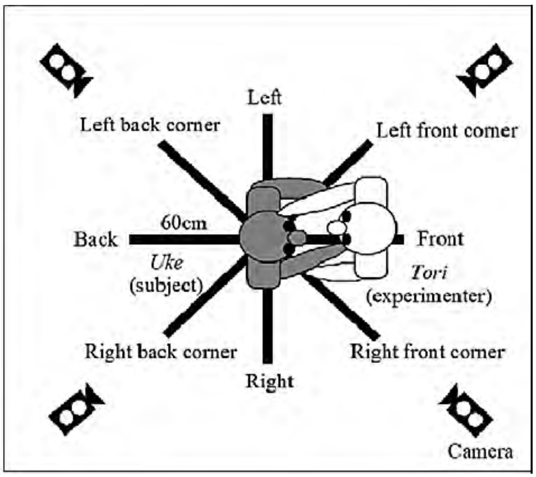
We must consider the happo no kuzushi as a didactic example of one of the numerous subdivisions in eight classes of straight horizontal directions. We can put the horizontal infinitive directions in order, about human body unbalance placed on a horizontal plane in the erect position.

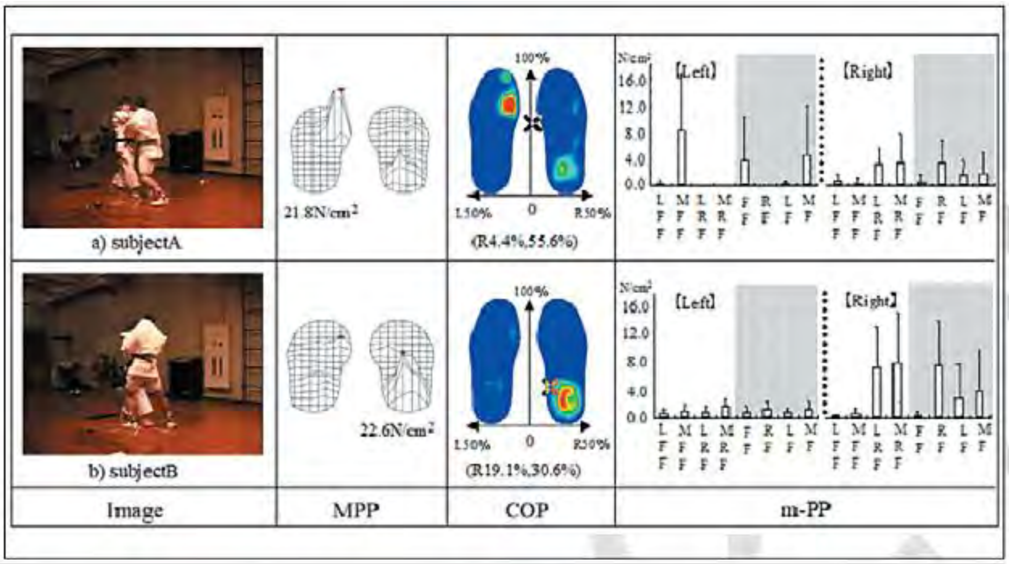
More electromyographic Japanese studies (*Studies on Judo technique with particular reference to Kamae and Kuzushi- Electromyographic studies in the "Nage Waza"/throwing techniques/ of Judo)* have proved that the competitor's effort, during the phase of kuzushi- tsukuri- kake, is focused on the frontal body muscles. While during nage (actual throwing phase) is the dorsal muscles of the competitor's body go into action, contracting violently to control the rival's body.

These researches have also proved that muscles' action is prominent in the left side body for the right-hand competitors in the kumi kata, only in the kake phase. Then in nage, the muscles of the right-side body go into an action considerably. It's the same argument for left-hand competitors, thanks to symmetry.

The kumi kata is considered the only means to transfer energy; from these studies emerged that, in the condition of positive physic work (isotonic contractions), the muscles of the superior bio-kinematic chains (biceps and triceps brachial), of the scapulohumeral dorsal fascia (deltoid, trapezius and teres superior) and the muscles of the inferior bio-kinematic chains (rectum femoral) were mainly involved, during dynamic action.

Very recent studies on happo no kuzushi by Sogabe and co-workers performed in 2008 to study the immediate changes in plantar pressure of Uke to fast Kuzushi showed that usually the reaction response is connected to a Tai Sabaki action (repositioning the body) or a Reflex action (stepping reaction). The following figures are shown the experimental setup and some results.





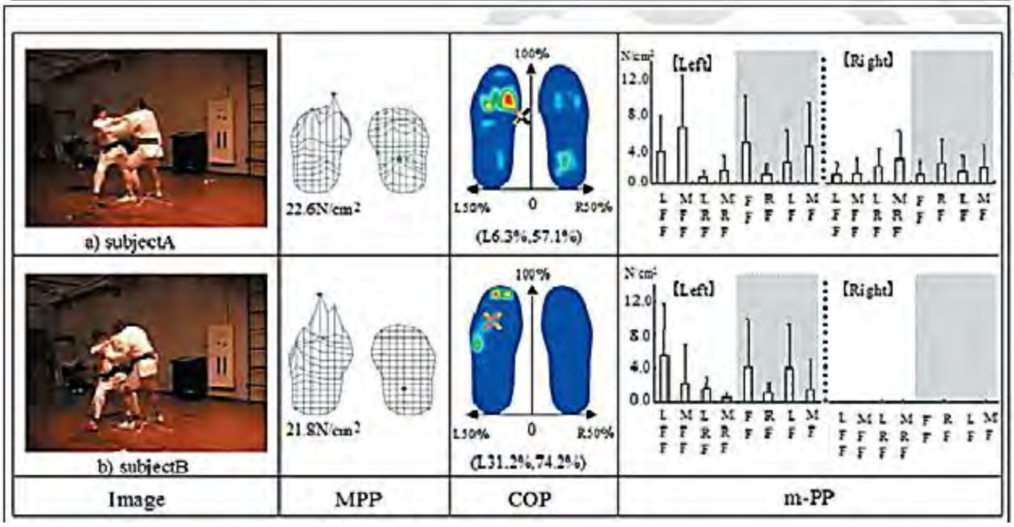


Fig 2.1.c,d,e Result exempla of Sogabe experiment on kuzushi (2008)

2.2 Abdominal Energy Exploitation (*Hara gei*)

To probe the unbalanced body's study in a static condition, it needs to consider the necessary forces into action.
This problem was separated according to growing analytic difficulty through a correct scientific approach.
From the transmission of one's impulse point of view and not directional, a profound analysis of these forces into action induced Kano to consider the *haragei* principle or *utilization of the abdominal energy.*
The *haragei* is, above all, a philosophic and spiritual concept, one of the fundamental in Zen Thought. Afterwards, it was also studied scientifically by one of the most influential experts, K. Harumitsu. They analyzed this problem with the physiologist K. Hirata. Such a principle is fundamentally based on the biomechanical concept of disaggregation of the human body in two bio kinematic chains

1. **pelvis—lower limbs**
2. **trunk—upper limbs**

Between three degrees of relatively free time, they can rotate one to the other. These chains are connected by the abdominal rectum, oblique and great dorsal; for this reason, a harmonic motion of kuzushi, tsukuri and kake, passes by correct co-ordination of two chains through the abdomen.
The abdomen plays a determinant part in the saving of throwing technique. This action causes the abdominal rectum, the most potent human body muscle, allows to transform the kinetic energy of a motion of roto-translation -first chain Pelvis—lower limbs- in potential energy of elastic contraction, abdomen, to re-transform it in kinetic rotational energy in the second chain- trunk—upper limbs. We can prove these transformations in the formula:

$$\underset{\text{lower chains}}{K_1} \rightarrow \underset{\text{abdomen}}{U} \rightarrow \underset{\text{trunk+upper chains}}{K_2}$$

$$\frac{1}{2}(I_1\omega_1^2 + mv_1^2) \rightarrow \frac{1}{2}kx^2 \rightarrow \frac{1}{2}I_2\omega_2^2$$

$$With\ K_1, K_2 = Kinetic\ Energy;\ U = Potential\ Energy$$

And so, the transfer of energy through the 'abdomen' must emerge optimally to obtain maximum energy in the second chain. This action is possible only if the forward competitor's body (tori) isn't still loose, elastic and using absolutely hips.
The principle of minimum effort and maximum efficiency can be translated in this phase, biomechanical action of the dynamic movement in two corollaries:

A) **<u>Better technique maximum economy in the movements</u>**

and in succession

B) **<u>Better technique maximum economy of the muscular energy</u>**

During the tsukuri and kake phases, the maximum economy in the movements involves an accurate study of the tsukuri phase of the technique in the different static and dynamic positions that the attacked competitor (uke) gains during the performance. In this contest, it's necessary to know the better direction of the attack. The optimal movement, either in biomechanical terms or in energetic terms, is one of the perpendicular (minimum distance) between barycentric throwing and the limit zone of maintenance.

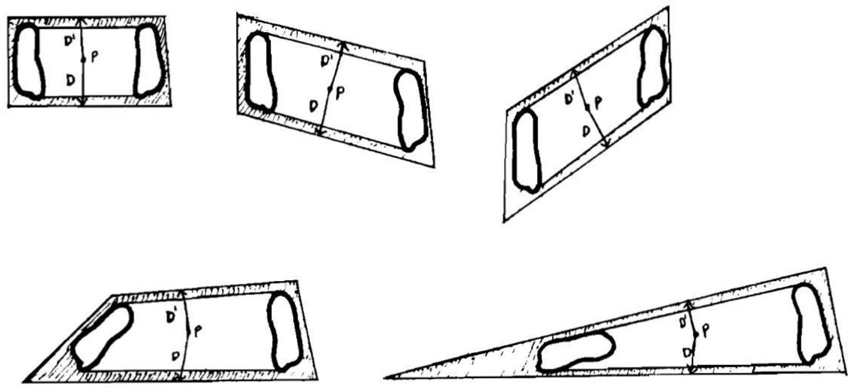


Fig 2.2 a Optimal attack directions
P =COM projections on the support base, D= minimum in the forward distance, D'= minimum in backward distance

The maximum effort economy involves, either in static phase or dynamic, an accurate study of the advanced competitor's barycentre (tori) trajectory during the attack; thus, he obtains an optimal relative position to throw rival (uke) with minimum waste of energy.
The principle of utilising abdominal energy in Judo must be interpreted as Correct centripetal pressure (Hirata), extending it to the application in defensive situations.
Correct use of abdominal contraction causes the lowering of the diaphragmatic part. Consequently, this pressure of the viscus and the abdominal fluids produces a little translation downward of the barycentre's competitor, maintaining a natural balance in the erect position.
All that can be expressed either in attack or in defence, the competitor manifests it through a sonorous emission called *kiai* in the Japanese language, also used in the other martial arts; it is so much important as technique, cause this emission permits to execute the correct use of the centripetal pressure

2.3 Placements and basic grips (*Shizen on Tai; Kihon Kumi Kata*)

Proper abdominal coordination assures the harmonic action of the body during the throwing technique. For this reason, the correct position is a base for rapid and effective action. The correct position in the *nage waza* must permit slight and fast moves to avoid friction and to develop contemporary better use of strength.

The most effective standing position, for its flexibility and all general peculiarities, is *Shizen hon tai*: feet and legs stretched like shoulder measurement; the bodyweight spread front-feet; heels just a little posed on *tatami;* knees slightly flexed; loose and relaxed hips; erect bust; arms relaxed along the body; head high with a present concentrated look; closed chin.

Fig 2.3a Three basic natural standing positions in judo

This position was considered the fittest in attack and defence. It was much time-analyzed by *Kodokan judo,* with another position called *jigo-tai,* used above all in the defence: it starts by the fundamental positions with some change like the expansion of the optimal trapezoid surface, flexing much more legs and lowering the barycentre with erect bust, the weight body balanced on the legs with heels put firmly on the *tatami*.

Fig 2.3b Three basic defensive standing positions in judo

Both positions have some variations: you can advance on the right, on the left, with equivalent feet and rotating the other foot on the inside.

Shizen hon tai is undoubtedly an ideal position; from a biomechanical view, the waste of energy is minimum, while it isn't the same thing for the *jigo-tai* cause there is no possibility to change our position. The first is more functional than the second. It lasts a very long time, and its flexibility makes

it suitable for ‘modern’ Judo. The direction, speed, and rhythm are fundamental elements. *Jigo-tai* is ideal for ‘ancient’ Judo, much more static and physical.
Biomechanical analyses about *kuzushi* and positions made in Japan (*Studies on Judo technique, with special reference to Kame and Kuzushi)* have proved that in the *shizen hon tai* aren’t many significant differences between thorax and neck. However, in *jigo-tai,* the difference exists, more resistance to thorax less to neck.
We have verified a diminution of resistance capability to the lateral traction on the right and the left in the left and correct defensive positions.
The biomechanical study about dynamic movement *kuzushi, tsukuri* and *kake,* passed naturally through the concept of transmission of the attack competitor’s impulse (tori) to the rival (uke).
According to Japanese didactics, the throwing technique is possible for two reasons: the passing on impetus capacity(*ikioi)* and the right moment of opportunity (*hazumi)*.
In the light of these facts, we can say that the control in the moving permits always to focus a proper position in evolution continuously, the correct contact with rival allows realizing a taisabaki correctly and then, the contact permits to the competitor to sense the aims and directions of an attack.
These phases have a common denominator: the grip to the rival’s cloak (*kumi kata*).
The contact, in general, is made by hands that seize rival’s judogi.
It’s essential to widen our knowledge of grips because they are indispensable in creating the correct nage waza technique.

Kihon kumi kata is the fundamental grips: right hand at the left collar on a level with axilla, to seize judogi with the little finger, annular, middle finger, and relax thumb and index; left hand at the right sleeve on a level with elbow grabbing much judogi. These grips are the most natural and straightforward.

Fig 2.3.c basic grip

Many variations depend on the competitor’s build, style, positions, and relative strength. It’s important to remember that grip must remain relaxed during the attack or defence.
The apprentices must study this fundamental grip during static training with a competitor (*Uchi komi*) or during the dynamic phase (*kakari geiko*); in fact, it’s essential to learn the ‘contact’ with a competitor using *kumi kata*.
The superior kinetic chains (arms) have four roles in the *kumi kata.*

1) ***<u>Active role: to transfer to the competitor’s body an impulse to realize the throwing technique.</u>***
2) ***<u>Passive role: to stop the impetus and the movement of the competitor during his throwing technique.</u>***
3) ***<u>Advising role: to receive information from the adversary’s body about his movements</u>***

4) Alert role: to receive from the adversary body's movements alert about his attack action

In the kihon kumi kata, the right arm, in a passive way, takes information about the directions of the moving body competitor. In contrast, the left arm takes the information about the direction of the unbalance.
Inactive way, the right arm affects translation to the 'mass' of the body competitor. In contrast, the left arm brings out the moving action with a real directional character.
A more advanced level is essential to study the best possible way to change the grips depending on the opportunity, with minimum energy.
At this level, the kumi kata obtains the capacity to sense information about rival movements and the ability *to impose his initiative, physical and psychological*.
The search for the correct energy utilization takes probably a variation on the competitor's balanced position (with kumi kata, in general, increases muscular body tension) and in the weight relative distribution; consequently, it rests on advanced-foot.
Some Japanese studies (*Studies on Judo techniques concerning the distribution of body weight)* have proved that the weight distribution was much more forward in the tested competitors. You pass from the natural and erect position *shizen hon tai* to the natural position with a grip on a rival; during this action, the muscular tone increases, and the moving body becomes more dynamic. These positions ought to give the action swift and a correct start position in the attack.
The consideration of the dynamic balance in the athlete's couple, like a single bio-kinematic grouping, proved that this couple is in permanent balance, through a whole of tensions, tractions and restraining reactions, even if each athlete has a position of abnormally unstable equilibrium.
In the light of these facts, you can make a correct analysis of competition only if you consider athletes considered as an exclusive whole: the biodynamic grouping ***"athletes couple" (a couple of athletes)***

2.4 The kernel of judo teaching by Kano (*Kuzushi, Tsukuri, Kake)*

The kernel of Judo teaching

As a substantial distinction from the old Ju-Jitsu schools, Kodokan Judo was scientifically organized as a modern teaching structure. With clear fundamentals concepts, like position (shisei), grips (Kumi kata), body movements (shintai), the matter or rather the Throwing Techniques (Nage Waza), carefully selected among old Jujitsu techniques or new entry (Invented by Kano and his students) classified by the tools able to apply the essential part of the force to throw: arm, legs, hips, (Te, Ashi, Koshi, Ma Sutemi and Yoko Sutemi Waza) organized in five lessons (Go Kyo), the introduction of how to handle the owns body in a fall (Ukemi) etc.

Judo structure was based on a steady scientific basis; in Judo Kyo-han French Edition (1911), the authors Yokoyama and Oshima state clearly that Judo throws work according to laws of physiology, mechanics, and psychology, in fact, Yokoyama, in his transcription of Dr Kano lessons in "Judo Kyohan" wrote: *"About physical training, Judo is important, because developing body it also gives the technical ability to fight, ...about fighting techniques, judo is again superior because every part of the body works in agreement to the physiological laws, the application of forces agrees with principles of mechanics, ...finally the mind works in agreement with psychology".* And in one chapter about the body's unbalanced, Yokoyama wrote again, "*Much erudite mathematical proof can be applied for the explication of this problem ... but we prefer to explain it by the simple example of a stick motion in space...*".
This entire means that science, just proto-biomechanics, was present among the founder and first students

But the inner kernel of Judo teaching is the triad structured by Dr Kano to teach or study throwing techniques: ***Kuzushi, Tsukuri, Kake.***
Kuzushi, Tsukuri, and Kake are the fundamental building blocks of Nage Waza.
In fact, during the years, Kano and his assistants realized, according to their evolution, biomechanical analyses ante litteram, three different phases in the throwing dynamic and static action: *Kuzushi, Tsukuri, Kake*. Then we have from the Kodokan dictionary of judo:

- ***Kuzushi: (Balance-breaking)*** *An action to unbalance your opponent in preparation for throwing him.*
- ***Tsukuri: (Positioning set-up)*** *An action to set up a throw after breaking your opponent balance.*
- ***Kake: (Application, Execution)*** *An action used to execute a technique such as a throw after breaking your opponent's balance (Kuzushi) and setting him in a disadvantageous position (Tsukuri).*

All this permits an efficacious rival throwing on the tatami.
A natural temporal division doesn't exist between these phases, as we have already seen in paragraph 2.1; it's an only explicative artificiality to teach a single, fluent and continuous movement.
The controversial matter about the priority of one of these phases, Kodokan's old scientific research has proved that through electromyography check-up of the competitors' fundamental musculature, the stages are connected (paragraph 2.1).
For this reason, we can declare that two phases, *kuzushi/tsukuri* are exactly a single continuous fluent movement because they start at the same time; and so, doesn't exist priority.
But this division is an advantageous and "modern" system to teach in a simple way complex matter.
In modern scientific language translation of sports teaching, differential analysis is applied (to dissect a complex movement, in more understandable conceptual sub-steps) to the whole throwing movements.

Kuzushi
This paragraph will not discuss the human body Unbalance; the argument already faced clearly and entirely in paragraphs 1.1.5 and 2.1.
We consider the complementary concept connected to balance, "Stability", which is essential during standing and motion.
Considering Kano explication, it is easy to understand that Mr Kano utilizing the Physic concept, assumes (for simplicity) the human body as a "Rigid Body".
This is why, among others, to unbalance the adversary, Kano suggests unbalancing the opponent (e.g. forward) by pulling it with a force of about 45 degrees angled upwards.
Why not with a force parallel to the mat, also possible?
Because in this way, the human body stretched forward and upward tended to stiffen, better simulating a "Rigid Body"; thus, facilitating the application of the unbalancing laws of the "Physical Rigid Body".
The criterion for overall stability during standing is for the centre of mass to be over the area spanned by the feet. This means that a vertical line passing through the centre of mass (the line of gravity) passes in this support base area (Fig.1.1.5. a). Otherwise, torques would not be balanced, and a "rigid" human would be unstable and topple over.

Tsukuri
The word *Tsukuri* (positioning set up) included the whole of the innumerable movements that the competitor can realize to prepare the throwing technique.
In judo books, this step is often mistranslated as *fitting in* movements or described relative to each Go-kyo throws.

In such a way, it is challenging to find a general description of the Tsukuri phase of the kernel of judo teaching.
One of the best it is possible to find in the old book Dynamic Judo by Kazuzo Kudo that wrote:
"*As we have explained several times, to apply a technique to your opponent, you must move together with him and push and pull him in such a way that you force him into a position in which your attack is easy to make and in which he is easy to throw. This is what we call the preparatory moves or, in Japanese, the Tsukuri."*
But there is also a fascinating addendum to such a clear explanation, the coupled system's inner concept. It is possible following to read to find…." *To apply the attack step of a technique, you must prepare both your opponent's body and your own."*
Then we can conclude that this is the phase during the throwing action when the thrower applies the throwing motion and constructs the throw.
"Tsuku" means preparing or building something, and "ri" implies doing it to a person. The concept of Tsukuri implies "preparing a person" to be thrown.
This all means that the thrower moves his body into position to prepare his opponent to be thrown.
Kuzushi and Tsukuri blend into a Kuzushi/Tsukuri movement rather than two separate actions. Tsukuri is dependant upon Kuzushi to be effective.

Kake
Kake translates to a phrase that implies "joining together." In other words, the attacker's body and the defender's body are joined or connected at the point of the attacker's throwing action, with the attacker in control of how the bodies get to the ground or mat.
The Kake phase is connected to the application of specific tools to throws.
What tools? Referring to the Kano Kodokan classification for throwing an opponent, there are only five tools: arms, legs, hips, and the owns' body weight (both on the back and the side).
*Kake (*application) definitively refers to various movements of an ending technique part, to global control and putting on a barrier or a hyper-extension, causing an unbalance's competitor too for throwing. This phase of the throwing attack is the actual execution of the throw.

Chapter 3 Advanced Judo Principles

3.1 Static and Dynamic Rotational Unbalances (*Tai Sabaki*)

The study of the no-resistance in Judo is the fundamental tactical principle; in fact, to neutralize the effect of a push with traction and vice versa is the foundation of this sport's entire theoretical and practical development. This principle isn’t so simple like it seems; to apply it in a practical situation is complex. In fact, offering no resistance, and keeping a correct balance position during an attack, in quickly variable circumstances, requires a great quickness of reflex a very intense constant training.
Jigoro Kano considered the no-resistance foundations at first only in the rectilinear acceptance. But more advanced research allowed him to process a new principle called *itsutsu no kata* or “five principles kata”, it was a creation in which there were universal scientific perceptions and profound esoteric significances; these elements permitted the stylized forms in using forces to become real, it was possible to go from the abstract to the concrete. This symbolic and obscure realization represents the extreme synthesis of Kano’s scientific-philosophical thought.
There are three readings about this kata

‘Physics’,	‘Naturalistic’,	Moral’ reading.
In the sphere of Physics:	***In the sphere of Naturalism:***	***In the sphere of Ethics***
1) Direct force sum	1) Wind	1) Perseverance
2) Direct force utilization	2) Water	2) Humility
3) Centripetal acceleration utilization.	3) Whirl	3) Attraction-Repulsion
4) the utilization of reflex force	4) Wave	4) Reluctance
5) the utilization of the inertia	5) Abyss	5) To annihilate himself

And so on. Unfortunately, this synthesis is incomplete, but it would be fascinating, from the philosophical point of view, to finish this work; in that case, the first and the last principle should be equal, symbolizing the continuous natural cycle that happens again.
Jigoro Kano could not develop his research, but he paved the way to permit a natural Judo evolution by this time. Ueshiba Aikido influenced kano's scientific method of study; his Judo acquired, developed and adapted the rotational unbalance concept.
Kusushi Tsukuri phase became mainly rotary, taking a correct biomechanical analysis of the throwing movement during competition into consideration. Kyuzo Mifune (10°dan) used to assert: "if the rival push you need to rotate your body; if he pulls, you need to shift against him in a diagonal direction."

The rotational unbalance naturally is very important to single out the importance of *Tai Sabaki,* which must be considered, an open mind, in a most general view. In fact, either in attack or in defence, the rotation is the base of an effective advanced Judo. *Tai Sabaki*, in all the meanings of the word, includes the whole of *Tori* body movements which will produce a rotational *Kuzushi-Tsu*kuri phase.
Mister Koizumi (8°dan) professed: "the action to throw should be a continuous curved line…".
From a didactic point of view, they are defining an attack *tai sabaki* and a defence *tai sabaki*. However, from a physical and biomechanical point of view, these subdivisions are useless cause they are too abstract.
The essence of the movement is, above all, the body's à rotation, using the forefoot as a pivot.
The unbalanced directions, tangents to the circle, developed, are infinite, like the previous rectilinear Kuzushi.

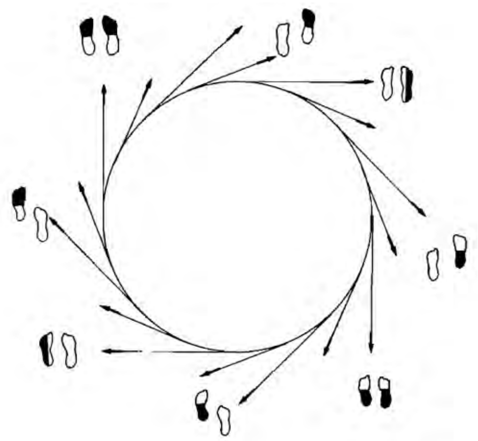


Fig . 3.1.a Rotational Unbalances

A very little rotational moving, just a few degrees, permits to switch often, with its deviation, the rival attack force, preventing each other from throwing action (defensive *Tai Sabaki*). It's possible, in a more dynamic phase, to benefit from the insufficient rival *kuzushi- tsukuri* action and then utilize one's own unbalance to realize a combined effect between one's kinetic energy and rival rotational deviation, in such way you can apply a throw (attacking *Tai Sabaki*).
There is also an "indirect" keen form of unbalance (*Hando no Kuzushi)* that the competitor brings out of balance himself during a defence to the adversary's attack. (Damashi Waza).
The introduction and execution of rotational *Kuzushi-Tsukuri* presuppose a condition of highly dynamic competition.
The superior agonistic Judo recently uses these rotational concepts as the most natural and appropriate to minimize the efforts and the energy, during the higher dynamic phases, in modern competition.

Taisabaki gradual training, to effect *nage waza* techniques, must pass from static phase (*uchi komi*) to moving stage (*yaku soku* geiko). However, it attains full accomplishment and thorough understanding only during his dynamic study (*randori).*

The effectiveness of *Taisabaki* originates from the higher or less (angular) velocity of execution and optimal mobility of the hips compared to the axis of rotation (*haragei). At the end of Nage, it completes itself* in the body's rotation at a maximum of its flexibility (*karada no ineri).*

These fundamental movements, used in Aikido too, *Irimi (* to rotate getting on adversary) and *Tenkan* (to rotate backing and going off adversary), is enforced unlikely in their simple form of pure rotation. However, often in the actual phases of competition, the whole rotational *Kuzushi Tsukuri* becomes complete and complex, from a biomechanical analysis point of view, with other specific movements like feet moving on the inside or outside attack direction. To and from (*Oikomi* and *Hikidashi*) to change suitably the relative distance; fast rotations with a little jump (*Tobikomi)* or with a feet pivot; cross-steps and the other combinations about these movements like *Suwari Seoi*, even though they break the principle of the competitor static stability, they are real and practical.

This concept seems a paradox, but there is a clear scientific explanation; in fact, the biomechanical analysis about the dynamic competition must be affected overall on the bio-kinematic grouping "athletes couple" and not only on one part: "the athlete".

This kind of analysis obliges us to consider each athlete's actions realizable above all in the couple: the adversary's presence, the estimate of the action forces, the vincular reactions of the grips or feet contact with *tatami,* all these actions are permitted only by this particular couple context.

For athletes alone, they are forbidden because they break very well-known physical conservation principles, like conservation of the momentum or the third principle of the dynamics, energy conservation, angular momentum conservation, etc.

Kodokan studies (*The kinetics of Judo*) pointed out that the centre of mass COM of the single biomechanical athlete, thanks to Knoll's method, during *kumi kata* competition could be outside the body. The barycentric perpendicular could be outside the support base.

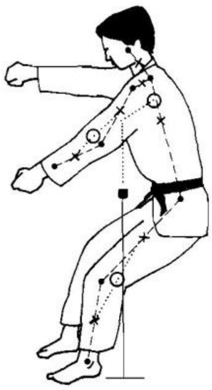


Fig 3.1.b In some positions COM for each athlete in judo is outside the body.

This unbalanced position is forbidden for each athlete for reasons of statics. However, it is also present in every athlete of the biodynamic couple. In contrast, the system "athlete couple" is in a stable, balanced condition on a support base vertex are the feet of athletes.

M_P – pulling torque of thrower	M_G - moment of gravity	M_D – dynamic moment of inertia	G – gravity mg
F_P – pulling force of thrower	K – faltering point	r_S – distance of shoulder to K	r_{CBG} – distance CBG to K
β_S – angle of shoulder during loss of balance	β_{CBG} – angle of CBG during loss of balance	β_F – faltering (tilting) acceleration of body during loss of balance	α – angle between feet
CBG – center of body mass gravity	J – moment of inertia		

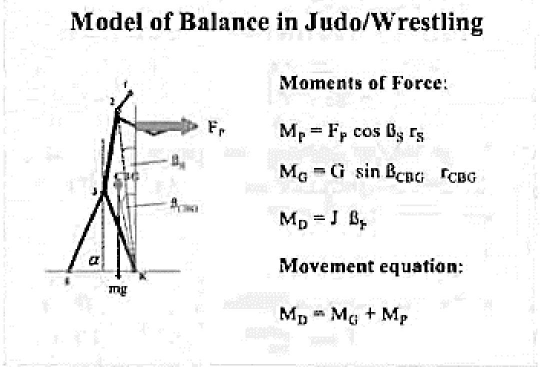


Fig.3.1.c **Simplified model of loss of balance as an effect of an outer force in forward direction (CBG-center of body mass gravity).**

Figure 3.1.c illustrates the simple biomechanical model utilized by Nowyski at ISBS 2005 in Beijing on the loss of balance demonstrated by torque principles (the first approximation of rotational unbalance). In this simplified model (tsukuri kuzushi), there is shown the opponent's tilting due to gravity and pulling forces without resistance. It could serve as the foundation for the calculation of a simple motion equation. Anthropometric parameters
are implicit in the athlete's moment of inertia *J*.

3.2 The fundamental unbalance concept in competition

Limitation of Kano's Principles

If we think about Kano's systematization, it was a beautiful expression of an excellent application of rational and scientific thinking, applied methodologically to organize in exact teaching way the wrestling matter called Judo, for that time.
But at a more cogent analysis, it has some shades in itself. For example, it is unusual to see the hands, hips or legs of Tori working alone to throwing tools. Furthermore, the Kodokan classification uses a different way to classify the body-abandoning techniques classified by the body side touching the mat. This is not coherent with the body's parts applying forces.
Time is gone, and scientific knowledge is increasing very fast. Today, Judo is a worldwide known Olympic Sport. It is time to review and reassess Judo's systematization part in light of modern biomechanical knowledge.

The Biomechanical Reassessment

Biomechanics involves both the quantitative description of human movements and the study of the causes of human movements.
The study of biomechanics is relevant to professional practice in many professions.
Both coaches who teach movement techniques and athletic trainers use biomechanics to qualitatively or quantitatively analyse movements.

Biomechanics' study requires an understanding of musculoskeletal systems' structure and their mechanical properties and their deep interconnection with the central nervous systems and the environmental influences on athletes.
Newtonian Mechanics is the branch of physics that measures objects' motion, finds the forces and explains the causes of that motion.
Judo Biomechanics applies particularly those aspects of human biomechanics related to this sports practice; also included are the mechanical properties and design of sports equipment (Tatami) and clothing (Judo-ji).
Knowledge of judo movements' mechanics allows professional coaches to understand those movements, develop specific training exercises, and change movement techniques to improve performance. Invent new throwing techniques, and teach judo more profoundly and helpfully.
The scientific knowledge is growing presses for an in-depth revision of well-established achievement in the old Judo world.
The Biomechanical reassessment of Judo Foundations is finalized to the matter's clearest vision, helping both coaches and teachers in their daily work.
The Biomechanical reassessment will help the teaching area of Judo (clarifying and simplifying some didactic aspects) and a better understanding of phenomena. It allows coaches to deepen competition aspects, improving their athlete’s performances.

The Revised Principles

The revision of Judo Foundations will be focalized on the Kernel of Judo Teaching, previously analyzed the triad: Kuzushi, Tsukuri, Kake (previously studied in paragraph 2.4), utilizing the right tools Newtonian Mechanics.
This reassessment will follow a focalization of the Kuzuri (unbalance) valuable concept for competition, a clear and easy classification and systematization of the Tsukuri phase utilizing General Action Invariants (GAI) for Judo teaching aspects, the deep revision of the Kake phase.

Kuzushi Right unbalance concept (Breaking symmetry)

All judo teachers and coaches are accustomed to the well-known concept of Kuzushi, the brilliant idea that Dr Kano Introduced in his Judo.
But there is a long conceptual distance between the theoretical explication (Happo no Kuzushi) and the practical application in the competition!
Usually, during a competition, it is impossible to apply the theoretical Kuzushi concept for many reasons; the most obvious one is the adversary's resistance.
As analyzed before (paragraphs; 1.1.5; 2.1; 2.4), theoretical explication by Kano was borrowed by the rigid body analysis from physics, but the human body is not fixed but articulated. Biomechanics persuades us that the Body’s Centre of Mass moves in a position inside and outside the body, changing the stability situation without totally unbalancing the body.
Usually, we are used to considering balance position in standing right situation, that is, a position of unstable equilibrium, if the athlete is still the Centre Of Mass (COM) is more or less under the navel in the origin of Athlete’s reference system, connected to the well-known three symmetry planes of body (frontal, sagittal and transverse).

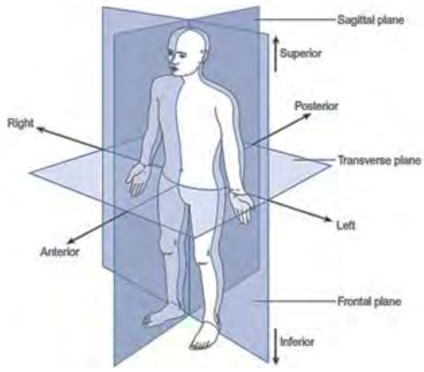


Fig.3.2. a Human Body Symmetry Planes

If the adversary's body is rigid, you can easily apply the Kano unbalance concept, but this is not always applicable in competition.
If the upper part of the body turns or bends on the side, you can't apply it. In these cases, COM shifts inside the body and changes its position. Both stability and mobility of the body are changed.
If stability increases, mobility decreases and with perfect timing, it is possible to profit from these transitory situations; this is the right and useful application of the unbalanced concept in competition.
Remembering that the human body is not a rigid system but an articulated one, we can understand the subtle application of the so-called: breaking symmetry.
Such actions like bending or turning are more comfortable applying or producing; increasing stability causes a decrease in mobility generated by the shifting of COM inside the body and sometimes outside.

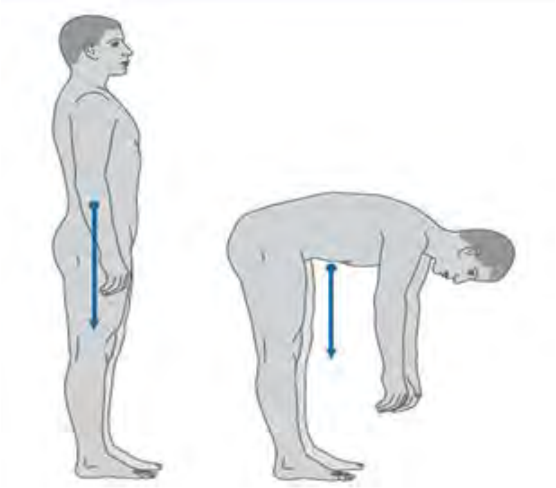


Fig.3.2.b. COM inside and outside the body

Usually, it is easier to induce the adversary to bend or turn during grips fighting because it is a natural reaction to pushing, and there is no knowledge about breaking the symmetry concept.
Breaking Symmetry changes the body's stability and slows down the adversary shifting capability so that it makes easier the application of throws.
This is the first part of the "***advanced kuzushi concept***".
The biomechanical explication for didactics splits the advanced kuzushi concept into two steps:

1) before slowing down the opponent with his symmetry breaking, profiting with a perfect timing attack
2) after, with a body collision, ends the practical kuzushi tzukuri phase starting the Kake.

There is another way to unbalance the adversary during the competition: ***to use his own's movements.*** Typically body movements of both athletes during a competition can increase the single unbalance situation helping the throwing action; the proper use of these other situations is called by Japanese Masters ***Hando No Kuzushi***.

Fig 3.2.c.d.e.f. Various examples of symmetry self-breaking in competition

Many people don't know this advanced unbalance concept and mistakes breaking his symmetry helping the adversary in his throwing action performed by Timing and Collision, depending on the transitory situation. See the next figures

Fig.3.2.g.h Examples of Timing and Collision in an actual throwing situation

Then in high dynamic situations, all judo throwing that is based on the two necessary biomechanical tools, Couple and Lever, will be applied by the following didactic steps that reflect a continuous and fluent movement:

Throws

Basic mechanic in high-Level competition

1. **First: breaking adversary's Symmetry to slow down the opponent *(i.e., starting the unbalancing action)***

2. **Second: timing, *i.e.*, applying the "*General Action Invariant*", with simultaneously overcoming the opponent's defensive grips resistance**

3. **Third: a sharp collision of bodies *(i.e., the end of unbalance action)***

Fourth:

A. **Application of "Couple of Forces" tool (*i.e.*, the type of throw), without any need of further, unbalance action,**

Or

B. **Use of the appropriate "Specific Action Invariants", needing to increase unbalance action, stopping the adversary for a while, to apply the "Lever" tool (*i.e.*, the type of throw) in Classic or Innovative or New (Chaotic) way.**

The previous steps represent the simplest movements, which occur in a connected way and usually throw the opponent in high competitions. All the concepts introduced previously will be explained in the following chapters (5; 8). Very often, though, far more complex situations can arise under actual fighting conditions.

These complex situations have evolved from the simple steps explained above, depending on the combination of both athletes' attack and defensive skills.

However, the actual *Collision* step is essential for applying any accurate throwing technique.

This kind of collision is almost a rigid body collision [35]. Nevertheless, using the rotational force's approach in the ***Advanced Kuzushi Concept*** seems the most effective in terms of the score.

In the following figures, it is shown the high-level unbalance concept in dynamic competition.

A) **Application of a couple technique without further unbalance.**

B) **Action Reaction tricks, breaking symmetry stopping the adversary and collision with Lever application.**

fig.3.2.k.i. l   diagonal application of trunk /leg couple without further unbalance

(uke rotates around his centre of mass)

Fig.3.2. m.n.o. Breaking symmetry, Collision and Lever Application with action-reaction strategy

(Uke Centre of Mass is translated in space)

Summarizing throwing action in Competition could happen in three sequential forms:

Classical: ***Kuzushi-Tsukuri-Kake.***
Semi Classical: ***Hando no Kuzushi-Tsukuri-Kake.***
Usual: ***Breaking Symmetry-Tsukuri (with Timing and Collision) -Kake***

All three sequences are only one fluid movement without steps. The division is a teaching tool that underlines the way to unbalance the adversary.
The first may happen when Tori and Uke have a big difference in Judo Knowledge and Skill.
The second one, when Uke makes a mistake in the displacement of the body, produced or induced by Tori
When Uke makes a mistake rotating or bending his trunk, produced or induced by Tori, the third one makes a mistake.
Collision grows in importance because, in the last time, collision with simultaneous throwing off his own body on the tatami is an essential part of the actual throws.
It is easy to understand that athletes for the high-level competition must work a lot around the study on symmetry breaking, how to produce it, and how to use it helpfully.
This is an original branch of analysis. Full of new exciting discoveries that high-level competition coaches must develop to give their athletes more valuable and updated tools.

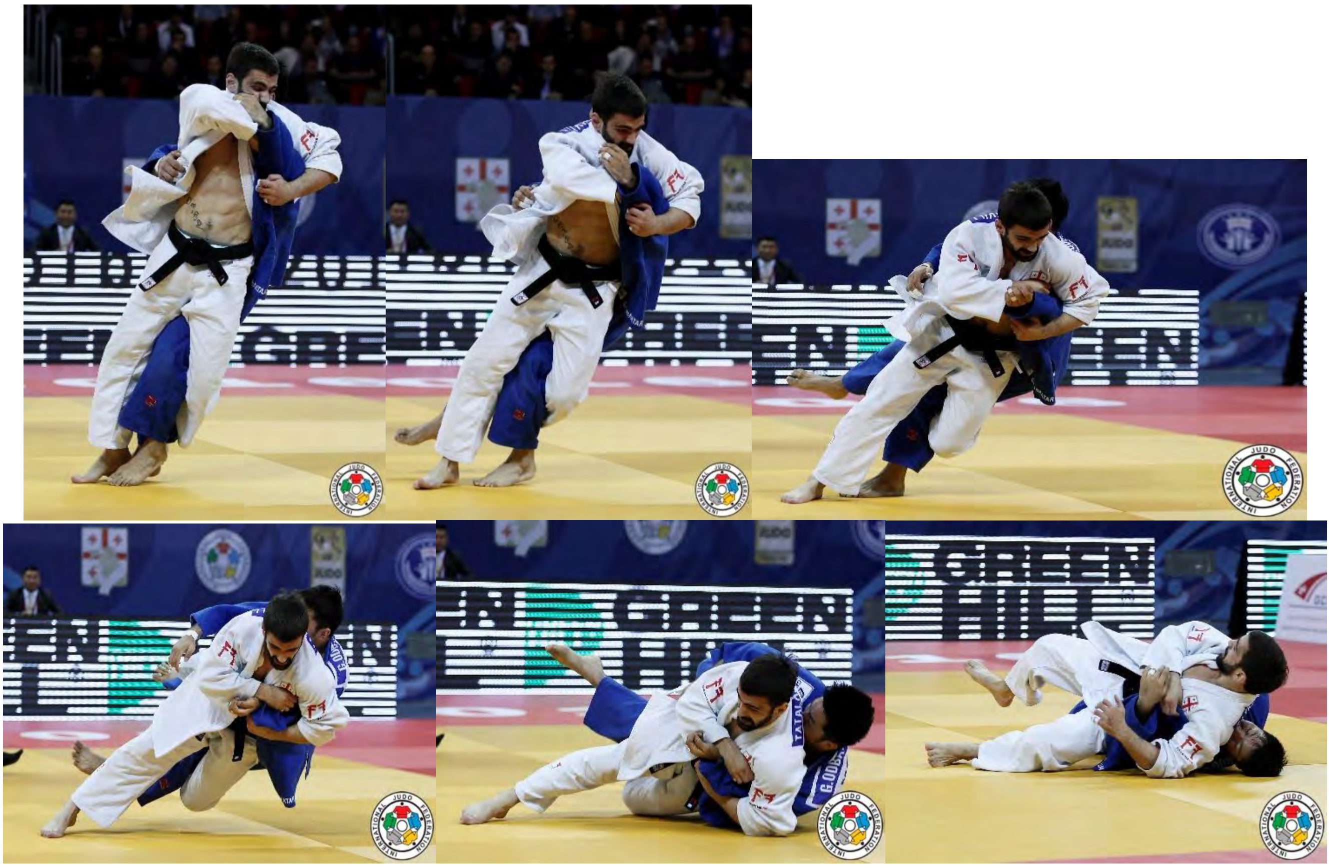


Fig.3.2.p.q.r.s.t.u Example of throw by Collision and simultaneous fall of attacking the body. These kinds of throws are Lever throws with plunge

3.3 Initiative as the exploitation of kinetic energy and angular momentum
(Sen [*Renzoku and Renraku Waza*])
(*Go no Sen* [*Bogyo Waza*])
(Sen *no Sen* [*Kaeshi Waza*])

Now, we're going to study the dynamic phase of competition as better utilization of owns kinetic energy, angular momentum or the adversary, and the problem of the dead time between preparation and attack. It's essential to study the most favourable solution, from a biomechanical perspective, about the initiative and its better utilization.

Every biomechanical consideration in this research refers to analysing the biodynamic grouping "athletes couple" about *Tori* actions concerning the corresponding *Uke* actions and positions.

The study of the initiative and its utilization leaves out of consideration the concept of attack and defence; in fact, the essence of defence is to grasp always the initiative, to utilize all one own and rival movements, to be able to realize a throwing technique; at this point, we can say that the defence is an attack and vice versa. In Japan, many ancient schools of martial arts have studied the initiative until to realize "*Densho"* books about secret principles, a wealth of each school.

Most impressive is the old Japanese approach the initiative during fights or competitions.

In the old *Densho,* the way of taking the initiative is explained in three stages.

1. ***Sen-sen-no-sen*** (superior initiative). The exceptional initiative is given play in a delicate situation where one confronts an opponent who intends to attack and gains mastery over him by subtly guessing his mentality and forestalling his actions.
2. ***Sen*** (initiative). This is to forestall your opponent by starting action before he begins the attack on you.
3. ***Ato-no-sen*** (an initiative in defence). This is not to guess your opponent's mentality and check his action before it is done, but to start action in defence when you have an inkling of your opponent's offensive. To avoid the opponent's attack the instant it is about to be launched upon you, make a counter-attack taking advantage of a pause in your opponent's movement and a disturbance in his posture. A man who takes the initiative in defence rises in opposition to his opponent's attack and parries or averts it.

In Judo competition, there are three base-form of energy utilization into action called, according to the ancient Japanese classification, ***Sen, Go no sen, Sen no sen:***

Sen— (the initiative) needs the correct use of *Renzoku waza* (connected techniques in the same direction) and *Renraku waza* (consecutive different techniques). The definitions are not so clear in ***"Kodokan new Japanese-English dictionary of judo"*** we found: *renraku waza* (combination techniques) application of several techniques in rapid succession, moving from one to the next in a smooth, unbroken sequence; *renzoku waza* (continuous combination techniques) continuous application of combination techniques, one leading into the next.

Go no sen— (the contrast of initiative) expresses by *Bogyo waza* (defensive techniques)

Sen no sen— (the initiative over the initiative) gets with *Kaeshi waza* (counter-attack techniques)

SEN (Renzoku and Renraku Waza)

Sen Principle is undoubtedly the most direct method to utilize the initiative by immediate and positive action. To have a more articulate *sen* initiative, we employ, as a discriminant factor, the previous or subsequent time to put into practice one's unique technique. The following subdivision is helpful to teach:

A) Direct attack with one's special (*Tokui waza*)
B) Repeated attack with the same technique in the same direction (*Renzoku Waza*)
C) Repeated attack with connected techniques *(Renzoku waza)*
D) Attack and variation in another technique cause of anticipated *Uke* defence (*Renraku waza)*
E) Attack after a feint *(Damashi waza*

A) Direct attack with one's special (*Tokui Waza***)**

This attack is a purer application of the *Sen* principle. The powerful technique (Kimari waza) is directly realized; for this reason, Tori must possess maximal kinetic energy and maximal impulse to develop maximum potency fundamental that Uke opposes a weaker resistance to have success in the action.

Necessary Condition: *Sufficient Condition*

$$\frac{1}{2}mv_T^2 + \frac{1}{2}I\omega_T^2 = Max. \qquad dp_T >> dp_U$$

dp_T =*Tori momentum*

dp_U =*Uke momentum*

The *Tsukuri-Kuzushi-Kake* phase is direct. Here one needs to use one's particular *Kumi kata*. It's also necessary the presence just now of the least suited rival from a physically and technically point of view, cause this kind of tactics becomes dangerous with a well-prepared opponent. In the last few years, the analysis of maximum competitions has proved that many champions change at the end the attack angle slightly "*to redirect into ineffective direction*" *Uke* defensive reaction.

Another competition trick is to use their body weight at the end of the kake (like *sutemi*), throwing his body on the mat. Tori helps the success of kake because, for Uke, it is more challenging to contrast both the impact force and bodyweight of the competitor.

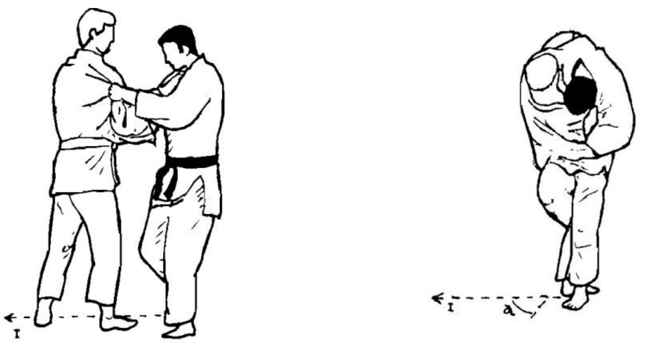


Fig 3.3.a SEN- O Soto Gari with a change in the attack angle

B) Repeated attack with the same technique (*Renzoku Waza***)**

This kind of *Sen* Principle is applied after *Uke* stops the first attack to repeat the same tokui waza taking advantage of Uke probable mental relaxation or attack angle variation. There is the same impulse in the first opportunity in the first and the second attack (*Nami sen*). However, the second impulse will be always less or the same as the one. The success of the technique (*Kake* phase) and throwing (*Nage* phase) will be possible only when the second reaction is less than the one and contemporary less than the second impulse.

$$1)\ dp'_T = dp'_U \rightarrow \ 2) dp''_T > dp''_U$$

In the second opportunity, even if the *Uke* reaction will be the same or greater than the first one, it will be frustrated by an appropriate Tori angle attack variation.

Hypothesys

$p'_T \geq p''_T$ *and* $p''_U \geq p'_U$

Throwing action in two time

1) $dp'_T = dp'_U \rightarrow$ 2)$dp''_T \cos\alpha > dp''_U \qquad 0 \leq \alpha \leq \dfrac{\pi}{2}$

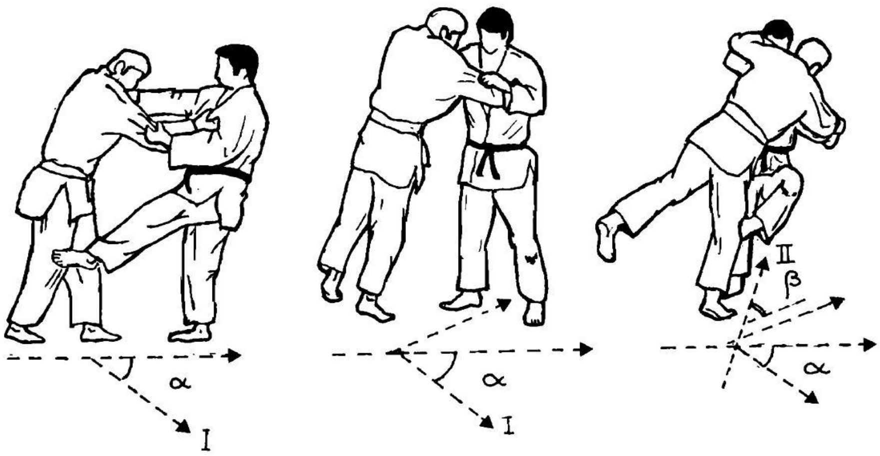


Fig 3.3.b SEN- Repeated throws with the same technique Hiza Guruma with angle change

C) Repeated attack with connected techniques (*Renzoku waza).*

This is the application of the *Sen* Principle in a connected series, using different techniques. The first action of *Tokui waza* causes *Uke* reaction who responds to a right direction to nullify the attack but producing an opportunity of vulnerability in a second or third attack, in which *Tori,* using at best adversary's energy, applies suitably the connected technique, which is in the direction of *Uke* less resistance.

The following connected techniques (*Renzoku waza*) must be considered a tactical construction. A strategic end to change direction to the applied impulse directs it towards minimum energy trajectory (geodetic). There is less resistance direction that the *Uke* reaction has produced.

The analysis of the specific directions can group them into three categories:

- Related techniques in the same direction (*Nami Sen)*
- Related techniques in the opposed direction (*Gyaku Sen)*
- Related techniques in side directions (*Yoko Sen)*

About two successive and different linked techniques, we can write this formula

Hypothesys

$$p'_T \neq p''_T \ \ and \ \ \frac{1}{2}mv''^2_T + \frac{1}{2}I\omega''^2_T = \min$$

$$p'_U \neq p''_U = \min$$

Throwing action in two time

$$1)\ dp'_T = dp'_U \rightarrow \ 2) dp''_T \cos\alpha > dp''_U \qquad 0 \leq \alpha \leq \pi$$

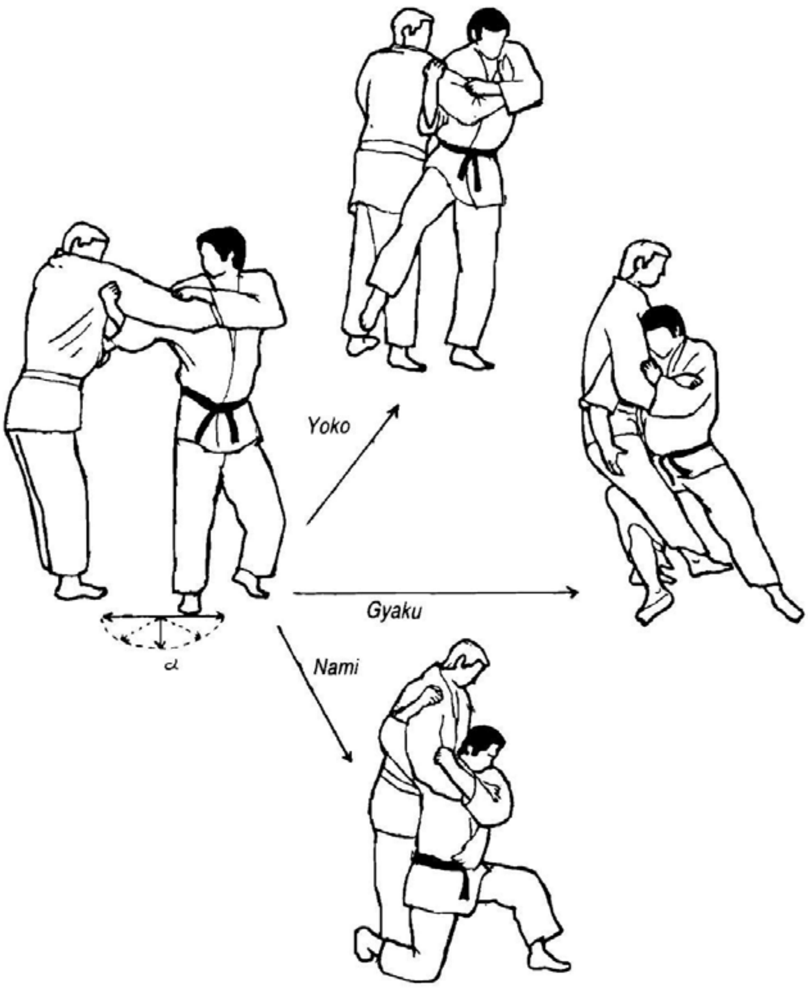


Fig 3.3.c SEN- Linked throws on Ippon Seoi Nage

D) Attack and variation in another technique cause of anticipated *Uke* defence (*Renraku waza)*

This is the Sen Principle's enforcement of the most fundamental principle, “maximum efficiency with minimum effort” inside biodynamic grouping. Everything is possible if, before Tokui waza, you affect the appropriate attack trajectory variation execution, related to minimum resistance direction, a cause of very advanced Uke defence.

Hypothesys

$$\frac{1}{2}mv''^{2}_{T}+\frac{1}{2}I\omega''^{2}_{T}=\min$$

$$p'_{U}=\min$$

Throwing action in one time

$$1)\ dp'_{T}\cos\alpha > dp'_{U}\cos\beta \qquad 0\le\alpha\le\pi \qquad 0\le\beta\le\frac{\pi}{2}$$

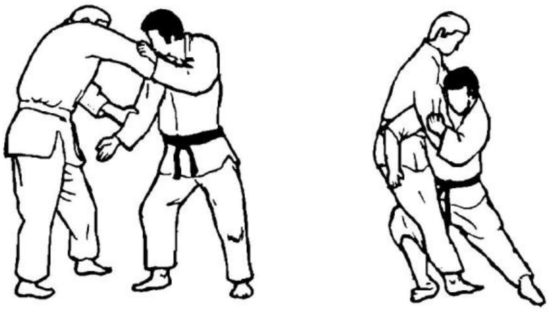


Fig 3.3.d SEN- Ko Uchi Makikomi attack on untimely defence on O goshi attack

E) Feint and subsequent attack (*Damashi waza)*

The *Sen* Principle application utilises a feint to apply the powerful throwing technique (*Kimari waza)* into Uke moving direction.

It’s essential to realize the whole feint action in the right way allows *Tori* to keep most of his kinetic energy and utilize it at best using *Uke* reaction.

In this way, *Tori* utilizes *Uke* energy to annul the feint, adding this energy to one’s own and using it in his *Tokui waza* during the *Kuzushi Tsukuri Kake* phase.

Hypothesys

$$E_{tot}=E_{T}+E_{u}=\frac{1}{2}m_{T}v_{T}^{2}+\frac{1}{2}I_{T}\omega_{T}^{2}+\frac{1}{2}m_{U}v_{U}^{2}+\frac{1}{2}I_{U}\omega_{U}$$

Throwing action in one time

$$1)\ dp'_{T}\cos\alpha > dp'_{U}\cos\beta \qquad 0\le\alpha\le\pi \qquad \frac{\pi}{2}\le\beta<\pi$$

Fig.3.3.e SEN – Hidari Damashi Migi O Soto gari

Noriyuki Shannoe performed an exciting evaluation of Sen by (Damashi waza) feints connecting feints to a different step of throws: tsukuri and kake, and utilizing a personal technical classification (throws divided into two types with rotation and without rotation), by binomial tests, obtained the following results if the feints were non-rotation, and techniques were of the same group all the feints were connected to kake phase, in the other way if the feints were non-rotation, and the throwing techniques were rotation the feints were applied during the tsukuri phase only.

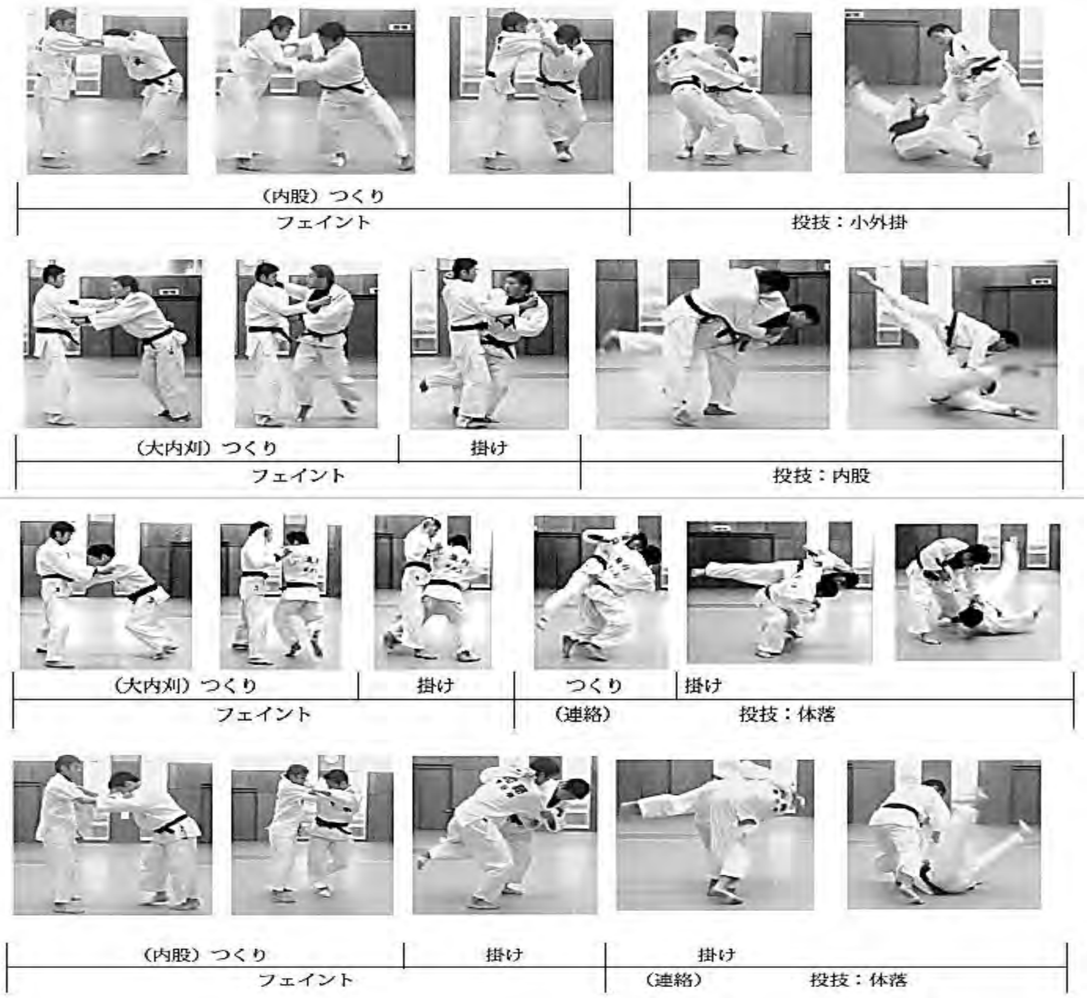


Fig3.3.f,g,h, i Shannoe experiments on Sen by (Damashi waza) connecting feints to kuzushi tsukuri.

GO NO SEN (Bogyo Waza)

The *Go no Sen* principle (the initiative contrast) is brought in *Bogyo waza* (defence techniques).
In a didactic classification, the Japanese school considers various possible principles about Tori actions that he can realize, during the attack, to oppose this attack before to effect or to develop the counter-attack.

The principles are:

A) ***Go***—to break, to stop
B) ***Chowa***—to avoid, to dodge
C) ***Yawara***—to support, to yield
D) ***Ura***— (to annul) back

It's essential to note that *Tori* effects his defensive technique after the ineffective *Uke* action. In general, you will find a delay time between the *Uke* attack and the beginning *Tori* counter-attack. The delay time, during these defensive actions, plays a fundamental part; in fact, the counter-attack will be more efficacious and less expensive from the energy point of view if, for example, it is effected at the end of *Uke* attack, cause in this way *Uke* isn't in a proper force position (*null Mechanical Momentum)* and before he acquires a new balance position.

Hypothesys

$$p_u = 0 \quad \equiv \quad mv_U = 0 \rightarrow v_U = 0$$

A---

The biodynamic analysis about energy in these actions permits us to comprehend the ***GO** actions, and* they are the most dissipative. The contrasts take place opposing to the *Uke* action the same and contrary reaction, in this way, this action is wholly annulled and stopped, but at the cost of considerable waste of energy; for this reason, it isn't wise for a correct resistance direction purposes in a protracted effort, to build one's defensive action entirely on these kinds of technical activities.

Hypothesys

$$E_{tot} = E_T + E_u = \frac{1}{2} m_T v_T^2 + \frac{1}{2} I_T \omega_T^2 + Q_T + \frac{1}{2} m_U v_U^2 + \frac{1}{2} I_U \omega_U + Q_U = Max$$

Stopping action and attack in one time

$$1)\ dp_T' = dp_U'$$

$$2)\ dp''_T \cos\alpha > dp''_U \cos\beta \qquad 0 \le \alpha \le \pi \qquad \frac{\pi}{2} \le \beta < \pi$$

Fig3.3. j Go no Sen –Uchi Mata Go defence

While, *Chowa, Yawara* and *Ura* actions are very close to the principle of '*maximum efficiency with minimum effort'*; in fact, they are founded on a "soft" defence, these techniques utilize a lot of *Uke* kinetic energy, having a significant advantage over him with minimum effort.

B---

Chowa defence is essentially founded on the mobility concept (*Tai sabaki)* and the utilization of the unbalanced position because of the inefficacious Uke attack; it is enforced at the end of the Uke action attack and to less resistance direction. About *Sen* principle, there are three classes of defences related to the direction:

Actions in the same attack direction (*nami chowa*)

Actions on the contrary attack direction (*gyaku chowa*)

Actions in lateral directions to the attack (*yoko chowa*)

$$p'_U \to 0$$

Throwing action in one time

$$1)\ dp'_T \cos\alpha > dp'_U \qquad 0 \le \alpha \le \pi$$

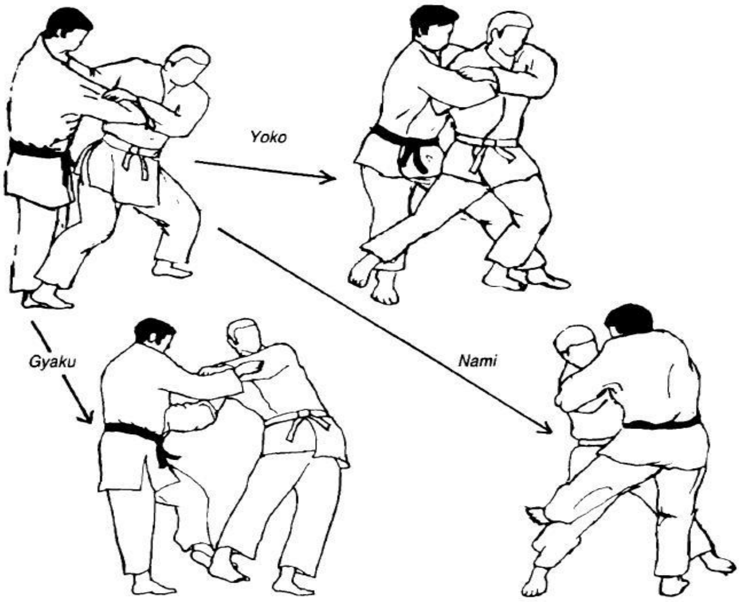


Fig 3.3.h - Go no Sen-Tai Otoshi Chowa defence

C--

The ***Yawara*** defence (preferred by Mifune) is even more delicate than *Chowa, and* it is founded on the dynamic concept of the partial kinetic energy utilization generated by *Uke* attack. This energy must be used before the attack action becomes effective and always in the same direction.

For these reasons, it's fundamental to have considerable acrobatic capabilities and a perfect sense of timing during the execution of the *yawara* defence. For the principle inherent in defence, making a mistake in timing would cause the Uke attack's success.

Hypothesys

$$E_{tot} = E_T + E_u = \frac{1}{2} m_T v_T^2 + \frac{1}{2} I_T \omega_T^2 + Q_T = \frac{1}{2} m_U v_U^2 + \frac{1}{2} I_U \omega_U + Q_U$$

Undergoing action and throws in one time

$$1)\ dp_U{}' > 0$$

$$2)\ dp''_T + dp''_U > 0$$

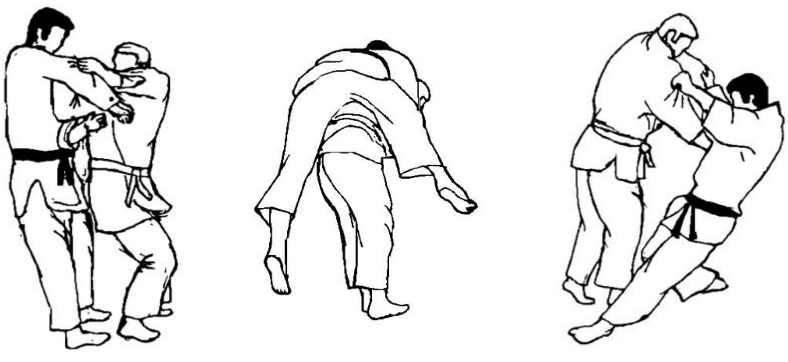


Fig 3.3.k -Go no Sen – Morote Seoi Nage Yawara defence

D---

The ***Ura*** defence (proposed by Kudo) is fascinating from the biomechanical analysis point of view of the energy into action. It is founded above all on the directional energy transformation; this defence's fundamental physical principle is to direct most of the kinetic energy of *Uke* attack in a particular direction to effect a *nage waza* throwing. These techniques (*Ura nage, Te guruma, Ushiro goshi, Utsuri goshi,* etc.) are above all specific movements aim to deviate, direct, and guide suitably the rival attack until final throwing.

Hypothesys

$$E_{tot} = E_T + E_u \cos\alpha = \frac{1}{2} m_T v_T^2 + \frac{1}{2} I_T \omega_T^2 + Q_T + (\frac{1}{2} m_U v_U^2 + \frac{1}{2} I_U \omega_U + Q_U)\cos\alpha$$

$0 \le \alpha \le \pi$

Re*directing action and throws in one time*

1) $dp_U' > 0$

2) $(dp''_T + dp''_U \cos\alpha) > 0 \qquad 0 \le \alpha \le \pi$

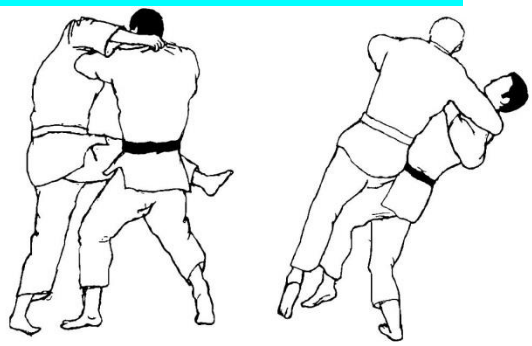


Fig 3.2.m -Go no Sen- O Soto Gari Ura Defence

It's important to remember during a competition, and often there are not only these forms of dynamic defence but also "passive" defence forms founded on the exclusive use of the bio-kinetic chains and the appropriate transfer of weight body. All these almost actions have in common the stiffening of arms to keep contact with other activity in a specific situation. They are also founded on the opening grip to stop with arms the throwing of one's body. In Judo, this dangerous practice is the most frequent motive of dislocations.

SEN NO SEN (Kaeshi Waza)

Sen no Sen principle (the initiative over the initiative) is perhaps the most delicate form to apply. There are two initiatives in the biodynamic grouping that mix in a single dynamic whole during its execution. The ideal action is: *Tori* realizes his counter-attack while the *Uke* attack is going to start; it's an advance and superior initiative form, but it requires an exceptional psychophysical capability, quick reflexes and a perfect athletic condition.

This kind of action has the advantage to take by surprise the rival during the attack keeps under his mental and physical pressure; this action also has the advantage to utilize the rival's energy exploiting the initial delicate phase of the transition from potential muscular strength to kinetic energy.

His practice needs a perfect and correct present opportunity perception; it requires absolute use of control and a full speed in execution to overcome *Uke* speed.

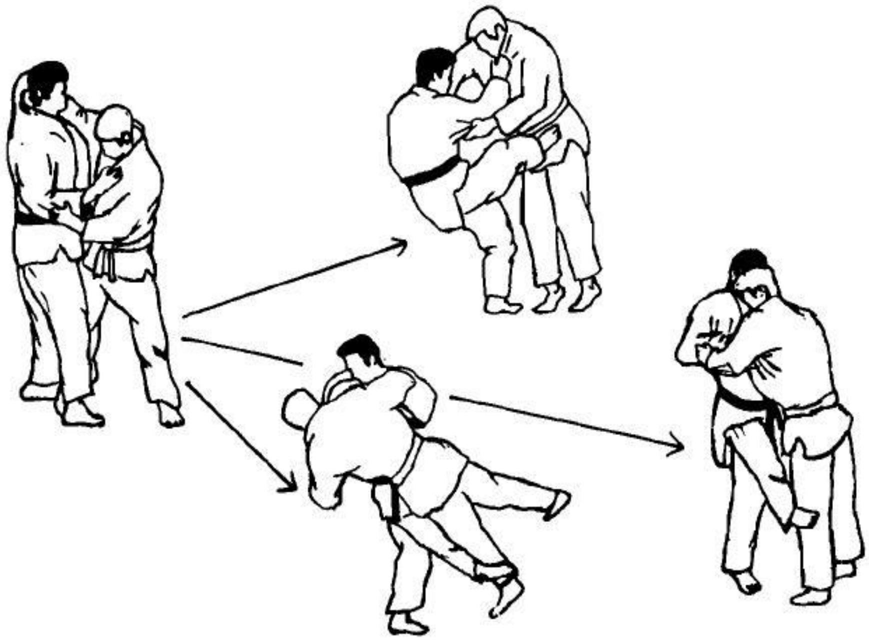


Fig 3.3. n Sen no sen-Kaeshi against ko uchi gari attack

The contrast between classical and biomechanical vision lifting a leg at different eight we have three other throwing techniques (classical concept) the same biomechanical principle application with different length of the lever arm

The techniques that embody this principle are Kaeshi waza (counter-techniques), which emphasize the fundamental aspect of opportunity during a counter-attack.

Now we'll distinguish them in this way:

A direct counter-attack in a direction to attack (*Nami Kaeshi*)

A direct counter-attack in the opposite direction to attack *(Gyaku Kaeshi)*

A direct counter-attack in the lateral direction to attack (*Yoko Kaeshi)*

Some analytical and complete studies made in Japan about fundamental problems and particular aspects of the dynamic phase during the competition (*Analytical studies on the contest performed at the All Japan Judo Championship Tournament 1971)* proved the 70% of powerful techniques *Kimari waza* are formed by *Ashi waza.*

The type of defence depends on the Judoka weight categories:

	Heavy	Light
Defence using weight body	65,6%	38,4%
Defence by skilful body movements	22%	50,4%
Defence with counter-techniques	12,4%	11,3%

The defensive methods utilized in the All-Japan judo championship concerning dome throws are shown in the following table.

The competition study performed in Japan in 1070 also showed that athletes with higher technical knowledge are the winner in 67.7%, and only 25.85 was with the inverted result. Kaeshi Waza wined 55.5%. From the other side, the maximum throws number for one athlete was 9 with a medium value between 4 or 5.

In the case of many techniques, 61.3% was the winner, and 22.6% was the loser.

These data show that at a higher judo level, it is necessary and valuable to know not only one *tokui waza* but more linked throws (see old Russian approach to the initiative).

	Method of Defence	%
Uchi Mata 122	1. by stretching both arms and by lifting the leg	23.8
	2. by stretching both arms and by lowering hips	22.1
	3. by stretching both arms and by dodging	18
	4. by unfolding the body's upper part, by stretching the pushing hand and by sweeping aside the pulling hand	14.8
	5. by twisting the body and lying prone	5.7
	6. others	15.6
O soto gari 122	1. by stretching both arms and by unfolding the body, and by preventing the reap of the leg	43.4
	2. by unfolding the body and by receding	20.5
	3. by unfolding the body and by tripping the opponent's leg	6.6
	4. by unfolding the body and by holding the opponent's foot and hip	5.7
	5. by stretching the pushing arm and by unfolding the body, and by sweeping aside the pulling arm	4.9
	6. Others	18.9
O uchi gari 103	1. by stretching both arms and by lowering the hips, and withdrawing the legs, thus preventing the attack	35.9
	2. by stretching both arms and by tripping the supporting leg of the opponent	22.3
	3. by stretching both arms	18.5
	4. by stretching both arms and by preventing the reap and by changing into another waza	8.7
	5. by stretching the pushing hand, by unfolding the body, and by sweeping aside the pulling hand	3.9
	6. Others	10.7
Ko uchi gari 73	1. by unfastening the opponent's reaping leg and by elevating the leg	38.4
	2. by stretching both arms and by extending the reaped leg	15.1
	3. by twisting the body and lying prone	12.3
	4. by stretching both arms and by changing into another waza	6.8
	5. by stretching both arms and by preventing the opponents reap	5.5
	6. Others	21.9
Tai otoshi 55	1. by stretching both arms and by preventing the attack by withdrawing the hips	52.7
	2. by changing into another waza at the moment of the attack	14.6
	3. by closing tight the pulling hands and by breaking the opponent's balance	10.9
	4. by jumping aside over the opponent's foot	9.1
	5. by stretching the pushing hand, by unfolding the body, and by sweeping aside the opponent's arm	9.1
	6. Others	3.6

Tab 3.3 a Defensive methods applied at all Japan Judo Championship 1971

The Old Russian approach to Initiative

The old Russian approach to the Fighting Initiative problem is very different from the Japanese one.
As already Iatskhevic and other authors underlined, the Russian approach is less philosophic, more pragmatic than the tremendous experience and old traditions in local wrestling.
The former Soviet Union considered judo as a unique "pyjama wrestling" with Olympic medals. Techniques have no Japanese names, the colour belt was not essential, because significant were the State degrees, of "Sport Master" (first, second and third level), classification and teaching methods were different. However, this unorthodox approach: the introduction of unusual techniques, uncompromising fighting attitude, gripping strategy and so on, helped the Judo growing.
The approach was very similar to the wrestling approach, but wrestling in the former Soviet Union was considered every sport scientifically. Biomechanics, periodization of conditioning, advanced strategy, and tactical style were typically known and used at the wrestling coaching level. Then the most straightforward way was to "translate" this knowledge into "Judo Language". In such way, the initiative was approached like wrestling initiative, not with the philosophical attention to timing and scope but, as Rajko Petrov stated in his golden book " *Free and Greco-Roman Wrestling*" Publisher FILA 1984, by the more pragmatic study of:

1. The strategy of technical action
2. The strategy of competition fight
3. The strategy of the whole competition.

These three aspects were based on the in-depth study of TTC (Technical-Tactical Complex).
The TTC is a set of technical-tactical combinations (more techniques linked).
In such an approach, the technique is the essential goal (as an application) inside the combinations part of TTC content. The classical point of view divided the TTC and the Combinations into three main categories two groups and three subcategories
a). Theoretical TTC. b). Elaborative TTC. c). Applicative TTC
All these three categories can be grouped as a goal like:
Attack TTC or **counter-attack TTC** into which it is possible to find
Structural TTC studies the attack possibility from a specific position: "freeze structure of the coupling system". ***Reflex*** TTC investigates the capability to produce specific reflex actions in the adversary to build a tactical possibility. ***Complex*** TTC studies the ability to attack using a complex combination of the two previous TTC
If we think of this old classification, it is possible to understand the uncompromising Judo Style; there is no defensive approach, but only two ways: attack and counter-attack.
Then we are in the presence of more elaborate construction (more than three techniques linked) as fundamental consideration of typical fight.
About grips, the Russian style sees grips not only as a control to exercise mechanical action on the adversary (Japanese view) but also as a system to control the spatial situation into the couple to obtain a favourable positional position to apply the throws
In the following table, there is a comparison of technical, tactical methods to apply a technique between old Russian Style and French Style (as the more like the classical Japanese)

Russian	Unbalances; Manoeuvres; Threat; Double attack; Serial attack; Feint; Block Understanding; Dissimulation ; Coordination ; Counter-attack; Psychological pressure; Pace regulation; Mistakes utilization; Tatami surface utilization
French	Dodges; Combinations; Double attack; Chaos and feint; Counter-attack; Block Overturning; Chance

Tab 3.3.b, Comparison between old Russian and French Main Technical-Tactical Methods to apply the technique

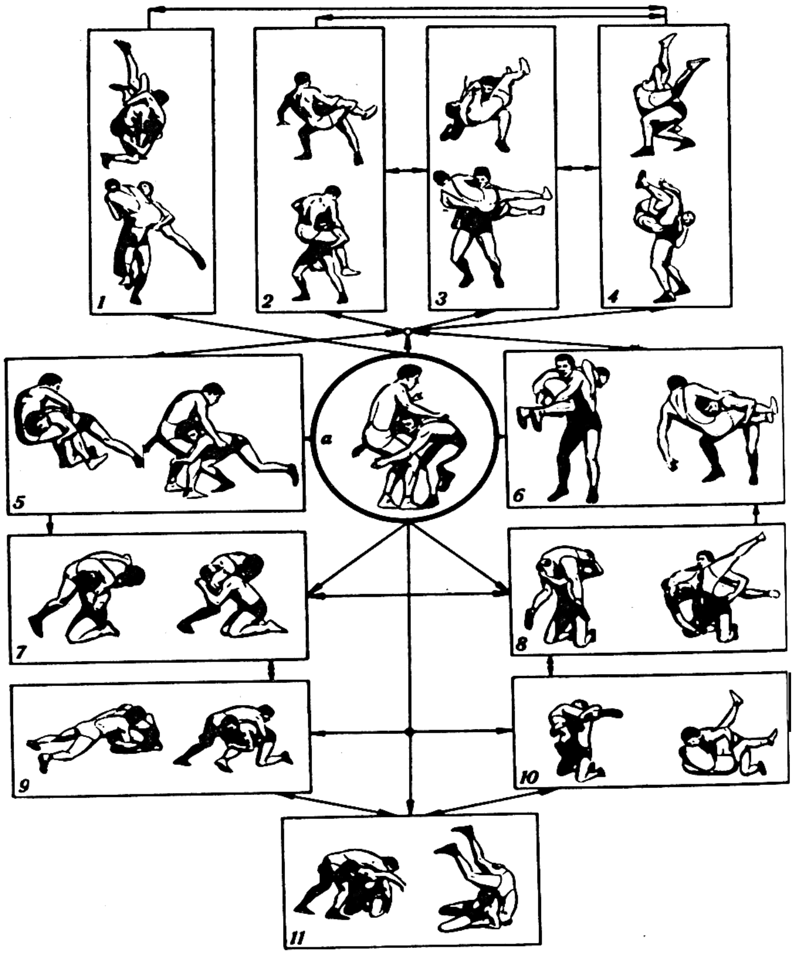


Fig3.3.o- Old Russian Initiative approach example like free wrestling study Technical-Tactical Complex Wrestling "LEGS SWEEPING" analogous at "MOROTE GARI" From Rajko Petrov Lutte Libre et Lutte Greco Romaine (Today these techniques are not allowed by the change in referees' rules)

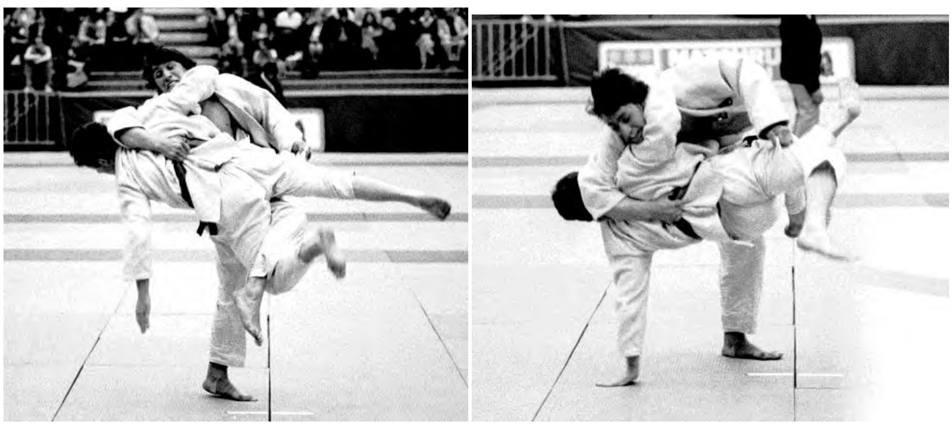


Fig3.3.p- Khabarelli: master of unorthodox grip and attack –This throw it is not o uchi gari changed in a strange lifting (Adams comment); but it is a well-known free wrestling throw called backwards Kliket made easier by the belt and trousers grips, how it is possible to see in the illustration of Prof Petrov's book. (Finch) (Today, these techniques are not allowed by the change in referees' rules)

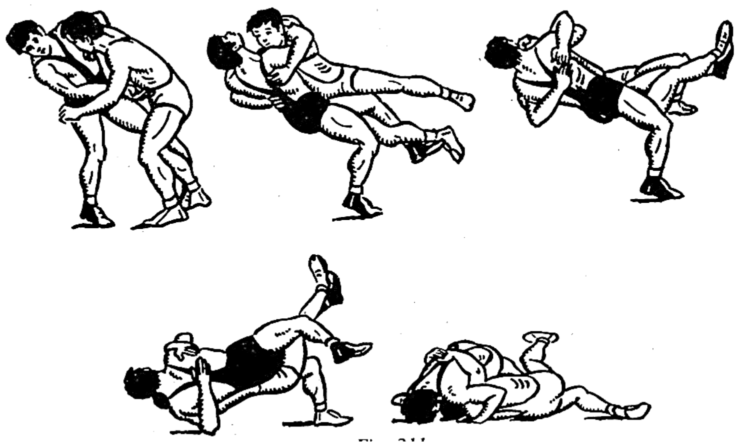


Fig.3.3.q -Backward Kliket
From Rajko Petrov Lutte Libre et Lutte Greco Romaine

Today, with the change in refereeing rules and Russia's birth from the Soviet Union, Russian athletes' style is very similar to Japanese and other leading countries athletes. The technical initiative is evolved from a robust static way to grip the vantage to a very dynamic skill applied with great timing.

3.4 Relative Range, Grips, and Timing (*Mai Ai, Kumi Kata, Kobo Ichi*)

The study of the biodynamic system "athletes couple" during a competition points out the fundamental significance of relative positions during the *Nage waza* technique. Particular positions coincide with different distances between athletes and overlap with other attack and defence methods at different close lengths.
The distances are classified, for didactic utility, related to dimension:

TO MA Great distance
MA medium distance
CHICA MA small distance

These concepts were studied widely by many ancient *budo* Masters, and in fact, it's exciting to note that the time of application in a throwing technique, either defensive or offensive, is the primary function of the relative distance between forward and rival.
Regarding the offensive, the distance concept is essential to make use of the right power. In fact, from this formula, $P = Fv = F\left(\frac{dr}{dt}\right)$ you can comprehend the developed power is directly proportionate to the distance between athletes, for this reason, the growing space is the equivalent of a higher dissipated power while at growing intervals follow up a contemporaneous decrease of the attack force which is inversely proportional to the time $F = m\left(\frac{dv}{dt}\right)$
Regarding defence, the distance has a part even more predominant. The defensive reaction, according to situations, will be different. The defensive action is a principal function of intervals between the start attack and the beginning contact of both bodies.
If this interval is long-lasting, the available time to select in keeping with reaction will be superior, and this interval is connected to the *Athlete reaction time*.
These defensive actions are also a function of the distance between competitors, the opportunity of an effective reaction related to the angle attack, for example, *defence utilizing a large taisabaki, using a*

little translation and of hips rotation. These connections prove this functional dependence and the importance of relative distance: on the velocity, superior distances will be covered in higher time $vdt = dr$

Greater is the relative distance between two athletes, and superior will be the inertial moment of biodynamic grouping and so will be superior the space for rotation: $I = mr^2$

For this reason, it is very fundamental, realizing a technique to use at best the concept of ***relative distance.***

Better distance to realize a technique is in the *balance* between optimal **Time** to have a contact and the available **Space** to realize the attack movement, preserving a sizeable **Inertial momentum** in the athlete’s couple.

Master in the right way the ***relative distance*** is the essence of attacking and defensive capability. More often in the competition, you can observe that the winner's ability is grounded on the capacity to solve by his body the relative distance problem.

And to adapt with high flexibility and coordinate his body to the adversary body position to gain the correct contact position, which is the best to throw.

The relative distance between athletes in a biodynamic grouping can be annulled to realize a technique by a *taisabaki* or controlled along the longitudinal axis by *guard position*. During a competition, there are many sorts of approaches that regulate the relative distance between two athletes.

To didactics, you can group them into three classes:

Diagonal guard positions

The athletes are placed so that the relative distance between them is almost zero, while on the other side is large and sometimes open.

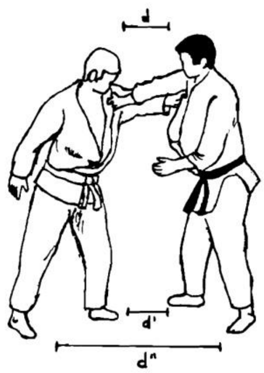


Fig 3.4.a diagonal guard d=d’<d’’

Normal guard positions

Two athletes are placed so that the relative distance is more or less the same on both sides. In this kind of guard position, there is also the one called by Japanese SHIZEN HON TAI

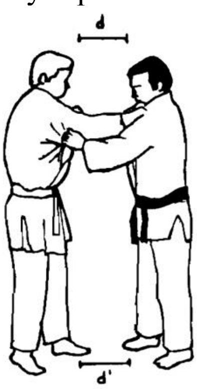


Fig.3.4.b Normal guard d=d.

Curled Up guard positions

Two athletes are placed so that the relative distance between them behind is almost null, while on a level with hips is larger possible, Japanese JIGO TAI calls these guard positions.

Fig.3.4.c Curled up guard d<<d.'

To everyone is associated with a particular group of *Kumi Kata*, to each of these guard positions will coincide
a specific competition of strategy and the capability to realize some throwing techniques.
In the dynamic field to these guards, positions are connected often a well-defined cadence or rhythm of attack in the biodynamic grouping "athletes couple" (see 9.2)
Nowadays, with high professional specialization at an international level, the evolution of superior Judo is present above all in two well-determined biomechanical aspects:

1) ***Increasing physical strengthening***
2) ***The Kumi Kata predominance, which originates from this approach.***

From the study of the world championship, Olympic games and other important competitions and from shiai experience points out some international competitors became a specialist about particular Kumi Kata to affect their unique technique (*Tokui waza*) in dynamic conditions.
From the study of the initial phase of these competitions, you can comprehend that the crucial match moment is "*the battle to impose one's Kumi Kata". M*any times, before *Kumi Kata,* there are some "hand *jumps*" which stabilize some *safety Kumi Kata* and permit to pose in profile towards adversary; in this way, the rival hasn't a great surface to grip and to attack, and so he's able to avoid the eventually believed dangerous and unfavourable grip (Diagonal guard positions). After this phase, the athlete tries to build carefully and slowly his favourite position of *Kumi Kata,* cause a little absent-mindedness and a brief weakness, during the control of points of contact (hands) moving, becomes a strong chance to win a match for a technically well-prepared adversary. Nowadays, the realization and definition of a unique *kumi kata* during a competition is considered an art in itself and a fundamental phase of "*Dynamic Superior Judo".* In the previous dynamic analysis, we have already talked about the critical role which hands, as points of contact, play; therefore, only by an arms action, with a proper body moving, will it be possible to unbalance one of the athletes in biodynamic grouping "athletes' couple". Many times, now, the defeat is much more in a *kumi kata* error instead of moving. The errors on the *shintai*, like feet from close up, jumps, crossed feet, aren't so important because of dynamic athlete balance, while *kumi kata* errors are directly reflected in the balance and the energy transfer to the single athlete. During the "superior dynamic Judo" practice, the *kumi kat*a hasn't only an information role but, above all, it becomes an essential psychological aspect about the imposition of one's will to the adversary to cross his reactions. All these concepts produce some fundamental characteristics required by every athlete:
--increasing physical strengthening
-increasing acrobatics capacities
--during a match-high and constant "rhythm."
--the capacity to use one's special kumi kata after having had the adversary kumi kata

--to study the opportunities realizing one's special kumi kata
-- Continual adjournment about Renzoku waza <u>originated from one's special kumi kata</u>

The number of *kumi kata* is infinite, but it's also important to classify them in groups in accordance only with the classification utilized by French Federation (FFJDA) (Les Kumi-Katas).

<u>RIGHT KUMI KATA:</u>

a) <u>Right-down Kumi Kata</u>
Left-hand catches right sleeve
Right-hand catches left collar, on a level with hips, over the belt
b) <u>Right-normal Kumi Kata</u>
Left-hand catches right sleeve
Right-hand catches left collar, below the clavicle
c) <u>Right-up Kumi Kata</u>
Left-hand catches right sleeve
Right-hand catches left collar at the back of the neck

<u>LEFT KUMI KATA:</u>

a) <u>Left-down Kumi Kata</u>
Right-hand catches left the sleeve
Left-hand catches right collar on a level with hips, over the belt
b) <u>Left-normal Kumi Kata</u>
Right-hand catches left the sleeve
Left-hand catches right collar, below the clavicle
c) <u>Left-up Kumi Kata</u>
Right-hand catches left the sleeve
Left-hand catches right collar at the back of the neck

<u>MIXED KUMI KATA</u>

a) <u>Mixed-normal Kumi Kata</u>
Both hands catch both collars below the clavicle
b) <u>Mixed-down Kumi Kata</u>
Both hands catch both collars on a level with hips

<u>SLEEVES KUMI KATA:</u>

a) Both hands to both sleeves

<u>KUMI KATA WITH OPPORTUNITIES:</u>

a) <u>Freehand</u>
The other hand at sleeve
The other hand at the collar

<u>CHANGE-OVER KUMI KATA</u>

a) <u>With one of the hands at the belt</u>
With one hand, catch the collar
With the other hand at the sleeve, by the same side

<u>CROSSED KUMI KATA</u>

a) <u>With a right hand at the edge of the right sleeve</u>
With a left hand at the left collar or vice-versa

Analytical studies on the *Kumi Kata*, used in competition, like right, left, mixed *Kumi Kata*, studied in Japan (*Analytical studies on the contests performed at all Japan Championship Tournament)* proved

Japanese competitors exercise only: 62,5% right *Kumi Kata;* 34,5% left *Kumi Kata*; 3% both grips and 0% mixed *Kumi Kata.* Some simple isometric exercises to produce a robust *Kumi Kata* are showed in Inokuma and Draeger's splendid book (*Weight Training for Championship Judo).*

Kobo Ichi

The *Kobo Ichi* (chance) study will be performed in the light of a few general parameters able to classify it in terms of the didactic point of view.

The competition analysis shows an unmistakable message *that Kobo Ichi* works in the physical-biomechanical field and the psychological area.

It will be possible to build an opportunity using both *Renzoku Waza* and *Damashi Waza;* as a matter of fact, all the Initiative study is tentative to find a chance.

But there are other subtler systems to create a chance, for example, to induce a psychological difficulty producing mistakes either in *Kumi Kata* or *Shintai.*

Or to apply a new, not known technique (see 5.3) or to utilize different shifting trajectories to perform tsukuri action.

The study of competitions showed about *Kumi Kata*, the utilization of unique transitory *Kumi Kata* to grasp a chance, utilization of right *Kumi Kata* to apply left throws or vice versa.

In the previously cited paper, 53% of athletes utilizing both rights and left Kumi Kata applied only left throws with more results than right athletes.

Also, the particular utilization of the fight surface was analysed. 28% of athletes fought on the boundary, while 36% ended the fight on the border.

These are why 75% of decisive throws (Kimari *Waza*) were applied to the boundaries. The other impressive result was the use of fight surface to *Kumi Kata* to find a chance. With the same *Kumi Kata,* the fighters were used to fight on the total surface.

With opposite *Kumi Kata* the fighters were used to fight only on the boundary.

This means that, in difficult conditions, in finding a chance into the biomechanical field, all the forces are used to increase the difficulty to obtain an option in the psychological area.

The Japanese way

Many people speak about classical judo or Japanese judo, but what do they mean about it?

Now we try to define in a biomechanical way the main features of Japanese judo. The classical Japanese grips are the so-called standard grips sleeve/ lapel, the old Russian style to acquire superior position trays to bend forward the adversary to increase his instability and slow down the shifting velocity must be obtained in a Japanese way. However, in another way, by the correct use of his own body's weight, Japanese people are specialized to apply by classical grips his weight on the adversaries. Japanese people and most modern Japanese competitors fight with right or left regular grips, few of the applied also sleep/high collar, but the relative distance is always medium (see Competition Invariants 8.2).

As Kenji Tomiki remembers us, "the old-school jujutsu consists of breaking the body's condition (symmetry), which has lost equilibrium. It is called kuzure-no-jotai (state of broken balance). Sometimes the opponent himself loses the balance, and at other times you positively destroy the opponent's balance, leading him to a vulnerable posture. In Judo, each technique is analysed into tsukuri (preparatory action) and kake (attack). Preparatory action is further divided into aite-no-tsukuri (preparing of the opponent) and jibun-no-tsukuri (preparing oneself). Preparing the opponent consists of destroying the opponent's balance before performing a technique and putting him in a posture where it will be easy to apply it. Simultaneously, the contestant himself must be in a posture and position in which it is easy to apply a technique. This is the preparing of self."

On this biomechanical basis, Japanese people have built their style to overcome adversaries' defensive systems and apply a practical kuzushi tsukuri phase strictly related to some well-defined motor abilities like athlete's fast speed change or quick-shifting velocity of the coupling system, classical grips, collision and timing. An exciting aspect is Japanese athletes' ability to take vantage right away from the adversaries' break of symmetry.

The previous motor attributes are connected to high skilful technical baggage and to the capability to overcome most competitors by a mix of superior speed, flexibility, coordination, acrobatic tools and sharp timing sensibility connected to a particular application of pressure (body's weight) by grips that slows down the adversaries and simultaneously makes light-footed their inferior biomechanical chains. From my perspective, this mixture of skill, speed, and fierce technical resolution is attractive, called "classical Japanese judo". They are open mind athletes able to govern in the right way many of the space problems (relative distance between athletes' bodies) that happen into the Couple of Athletes System during competition.

Fig.3.4 d,e,f,g,h,i -Classical attack of right Seoi Nage from Japanese Koga (Finch)

The Old Russian Way

It does not matter in a different style or different point of view; biomechanics helps us understand the old Russian way of fighting Judo's inner meaning. The first part of this paragraph shows the Japanese point of view, strictly related to speed, fast shifting velocity, classical grips, and timing.
Motor attributes that, in our vision at the end, are connected to the capability to overcome an equal adversary by superior speed and skill.
Ordinarily, Japanese people fight with right or left regular grips (the standard sleeve/ lapel), after sometimes they applied also sleep/high collar and in a particular situation even sleeve/belt on the side at medium relative distance (see Competition Invariants 8.2) on this biomechanical stylistic basis they have built all the studies to overcome defensive systems and apply a practical kuzushi tsukuri phase, with the flowing, attractive "classical judo".
The Russian approach seems more pragmatic and less related to the Bushi Do spirit.
As a practical fighter, Russian way trays to acquire at the start a strong vantage by the grips, more easily and with more degrees of freedom than in free wrestling for the presence of Jacket, bending the adversary forward, lessening shoulder distance, and (see Competition Invariants 8.2) putting in that way the adversary's body in a more unbalanced and consequently static position, this means not allow him to acquire high shifting velocity.
In that position, timing in the attack is critical but is different and broader in meaning; from timing in "classical Judo", which is based on other speed motion in the coupled system, the attacker can inveigle his opponent to go in a predetermined direction which will bring him into one hand kuzushi position to be thrown.
Timing in Russian grips is not based on the whole-body motion understanding and forecasting, like in Japanese grips, but on the most challenging step, body motion forecasting.
Considering the attack on the adversary's body example, usually, the following situations will happen.
When using Russian grips, the trunk's relative distance is shorter, which means that by hand /arm (on the deep belt grip on the back) sensibility, it is possible to understand and forecast trunk motion and apply the right throw. With the second harm at the sleeve, it is possible to control and predict the adversary's waist /legs motion using the right throw again.
Considering the direct attack on the adversary's body, usually, this other situation will happen.
Tori, after to grips Uke, moves on his side, this lateralization makes more difficult both defence and counterattacks for Uke, and Tori can apply, thanks to the adversary more static position, a vast number of a couple of forces attacks in many different directions: front, back, swing around and so on. In fact, by lessening the shifting velocity, the dynamical friction (depending on the velocity as $F = -\mu v$) will grow because the friction coefficient grows when the velocity decreases, this means a higher energy consumption for the technical movements that often are connected to the vertical lift, with an increased power need to fight against gravity force.
Other considerations connected to the Russian way are the broad-minded approach to the active use of harm as handy throwing tools (see the last figure) and the consequent athletes strong muscular powered arms. Another need, connected to the increase in stability and the decrease in shifting velocity of the coupling system, is the need to go down the adversary's centre of mass for the techniques of a physical lever.
Remember the increase of the tama guruma or suwari kata guruma application by athletes a few times ago, but today not allowed. Applying a more significant muscular power accounts for the increase in the harm used to unload the adversary's body.
In the following figures, we can see starting from a Russian multipurpose grip position a classical Russian attack – Ushiro Hiza Ura Nage (as Roy Inman named) with a decisive throwing action
Finally, an efficient lever application by one arm Suwari Te osoto otoshi (Inman) .because one arm can't apply a couple of forces against the more robust legs and could only be used as a stopping point.

Fig.3.4.j,k,m,n,o,p.q,r,s,t-Russian old-Style attack sequences : Ushiro Hiza Ura Nage, Suwari Te Osoto Otoshi. (Finch) this last technique is today not allowed (the names are from Roy Inman)

Modern Unified Style

During these few years from the second edition, the IJF Federation faced the necessity to change the refereeing rules to inject more judo competition dynamics.
With the last change (see 8.1), the goal is achieved clearly, but with a unified combat style by different countries' athletes.
Athletes worldwide are complete because they have to master this new unified style, but, in some situations, they must fight against (and in accord with) the old-style knowledge acquired.
This means that actual athletes have to be more flexible and versatile than older athletes.
In Chapters 8 & 9, this situation will be analyzed in deep. Here only, as gross information, the main aspect of this unified style will be underlined.
1)More classical right position in a competition (less breaking in symmetry), 2) more use of classical grips, 3) extensive use of leg Techniques (with couple tool applied), 4) increase in explosive force, 5) higher shifting velocity of the Athletes couple system, 6) robust grip control.
Then, outside the ever-present application of Seoi, Suwari Seoi, Uchi Mata, O Soto Gari and Harai Goshi/Ashi guruma, new entries like Okuri Ashi, De Ashi, Harai Tsurikomi Ashi, Ko Uchi Gake, O Soto Gake and Hiza guruma are applied more often in high-level competitions.
New countries Star born in this time, with the usual European "first of class" Russia and France, we see Georgia, Azerbaijan, Romania, Israel with some old star like England, Nederland, Germany, Italy and in Asia with Japan and Korea, Mongolia and China grow, sometimes also Cuba, the United States and Canada shine.
In the following figures, there are shown some modern examples of this unified style.

Fig.3.4.u.v.w.z Sen No Sen: Ko Uchi Gari counter on Sasae Tsurikomi Ashi attack between Russian Athletes modern unified style

Fig.3.4.α.β.γ.δ. Modern Form of Ko Soto Gake performed by a Mongolian Athlete

Fig.3.4 ε.ζ.η.θ.ι.κ. A modern form of Lever application Eri Seoi otoshi Basile Olympic Games 2016

Fig.3.4.λ.μ.ν.ξ.ο.π. Modern Form of Couple Technique Ko Uchi Gake/ Makikomi Ono Olympic Games 2016

Chapter 4 Biomechanical principles of Judo Training

4.1 Conditioning: Classical linear approximation

Training for fighting sports has changed very much in the last fifteen years.
One of the main changes has been the introduction of sports sciences into the process: Exercise physiology, biomechanics, training science is consistently used in a multidisciplinary model.
Classical conditioning entails exposing the organism to a training work stress of sufficient intensity, duration and frequency to produce a measurable effect.
The conditioning load is, therefore, relative to the level of fitness of the athlete.
The basic conditioning principles are shown in the following diagram

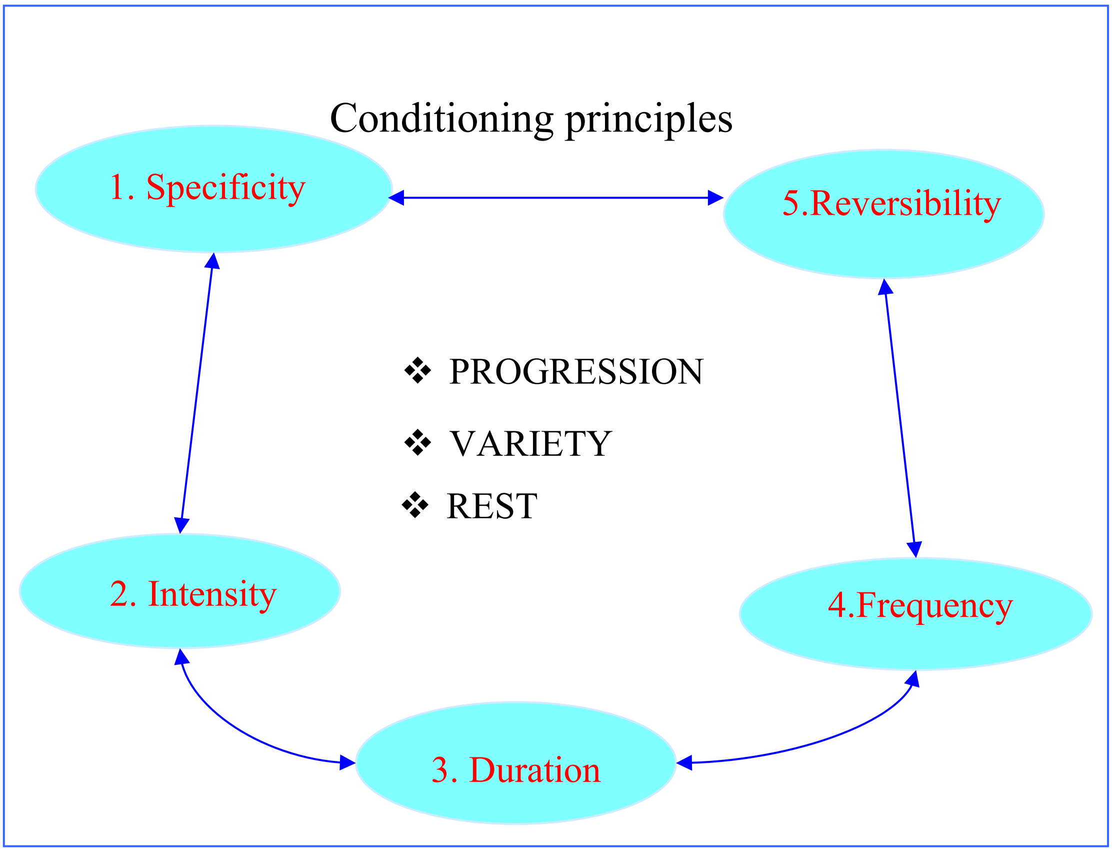


Fig 4.1 a basic conditioning principle

The linearity is focalized on the human body adaptation effect: *adaptation to a given load occurs; the conditioning intensity has to be increased naturally on a linear basis to achieve further improvement.*
The simple causal relationship, reductionism and linearization of the data collection are part of the traditional thinking applied to biological problems. The linearization synthesizes such procedures once it means that causal mechanisms may explain a phenomenon that, once involved, with many factors, uses the strategy of differentiating the system in many parts with their later sum. For instance, concerning physical performance, the presence of factors that limit or promote the development of fatigue is usually accepted.
More specifically, on data linearization, it is still currently verified using terms reflecting this way of thinking as a balance, homeostasis or steady-state applied to the Athlete conditioning.
However, it is well known that linearity is only theoretical. There is no linear relationship between the amount of conditioning and the effect of conditioning. For instance, 2 hrs of training per week may cause an increase in maximal oxygen uptake, for a specific amount, if the conditioning is twice as much, which

is 4 hr per week, the increase in oxygen uptake will not come twice as greater the previous amount. However, only for instance a few per cent greater, this underlines the non-linearity of the system, but for the sake of simplicity, in gross approximation, all sportspeople go on thinking linear.
Physical conditioning can be defined as improving motor and functional (energetic) abilities, morphological characteristics, and athletes' health status.
Physical conditioning has its versatile, basic, specific and situational directivity.
Domination of each aspect of physical conditioning depends on the long term sports development phase, short term training periodization, sport discipline characteristics and the athlete's characteristics. Recent times have brought on the need to use a variety of additional aspects of conditioning preparation.
Therefore, the purpose of physical conditioning is the improvement and development of human body characteristics.
This system of improvement aims to reach a higher level of physical efficacy, which is according to the physical education theory known as conditioning preparedness. Physical preparedness contains three elements: physical health, physical development and physical effectiveness. Combining these elements determine the morphological-functional potential of an athlete, performing many, by quantity and intensity, motor activities.
Systematic action on these elements through training programs produces the improvement of physical abilities. However, there are also different opinions about conditioning preparation. Generally, researchers define conditioning training in both a comprehensive and specialized sense.
The term condition in the broader sense considers all psychological, physical, technical, tactical, cognitive and social factors of achievement, while the condition in its specialized mind is based only on physical characteristics (endurance, strength, speed and flexibility).
In this specialized vision, Carlo Vittori gives us such definition of conditioning "*the organization of the physical exercises, performed in such amount and intensity that the result must be the progressive increase of strain which stimulates the physiological adaptive processes, helping the growth of Athlete's physical, psychical and technical capabilities in order both to strengthen and increase the performance result.*
Usually, judo conditioning programs are based on three phases: Basic, Intermediate, and Advanced.

• The first phase (***Basic***) consists of the work involved in a training program which is aimed at the development of the so-called basic foundations (strength and endurance), which take up a significant part of general many-sided training,

• The second phase (***Intermediate***) requires a smaller amount of overall work, but a greater intensity of effort, to develop the so-called specific competitive foundations of judoka,

• The third phase (***Advanced***) builds up specific abilities, the competitors' agility, and motor and situational motor skills.

In the following diagram, it is possible to see the physical conditioning structure for complex sports like judo.
Conditioning is connected to the first and second phases of judo training.

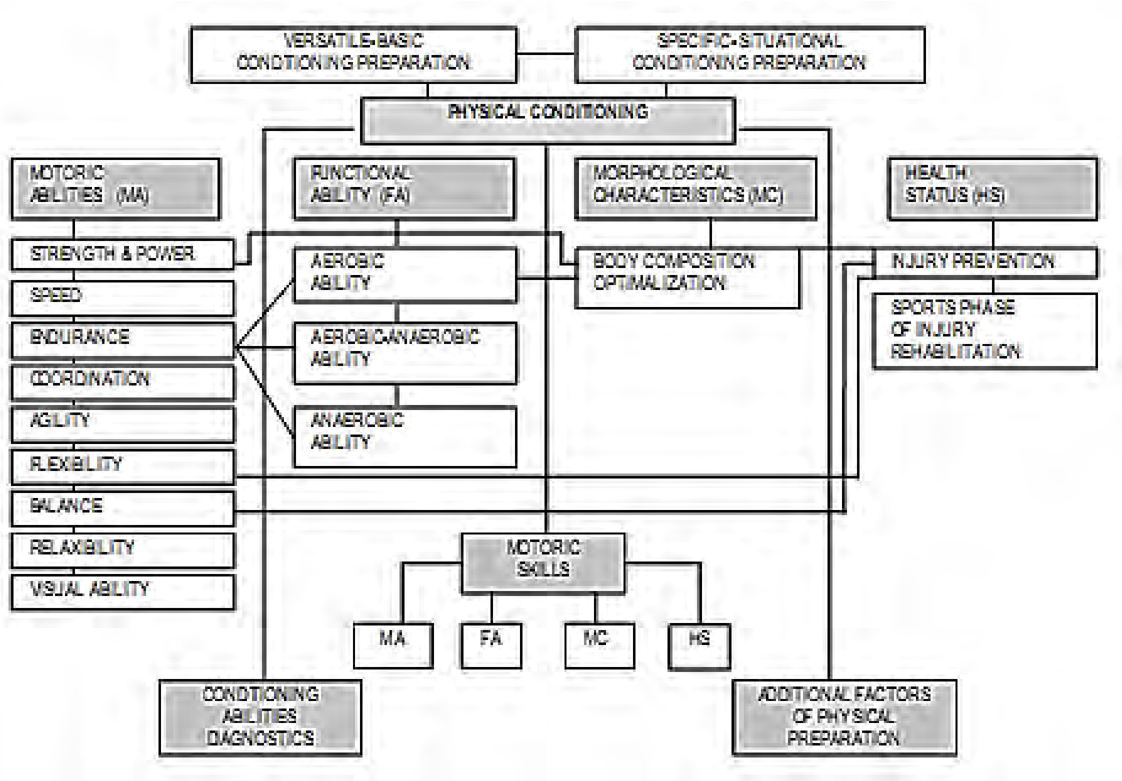


Fig.4.1.b structure of physical conditioning for complex sports

The modern professional way to build up these two phases is the application of periodization.
The old way was most more naïf and unprofessional, but anyway efficient, it is possible to see the old champion Anton Geesink during his own way to conditioning in the following figures.

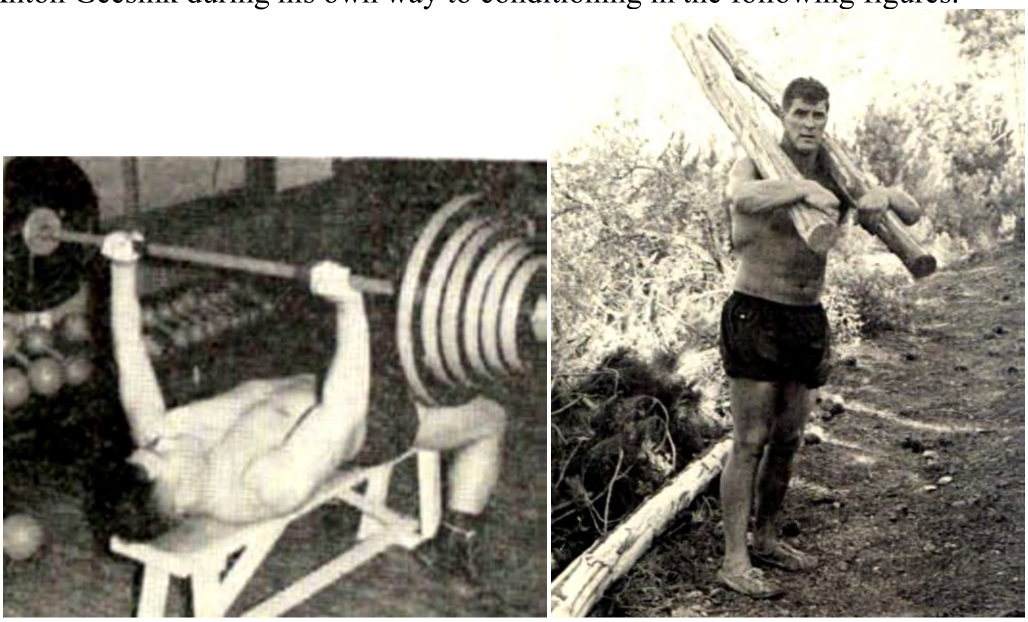


Fig4.1.c.d Anton Geesink and his old way of conditioning

In the following figures, we can see an old and the current way in many judo clubs, the use of training aids like an inner tube, or expander, or elastic band. In recent time 2003, Wang Chia Chun, in his thesis, analysed the biomechanics of strength during judo elastic band training. The results were that it is possible to use two different training methods (same direction) and (inverse order) steps. The first can help create a more vigorous short burst of force. The other could be used to create a longer-lasting threatening power in the tsukuri kuzushi phase.

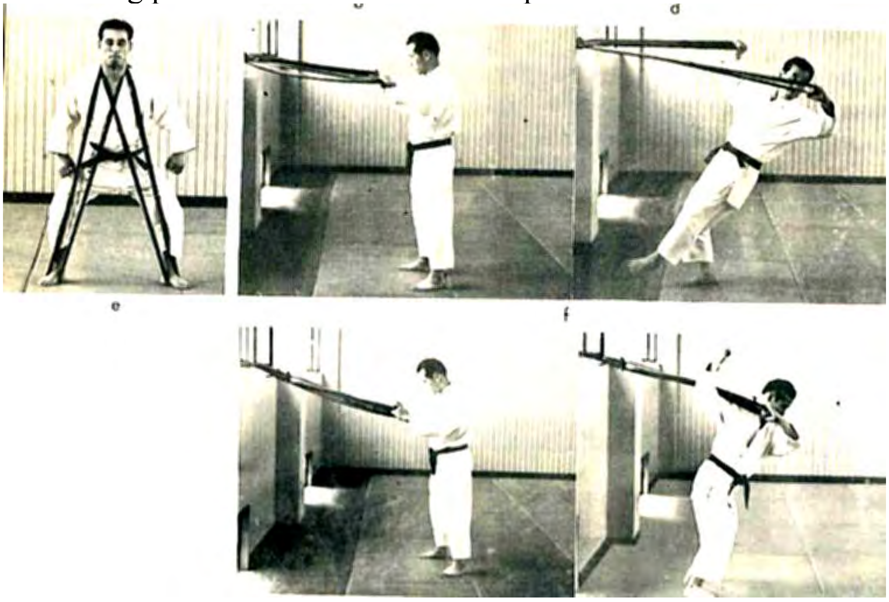


Fig.4.1e. Old but useful and always actual conditioning way "from Judo for High School."

Fig.4.1f. Practical and always actual conditioning Japanese exercises in a couple

But if we think about national teams' professional preparation, things must go differently.
A national team in preparation for Continental Championship, or Olympic, or World Championship needs to solve training scientifically and overcome the overtraining danger.
The modern way, as it is well known, is called "Periodization".
The progression of training and the balance of volume and intensity of workloads have been introduced in recent years.
The concept of periodization means "structuring training phases to lead to the highest level of speed, strength, and endurance".
It is also used to mean "the division of the annual plan to ensure optimal performance for the main competition".
Periodization then is the regulation of resistance training program variables over time, which results in the prevention of overtraining.
It was developed in Russia at the end of the 1950s, was modelled after Selye's based on General Adaptation Syndrome describing the human body response to stress, and was popularized by Metveyev and Bompa in early 1960.
Periodic training systems typically are composed in time into three types of cycles: micro-cycle, mesocycle and macrocycle.
The micro-cycle is generally up to 7 days. The mesocycle may vary from 2 weeks to a few months, and a macro-cycle refers to the overall training period, usually representing one year or two.
The essence of periodization is a program that allows the individual undergoing resistance training to alternate periods of rest with periods of intense lifting.
Correct periodization of training enables adequate functional adaptation to judo athletes.
The program can serve as a basis for planning and programming the first and second phases of the judo athletes' training process.
In that way, it is possible to achieve a higher level of physical capabilities for the most important competitions in a year.
If we think about it, the training theory was established when knowledge of the athlete's preparation was very far from complete about biological and physiological applied studies.
After fifty years, knowledge increased, and sports science experienced significant changes. Fifty years ago born the periodization training system, the yearly division of the seasonal program into small training units over short periods. This system experienced worldwide success, but after fifty years, periodization has received a few improvements; however, it is today's primary training system. Some contradictions between classical periodization and the request for high-performance sports practice have inevitably developed in the last ten years. For example:

1. One drawback of the traditional theory is its inability to participate in many competitions as an actual judo program.
2. limitations imposed by excessively prolonged periods of necessary and sport-specific preparation
3. High fatigue is produced by a prolonged period of multi-targeted training.
4. Conflicting physiological responses are produced by mixed athletic abilities training performed by medium or low workloads concentration.

These circumstances and factors contributed to the search for alternative training approaches offered by creative coaches and scientists with a practical orientation.
Classical periodization is based on the simultaneous development of multiple abilities over a more extended preparation period and large volumes of work. It prevents the athletes from participating successfully in several competitions during the season, but recently in Russia, was proposed a "Block Periodization Model" to train " was proposed athletes.
A recent comparative study between block periodization and traditional periodization performed by Bartolomei and co-workers (2014) shows that Block Periodization may enhance upper-body power

expression to a greater extent than Classical Periodization with equal volume; however, no differences were detected for lower-body performance and body composition measures.

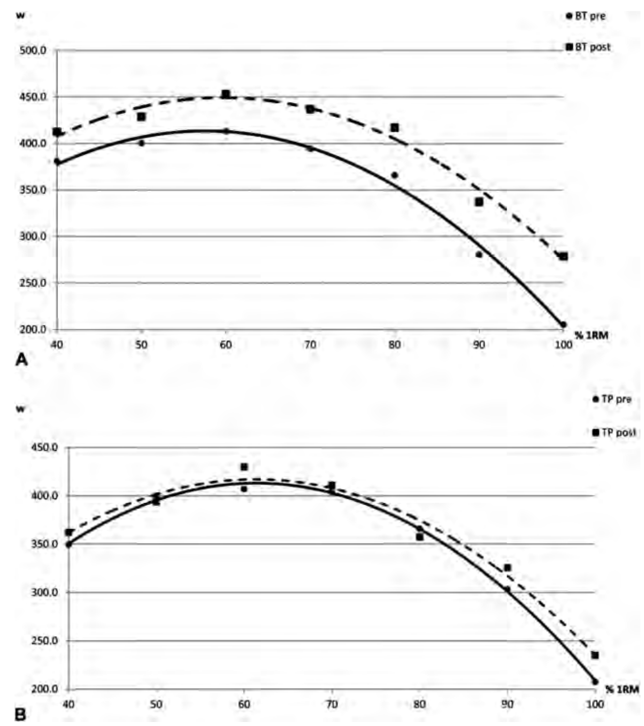
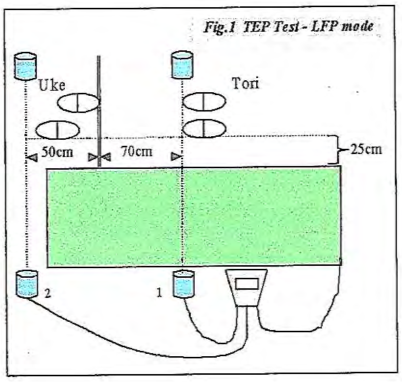


Fig.4.1.g Force Power curve in Block and Traditional Periodization before and after training (Bartolomei 2014)

A fascinating but less studied area is the recovery method. During the lag time between two o more contests during the high-level championship, a very up data paper presented by Franchini and co-workers (2009) show that the difference between active and passive recovery obtained different methods. The finding of this research is that active recovery can improve many time the attack capability
Judo is a highly complex sport that needs a complete development of an athlete’s skill and capabilities through very specialized: power, speed, flexibility, endurance, complex movements, and so on.
On this basis, the advanced phase of conditioning needs thorough training “methodologies”; most of them have been developed and proposed during these years.
These “methodologies” are built to complement Judo athletes' physical conditioning, both Basic and Intermediate.
Some of the most exciting attempts published in these years are carried out as examples in the following.

Some Special Advanced methods

An exciting method, performed by Villani and Di Vincenzo (2001), showed the increase of the throwing speed by utilising classical Butsukari and Nagekomi exercises.



	TEST SPLIT	RETEST SPLIT	TEST TIME	RETEST TIME
Media	0,71	0,60	1,08	0,96
Ds	0,13	0,08	0,11	0,07
Max	0,98	0,7	1,2	1,06
Min	0,45	0,45	0,88	0,84
Diff.%	-14,91%		-11,19%	
One-factor Anova	P<0,05		P<0,01	

TAB.1 comparison test-restest experimental group.

Fig 4.1 h. Experimental setup and results for conditioning (Villani)

Whole Body Vibrations were utilized for training in many sports in these times.

In Judo, some unpublished data produced in a Master thesis at the University of Roma Tor Vergata showed that a group of 10 athletes trained by WBV 30 Hz till just a day before the competition, and the control group, trained with classical weights and rest had had the same increase in muscular power and jump ability.

This means that WBV can be utilized for judo athletes to preserve training conditions, just before the fight, without any danger (overtraining or fatigue).

In the other edge of the Mediterranean Sea, from Israel, in 1998, Issurin and Tenenbaum applied vibratory stimulation during bilateral biceps curl exercises of explosive strength exertion. The athletes performed two separate series of three sets of exercises in random order. The second set of one series was administered with superimposed vibration of 44 Hz and acceleration of about 30 ms^{-2}, transmitted through the two-arms handle to the arm muscles.

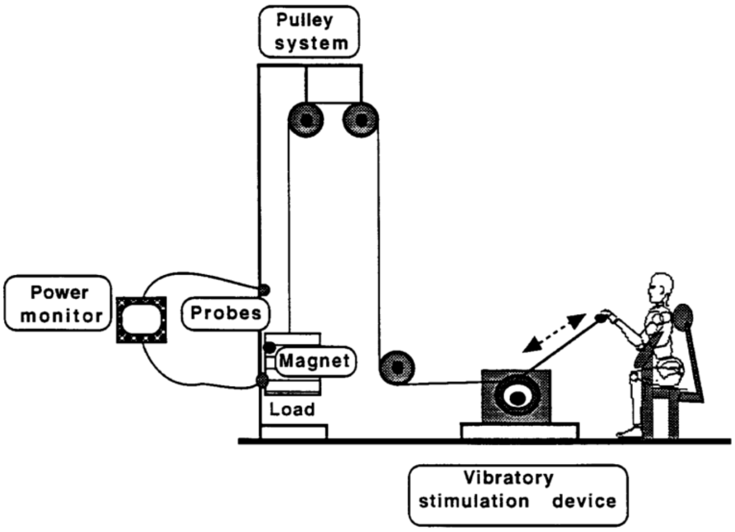


Fig.4.1.k. Experimental setup for vibrational conditioning (Israel)

The `Power Teach' instrument measured the mechanical power of each repetition.

The maximal and mean power values for each set were automatically recorded and shown on the screen.

The results showed that exercise mode (with *vs* without vibratory stimulation) resulted in a significant immediate effect for mean power and maximal power, around 10.4% and 10.2% for maximal and meant power, respectively, in the elite group.

To provide some understanding of the physiological capabilities underlying successful judo performance, Franchini and co-workers determined the representative values for various physiological variables in nationally ranked male and female judo athletes.
Body composition, aerobic capacity, isokinetic elbow and knee flexor and extensor strength, and the muscle fibre size and composition, such as the vastus lateralis, were examined.
Comparisons across weight divisions indicate that the values of many characteristics varied as a function of size. As weight division increased, relative VO2 decreased ($r = -0.53$ and -0.63 for males and females, respectively), % body fat increased ($r = 0.64$, 0.72), and the cross-sectional areas of Type I ($r = 0.55$, 0.77) and Type IIA ($r = 0.47$, $= 0.76$) muscle fibres increased.
Among females, in particular, athletes in the higher weight divisions were stronger relative to LBM than those in the lower division.
These results indicate that the physiological profiles of lower and upper weight division elite judo players differ markedly.
In a fascinating paper, Sadowski points to the Coordination Motor Abilities' attention in a comparative analysis among different combat sports. Extracting judo data from this work, the dominant Coordinative Motor Abilities are shown in the following table

Type of Sport	Coordination Motor Abilities	Author
Judo	Precise reproduction of basic movement variables.	Pidoria 1988
	Precise reproduction of basic movement variables, rhythm muscle relaxation.	Wengliarskyj 1980
	Movement combining, precise differentiation of motion, force variables, space orientation.	Manolaki 1990
	Fast and precise reacting, differentiation of movement force variables.	Martemianow 1990
	Movement differentiation, space orientation, balance, the speed of reaction, movement combining and adjustment	Schich 1979

Table 4.1.a Coordination Motor Abilities for judo

Coordination Abilities	**Judo**
Motor Adjustment	1
Speed of Reaction	2
Dynamic and Static Combining	3
Time and Space Orientation	4
Movement Combining	5
Movement Differentiation	6
Muscle Relaxation	7
Rhythm	8

Tab 4.1.b The particular significance of the specific Coordination Motor Abilities in Judo

4.1.1 Advances in linear conditioning: software help

Technology has long since entered the sporting arena, with computer-aided analysis forming an integral part of the athlete's daily training regime. However, the application of new technology in today's judo conditioning is not applied in many countries.

Professional systems

In other complex sport like wushu, training is measured, and the number of physical activities was analysed using skin temperature, energy expenditure, heat flux, GSR and step counter, for example, by data recorded in a special armband.

Body Media Company developed the SenseWear® PRO2 Armband tool in Figure to collect signals for measuring the number of physical activities. The armband contains a skin temperature sensor, a near-body temperature sensor, an accelerometer, a heat flux sensor for measuring calories emitted from the body, and a galvanic skin response sensor for measuring the electrical conduction of the skin. Data obtained from the sensors were recorded in a store inside the armband, and the data resulting from the wushu trainees' physical activities were analysed using InnerView Wearer Software in Figure

Fig.4.1.1a SenseWear® PRO2 Armband

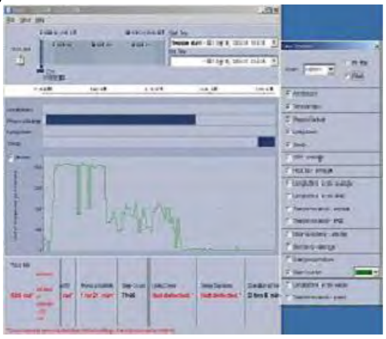


Fig.4.1.1.b Inner View Wearer Software

Today there is much software that can be easily applied to conditioning. One, for example, is Firstbeat PRO, which is an advanced heartbeat analysis and reporting software tool

Data import from different beat-by-beat recording equipment, including memory chest belts, heart rate monitors. The software can perform advanced and fully automatic heartbeat analysis and obtain conditioning data analysis.

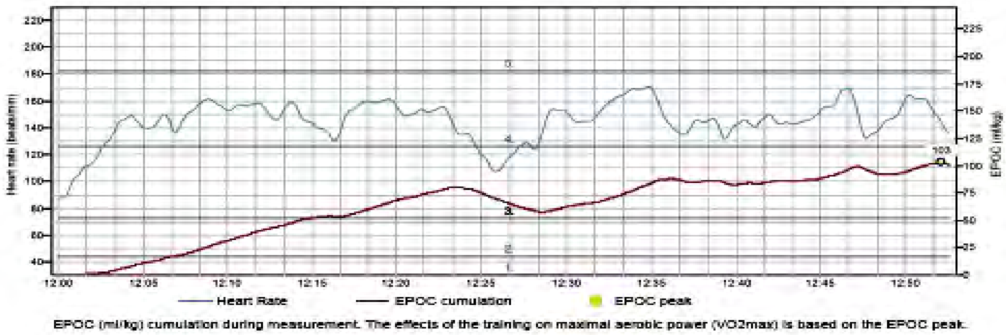


Fig.4.1.1c. Fristbeat Pro software result exempla

Professional software

Today much professional software is present on the web. Without any question about these business solutions' quality or capabilities, we give a few names the others could found easily online; ***Dartfish, Athlete Analyzer, Sportlyzer, Quiko, Bio-Graph, 2Peak, Edge10, XPS network***, etc.

Homemade systems

The Italian FSP 2000 was created (at Cassino University), taking the cue from software employed in other disciplines, such as those of the *TOP series* of the Prof. Pellis, the *Pro Pulses Perf* of the Prof. Cometti, the *Pro Judo 4* of Prof. Villani, etc...
The software can plan training starting from the age and the technical athletic features of each athlete, identifying the program's objectives through the so-called “match analysis” method and questionnaires (those functions are included in the software).
Such training might be organized following the classical model of periodization (Matwejew, Tschiene) or the blocks (Verchoshanskij) or mixed models.
With FSP 2000, you can decide what to do during your training session: Karate's agonistic training or technical teaching (low-level belt and young activity). Each exercise's performance is shown by a descriptive and a multimedia section (through video and images). You can also choose the exercise parameters: execution time, recovery time, repetitions, series, volume, density, intensity, loading percentage.
The software can display the trend of the training's loading, both for a single session and a longer one, through the intensity/volume chart and the time-sharing for each objective.

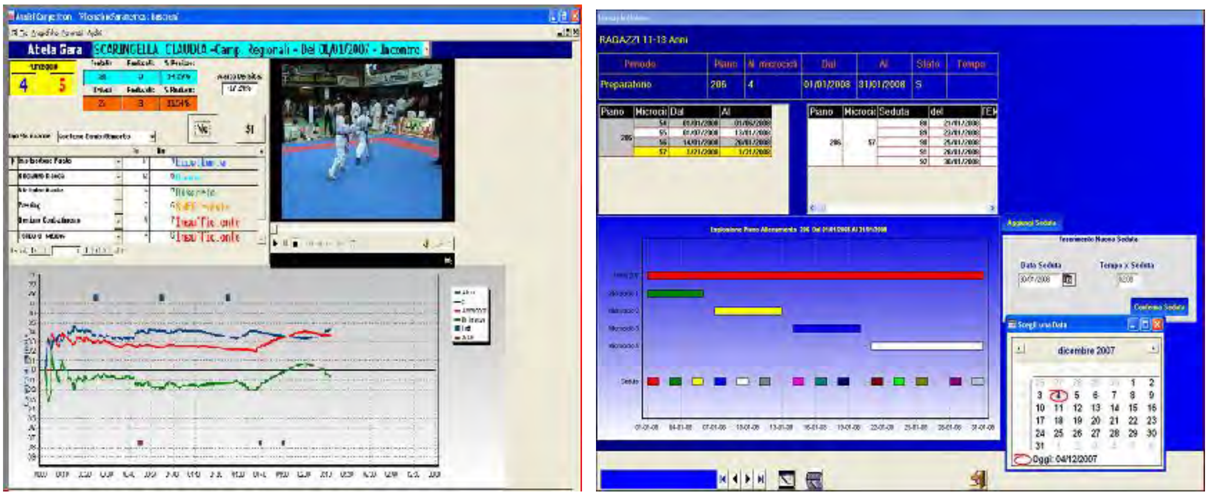


Fig 4.1.1.d. FSP 2000 homemade software for Martial arts Conditioning. (Cassino University)

4.1.2 Advances in linear conditioning: Special Biomechanical Instruments

Many analyses have shown that adequate testing equipment allows for the training of parts of techniques very similar to the actual movements with an opponent.
The training methodology is based on coupling valid and reliable measuring devices that allow specific fighting movements to evaluate fitness factors.
For example, many training data are built by standard physiological instruments like real-time Oxygen Analyzer like "Cosmed k4" or blood analyses.
Nevertheless, for a better understanding of energy consumption or muscular action in throwing, many specific and unique biomechanical instruments were built and utilized in judo during these years worldwide. In the following, there are shown some interesting examples from a few published papers.
Starting from the first works, abroad understandable, on judo techniques published in Japan, by Y. Matsumoto and Ikai (The Kinetics of Judo 1958) in which there was no reference to unusual instrumentation because it was made by photographs, the first appearance of a special ergometer, in the author knowledge, was into the paper of Shukoh Haga (University of Tsukuba) and Kyomi Ueya (Yamanashi Univ.) –*Techniques of Nage Waza of judo a biomechanical study*- In which it can be possible to see the following special Biomechanical Ergometers,

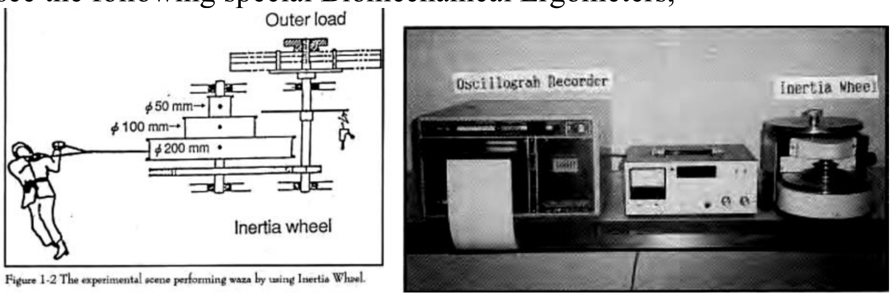


Fig.4.1.2.a Japanese old biomechanical ergometer

The same authors published a similar paper on female judo in the Kodokan Bulletin 1984.
The goal of these papers was to obtain data on force, velocity, and power of motion.
Many others come from Europe or the US in the following figures we can see special "ergometers" from Portugal, a work of Joao Roquette (1992) to find the relative energy cost between Ko Uchi Gari and Osoto Gari, the results were that with this ergometer, no difference could be evaluated.

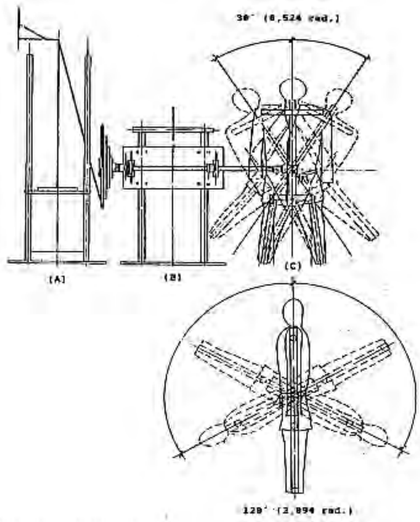


Fig.4.1.2.b. Portuguese Ergometers 1992

Other similar ergometers were utilized in Germany at the Olympic Service and Training Centre in Hanover by Nowoisky (2005) to study the interconnection of stability parameters and pull forces for unbalance movements in judo (ref Chap2, 3, 4).

Fig.4.1.2.c. German Ergometer

Other fields and approaches were utilized in Spain by Silvia Ribeiro and co-workers (2006) to obtain data by EMG. Because in judo competitions, the numbers of fights to what athletes are submitted and their respective endurance and intervals are randomized, these factors may influence the training performance. This study investigated the hypothesis that different fight endurances, the 90s, 180s, and 300s, could affect the enzymatic and muscular electrical activity. The results were positive.

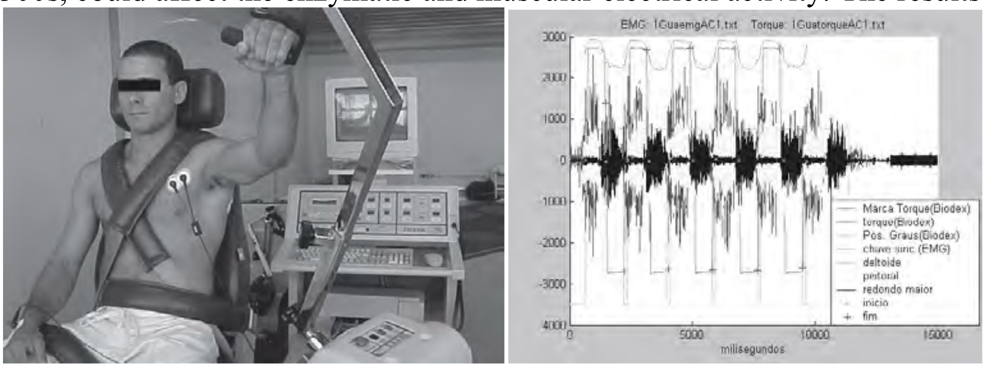


Fig.4.1.2.d Spanish experiment on conditioning

The most modern and advanced research in Biomechanics of Judo Techniques is represented by the studies performed at the University of Poitiers, into the Solid Mechanics Laboratory by the "Equipe mecanique des gestes sportifs", mainly Prof. Trilles, Blais and Lacouture. (2006-2009)This team is now working on a biomechanical technical methodology for the French Federation. The following figures show some of the measurements system utilized (accelerometers, strain gauges, etc.) and specific ergometers built at this University.

And the arrangement phase for one judo experiment, with the force transducers to obtain data on push/pull forces by grips.



Fig.4.1.2.e,f,g. France Supplementary advanced tools for judo researches

Fig.4.1.2.h, i,j,k,l, France application of tools to biomechanics judo study

The advanced primary system utilized in Poitiers University is a **Biogesta –Saga 3D system** (a unique tool by four or more infrared cameras gives complete information about kinetics and kinematics of athletes' sportive motion).

This system is related to some advanced software tools that can deepen the understanding of, in that case, the Judo Throwing Phenomenon. The following figures show some research situations to study the push-pull forces and the energetics of each biokinetics chain, the Input Athlete, and some electronic outputs and data arranged.

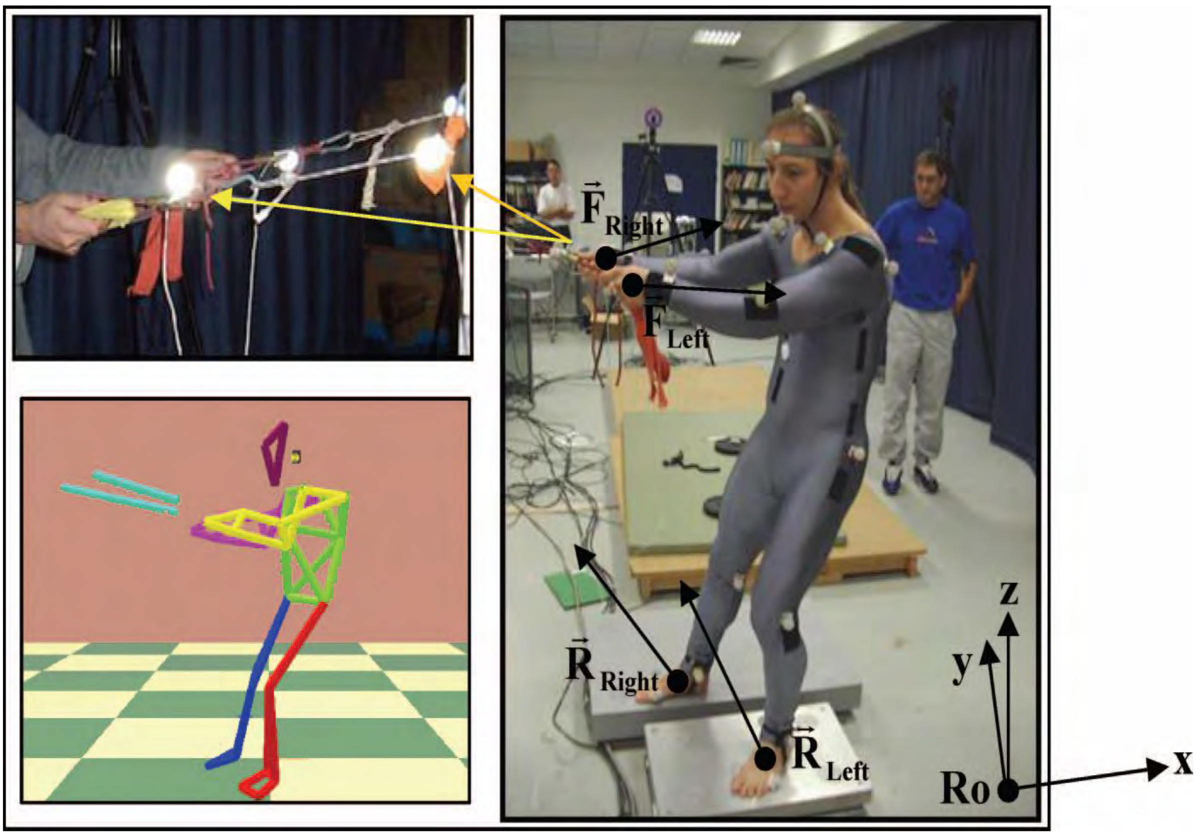


Fig.4.1.2.m,n,o, France very advanced experimental judo setup (Poitiers Univ.)

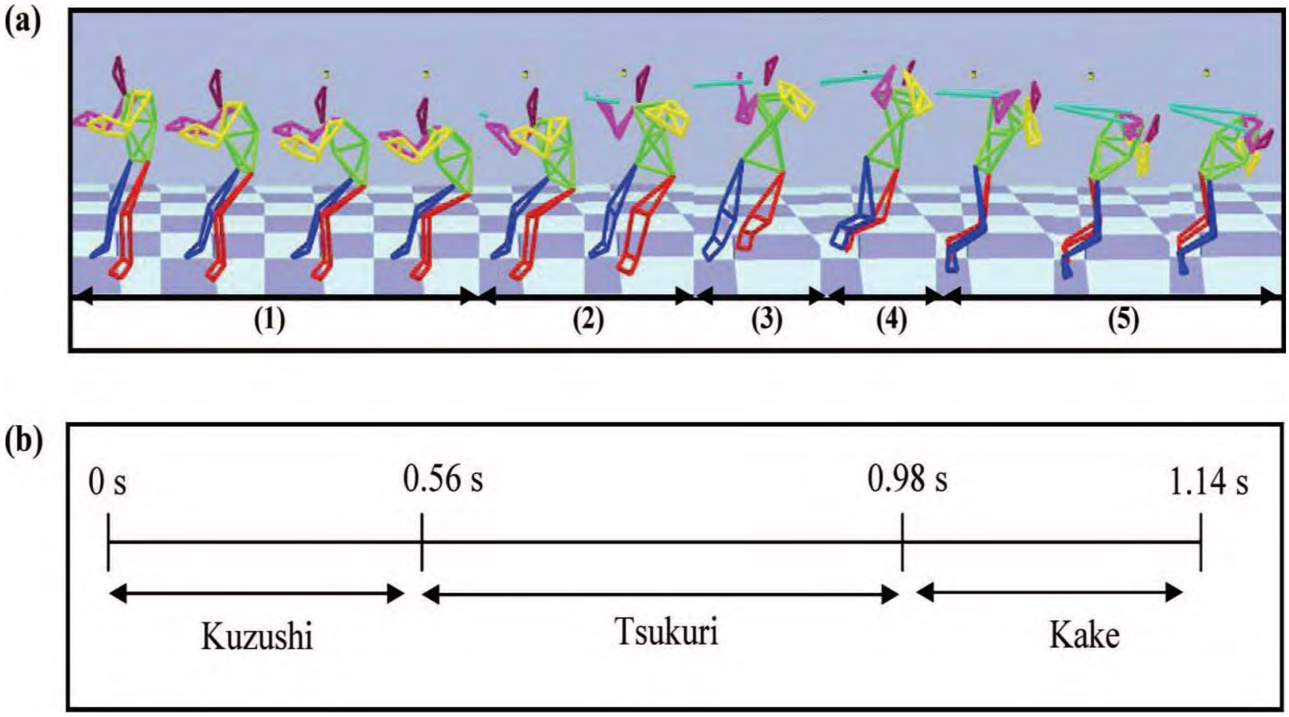


Fig.4.1.2.p,q, France (Poitiers University) Some biomechanical results on kuzushi tsukuri kake phases.

The following figure shows special ergometers (Mayeur's Ergometers) used by the team for studying the forces utilized during actual practice and with ergometers.

The goal of this research was:

- To obtain traction forces evolution in time both right and left side.
- To obtain specific performance indexes for athletes' evaluation.
- To confront the action forces in the two situations performed, real and ergometers.

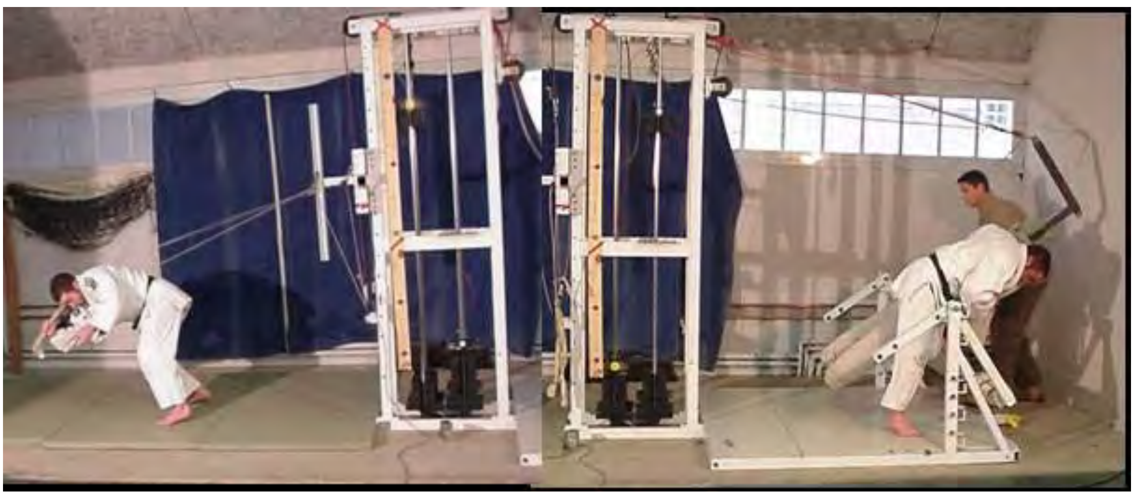


Fig.4.1.2.r, France Mayeur's ergometer at Poitiers University

4.2 Conditioning: New Trends non-linear (undulating) approximation

Fractals, as before seen, occur in human physiology, like heartbeats, brain waves and gait cycle, breathing rate variability, strength expression, temperature fluctuations and so on. (see Appendix II)

Kinesiologists, physiologists, biomechanists, and even professionals involved with physical exercise have been recently increasing their interests in non-linear dynamics, and a scientific theory developed mainly in physics, which is known as the Complexity Theory.

According to the Complexity Theory, since non-linear interactions existing in biological systems are emphasized, it is observed that not only the increase (overcompensation) of the body components with the practice of physical exercises but also those which cause atrophy (decompensation) in parallel, once they can compromise the functionality of these systems.

Thus, contrary to the emphasis given in the physical training to the monotonous repetition of intense physical activity and emphasising positive specific effects that invariably promote the body's simplification, more considerable qualitative and quantitative variation is recommended in the exercise practice.

This new vision was the origin of the self-similar periodization theory, generally known as Undulating non-linear periodization.

This non-linear program enables variation by rotating different protocols over the conditioning program's course, and these non-linear methods attempt to train the various component of the neuromuscular system in the same cycle.

Traditional periodisation models describe a progression from high volume and low-intensity work towards decreasing volume and increasing intensity during the different cycles.

If we draw this new kind of conditioning along two axis Intensity/volume and time, we easily can see some undulating diagrams in which the peaks are periods of very intense lifting, approaching 90 - 100 per cent of a one-repetition maximum (1RM) lift. The minima rest periods allow the body's energy systems to re-fuel and allow the neuromuscular system to adapt to the changing stressor; as it is well known, overtraining will occur without rest periods.

It is also essential to set up the volume of exercise, so if we analyse the graph, it astonishingly displays the reverse self-similarity. In other words, volume and intensity follow opposite patterns in that while intensity increases, volume decreases. Reducing volume in conjunction with high-intensity lifts allows an individual to avoid overtraining and possible injury further.

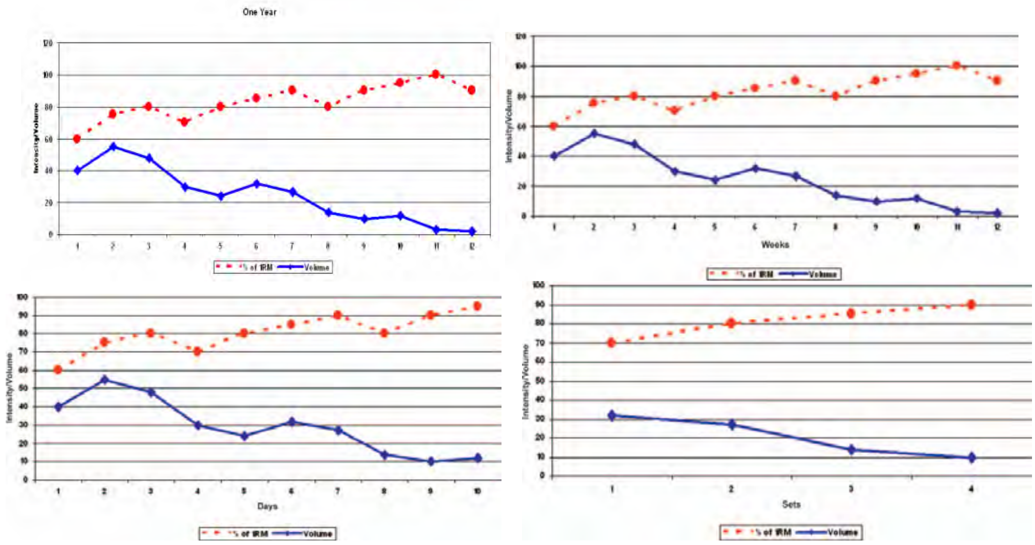


Fig4.2.a,b,c,d Typical periodization self-similarity Macro 1 year, Meso 3 months, Micro 10 days, One-day training. From Brown and Greenwood Periodization Essentials and Innovations in Resistance Training Protocols National Strength and Conditioning Association Volume 27, Number 4, pages 80–85

Not only, this model has compared favourably with the classical periodized and non-periodized models, but it has also been shown to have distinct advantages in comparison with non-periodized low volume training.
An essential aspect to organisms that justifies the previous position has to do with its extraordinary complexity. One should consider the analysis of human body complexity a large number of structures and processes that non-linearly interact through refereeing mechanisms, with the possibility of the birth of other functions and many unexpected response behaviours.
As a demonstration of the right fractals-complex view of conditioning, some new study seems to accord with this position. In a fascinating work, Yun et co-workers have suggested that the progressive decrease in the variation width of environmental stimuli to which the body is daily submitted may contribute to health dysfunctions and, on the contrary, that the expansion in this width through possible strategies such as physical exercise, may be beneficial.
The authors highlight that three systems as endocrine, autonomous, and skeletal-muscular, may suffer harmful effects due to this loss of environmental stimuli variation.
In general, concerning physical activity, it has been described that the decrease in its variation with the environmental stress caused by modern societies due to the new lifestyle they offer may reduce the width of the dynamics of the autonomous nervous system.
Therefore, it is recommended that variation in physical exercise when activating the autonomous nervous system could positively contribute to the maintenance of the heart rate variation, obviously a crucial function.
Therefore, for a logical extension, it is recommendable that at the light of the complex vision of the human body, in the specific conditioning for a complex sport like judo, a new, more profound and perhaps correct approach must be applied; in the short term variation (new) versus the linear (old) system.
The conditioning should be fractal-like because it is based on a combination of fractal structures as respiration, heart rate, locomotion, volume, intensity, remembering that periodization is also a fractal time series.
Future conditioning must be varied, both qualitatively and quantitatively, this kind of motor experiences variation is already emphasized in the sports field, but experimental data for cyclic Sports are very few. For situation, Sports, like judo, does not have both: theoretical or empirical knowledge yet. However, it is correct to believe that understanding the human body's complexity may help introduce this new conditioning method based on high variation in motor experiences.
In the light of new knowledge, we must consider that the (same actually) response signals or data from the Athletes body analysed with new and more advanced methodologies could give us more information than the present classical evaluations.
In the end, coming to the facts, this new vision gives us two points about the actual needs in conditioning theory:

1. ***Read the signals from athletes' bodies with more advanced mathematical methods to obtain information today hidden*.***

2. ***We need to apply short term variations, both qualitatively and quantitatively, in the conditioning methodology.***

The solution for the second need will be found in the complexity of Judo itself. Let's think of conditioning with an open mind. We can apply, for example, the judo specific movements as lifting exercises if they will be less comparable and less standardized as weightlifting exercises. However, if the rule that must be followed is changing based on complex variability, this paradigm could be satisfied with the judo techniques or movements. This shows us as judo is in itself a proper exercise for the human body complex systems.

*As example of the first statement the French paper “***Étude comparative de l’analyse spectrale de la fréquence cardiaque au cour de l’exercice sur ergocycle et de l’entraînement en judo***” Cottin and coworkers shows very clearly that by the analysis in frequency of HR it is possible to show if the subjects are subjected to endurance effort (ergocycle) or chaotic effort (judo)
These findings show, for example, that the exact value of heart rate as R.R. $(329 \pm 12 vs. 326 \pm 14)$ represents a very different kind of effort, with various human body organized responses.

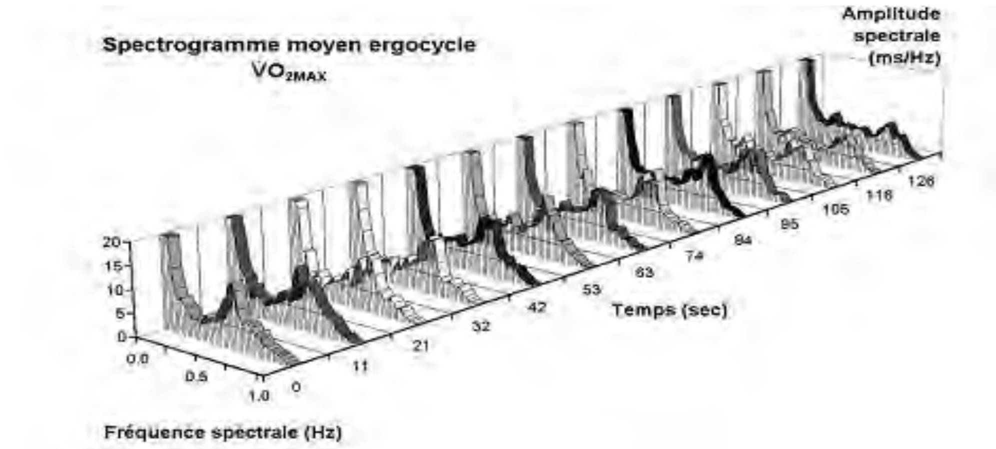


Figure 3. Spectrogramme moyen de la fréquence cardiaque des dix sujets sur ergocycle

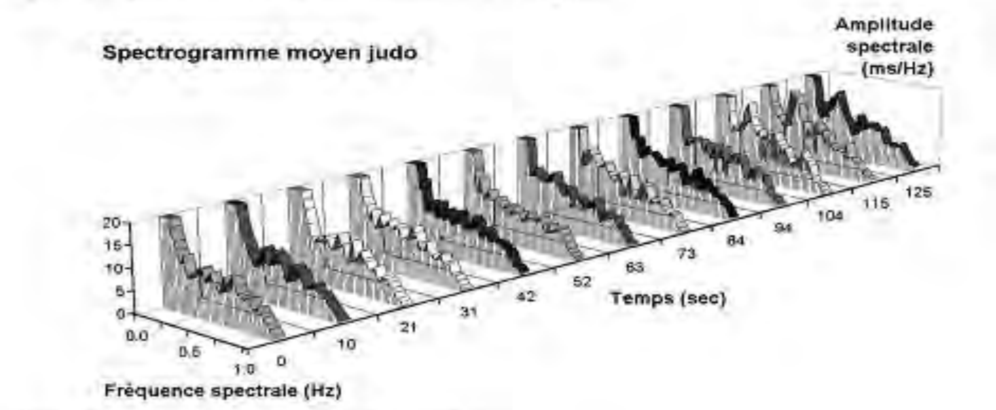


Figure 4. Spectrogramme moyen de la fréquence cardiaque des dix sujets en judo

Fig.4.2.e.f, Comparative analysis of “equal” heart rate spectrograms

Recently, the concept of nonlinear (or ondulating) periodized training has been developed to maintain variation in the training stimulus. The nonlinear activity makes program implementation possible when competitive requirements are more intense.
The nonlinear program allows for variation in intensity and volume within each training session. This unique approach, different for variation each week, is helpful for situation sports like Judo.
One interesting comparative complete work on the matter, explicitly applied to judo, was performed by Franchini and coworkers: *judo-Influence of linear and undulating strength periodization on physical fitness, physiological and performance responses to simulated judo matches*.
This study demonstrated that eight weeks of linear and undulating strength training are sufficient to increase athletes' judo performance in a judo-specific test, both isometric and dynamic maximal strength and strength-endurance, but not to change obviously, the quality of technical actions during judo match simulations.
However, this study for the authors could be considered an essential adaptation for judo athletes.
The number of throws increased in two sets of the SJFT (Special Judo Fitness Test).

Both groups are 30s long, which is the typical time of a combat sequence in judo, i.e., the time between the
command to start the judo combat and the time to stop. This suggests that the strength training protocols could change performance in a judo-specific action when performed in a controlled condition.
The following table shows the protocol applied in this research as a load during linear and nonlinear (undulating) training.

	Linear		Undulating	
	Week1	Week2	Week1	Week2
Monday	3-5 RM	3-5 RM	3-5 RM	power exercises
Tuesday				
Wednesday	3-5 RM	3-5 RM	power exercises	15-20 RM
Thursday				
Friday	3-5 RM	3-5 RM	15-20 RM	3-5 RM

	Week3	Week4	Week5	Week3	Week4	Week5
Monday	power exercises	power exercises	power exercises	3-5 RM	15-20 RM	power exercises
Tuesday						
Wednesday	power exercises	power exercises	power exercises	power exercises	3-5 RM	15-20 RM
Thursday						
Friday	Power exercises	power exercises	power exercises	15-20 RM	power exercises	power exercises
	Week6	Week7	Week8	Week6	Week7	Week8
Monday	15-20 RM	15-20 RM	15-20 RM	power exercises	15-20 RM	15-20 RM
Tuesday						
Wednesday	15-20 RM	15-20 RM	15-20 RM	15-20 RM	power exercises	3-5 RM
Thursday						
Friday	15-20 RM	15-20 RM	15-20 RM	3-5 RM	15-20 RM	power exercises

Tab.4.2.a Training load distribution (Linear and Nonlinear)during the research (Franchini and Coworkers)

Conclusion
However, periodization has contributed substantially to the training practice. Considering the complexities of Judo and human biology, there is clear reasoning that suggests an urgent need to realign the so-called ***linear practices*** with contemporary elite practice and modern scientific models. Concluding emphasis must be done to implement the ***linear practice*** with ***a nonlinear practice*** grounded on a responsive and sensitive training system to obtain customized-specific training planning solutions.

4.3 Technical training

The problem to teach the techniques in judo was approached by Kano in a very sound and scientific way, as it shall show in the following paragraphs.

Biomechanically speaking, the Judo techniques should be defined as *a system of specific connected motor actions able to overcome the adversary both standing or on the mat*; from the biomechanical point of view, this is the definition of the ***"Rational Sportive Technique***" the ideal model to that every coach or master refers and tries to teach.

The ideal model does not exist. The personal application, depending on the anthropometric characteristics, is named "***Effective Sportive Techniqu***e": *the personal adapted right system of specific connected motor actions able to overcome the adversary both standing or on the mat*.

Generally speaking, the technical teaching process is a complex problem, in it is possible to find two main areas:

1st. The Cognitive Intellective Area concerns the logical classification of techniques to understand the basic principles to throw.

2nd. The Cognitive-Motor Area concerns both the motor learning and the technical arrangement of these specific movements to teach them. With the worldwide judo expansion, this area can be subdivided into three very specialized and different subareas.

2.1 to teach children

2.2 to teach an adult

2.3 to teach elite athletes

Children methodologies and approaches to proficient adult athletes will be analyzed in the following two subparagraphs. For elite athletes will be analyzed the less known and perhaps underestimated impact of biomechanics on this technical area.

About elite athletes, modern technical teaching must take into consideration the specific character of the fight.

A significant advancement in teaching methodology at high-level judo has been the catalyst for structuring the teaching and coaching process to adapt it to the situation—Fight-based and thus emphasising the role of strategy tactics already in the initial stages of the competition.

The priority for these elite athletes is to understand the fight, develop a fighting sense and learn practical competencies, e.g. how to attack effectively in a determined "*Guard Position*" with correct pace, not just how to perform a "beautiful" technique esthetically speaking.

Athletes must learn how to solve different tactical problems.

Coaches working according to this methodology first try to develop cognitive skills, and later, if necessary, they use the technique, open drills. So, the topic/tactical problem of the lesson might be "Setting up to attack by creating the right space in the opponent's grip."

Modern judo training must consider the importance of fight as a whole, a global approach to coaching, and the principle of integration vs differentiation.

These terms refer to a global vision of Judo training in which all components are integrated and are put into practice using a "complex" training approach.

The concept of integrated training for judo states that the traditional distinction between technique, tactics, conditioning, and mentality is more artificial than real.

It is applied following the principle that athletes are also working tactics, conditioning, mentality, and vice versa since there are an interrelation and interdependence between all of them when working on technical aspects.

This is the reason that a modern high-level judo lesson should have a versatile character concerning all the aspects of competition.

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4.3.10Technical teaching methods historical Analysis (*Go Kyo and Others*)

4.3.1.1 Cognitive classification

The classification of standard Judo throwing techniques (Nage Waza) as ***Rational Sportive Techniques*** was born from the following didactic requirement - To group the traditional techniques under logical criteria for an easier understanding and proper systematic study.
The two problems of Classification and Teaching arrangement were tackled and solved by Dr Kano (founder of Judo) and his assistants in a scientific way, according to their time.
The first ***Rational Sportive Techniques*** classification of KODOKAN, Nage Waza (1882), was very different from that known worldwide, and all techniques were divided into three other groups.
Taosu Koto (overturning techniques), ***Otosu Koto*** (knock-out techniques); ***Uchi Tsukeru*** (Throwing Techniques)
After some time (1885), Kano carried out a new extraordinary classification based on a simple proto-biomechanical method.
The standard techniques were classified by parts of Tori's (the attacker) body, which work as a greater contact point for energy transfer in throwing.
From that, we have the "Kodokan Classification": ***Te waza*** = shoulder, arm and hand techniques; ***Koshi waza*** = hip techniques; ***Ashi waza*** = leg techniques; ***Sutemi waza*** = body-abandoning techniques or sacrifice techniques.
This admirable classification is simple, intelligible and almost perfect, was rearranged three times 1885 -1922-1982.
That is the reason for its prolonged success even if it has some shades in itself; in fact, it is unusual to see the hands, hips or legs of Tori working alone in throwing.
The Kodokan classification uses a different way to classify the body-abandoning techniques, classified by the body side touching the mat: Ma sutemi waza and Yoko sutemi waza, body abandoning techniques on his own back and his side. (Tab 4.3.1.1.a.b.c)
In his golden book "My Study of Judo", G. Koizumi classified the standard judo techniques by Uke's (the defender) body motion.
This study, performed as a systematical analysis of Nage Waza, permits the group of the standard techniques in three sets according to the technical principles.
Namely, the" Koizumi Classification": ***Kuruma waza*** = wheel techniques.
Throws that are affected so that Uke's body is curled and turned like a wheel are affected.
Tenbin waza = Scale techniques. Throws are affected by tripping or propping Uke's body as a scale while it is held as a pole.
Tsumazukase waza = Tripping techniques. Throws affected by tripping Uke's foot or leg, preventing it from moving to regain or maintain stability. (Tab 4.3.1.1.d)
Kawaishi, in his classification, follows the Kodokan classification with the insertion of one other group, the Kata waza, with other technical content. This classification was also a motor learning assessment. Practically Kawaishi, in his classification after the kata waza introduction, organized the techniques in a sort of evolution structured and based on motion. (Tab 4.3.1.1.e).
Another Japanese cognitive classification was applied in the scholar judo both in Japan and the US, focalized on similar kuzushi, the motion of legs and force application. ***Ateru Waza*** (placing techniques), ***Karu Waza*** (reaping techniques), and ***Harau Waza*** (sweeping techniques) (Tab 4.3.1.1.f)

Tachi Waza	Te Waza	Uki waza Seoi nage Kata guruma Tai otoshi Obi otoshi Seoi otoshi Uki otoshi
	Koshi Waza	Uki goshi Harai goshi Tsuri lomi goshi O goshi Koshi guruma Ushiro goshi Hane goshi Tsuri goshi Utsuri goshi
	Ashi Waza	Okuri ashi harai Sasae tesurikomi ashi Uchi mata Hiza guruma O soto gari De ashi barai Ko uchi gari Harai tsurikomi ashi O uchi gari Yama Arashi O soto guruma O soto otoshi
Sutemi Waza	Ma sutemi waza	Tomoe nage Ura nage Sumi kaeshi Tsuri otoshi Tawara gaeshi
	Yoko sutemi waza	Yoko gake Yoko guruma Yoko otoshi Daki wakare Yoko wakare Soto makikomi Uchi makikomi Tani otoshi

Tab 4.3.1.1.a Kodokan 1888

Tachi Waza	Te Waza	Seoi nage Tai otoshi Kata guruma Uki otoshi Sumi otoshi Sukui nage
	Koshi Waza	Uki goshi O goshi Koshi guruma Tsuri Komi goshi Harai goshi Tsuri goshi Hane goshi Ushiro goshi Utsuri goshi
	Ashi Waza	De ashi barai Hiza guruma Sasae tsuri komi ashi O soto gari O uchi gari Ko soto gari Ko uchi gari Okuri ashi barai Uchi mata Ko soto gake Ashi guruma Harai tsuri komi ashi O guruma
Sutemi Waza	Ma sutemi waza	Tomoe nage Ura nage Sumi gaeshi Tawara gaeshi Hikki Komi gaeshi
	Yoko sutemi waza	Uki waza Yoko gake Yoko guruma Tani otoshi Yoko wakare Soto makikomi

Tab.4.3.1.1.b, Kodokan 1922

Tachi Waza	Te Waza	Seoi nage Tai otoshi Kata guruma Sukui nage Uki otoshi Sumi otoshi Obi otoshi Seoi otoshi Yama Arashi
	Ashi Waza	De ashi barai Hiza guruma Sasae tsuri komi ashi O soto gari O uchi gari Ko soto gari Ko uchi gari Okuri ashi barai Uchi mata Ko soto gake Ashi guruma Harai tsuri komi ashi O guruma O soto guruma O soto otoshi
	Koshi Waza	Uki goshi O goshi Koshi guruma Tsuri Komi goshi Harai goshi Tsuri goshi Hane goshi Utsuri goshi Ushiro goshi
Sutemi Waza	Ma sutemi waza	Tomoe nage Ura nage Sumi gaeshi Hiki komi gaeshi Tawara gaeshi
	Yoko Sutemi waza	Yoko otoshi Tani otoshi Hane makikomi Soto makikomi Uki waza Yoko wakare Yoko gake Daki wakare Uchi makikomi

Tab.4.3.1.1.c, Kodokan 1985

Kuruma Waza	Uki otoshi Dai Sharin Seoi nage Kata guruma Tai otoshi Yoko otoshi Sumi otoshi	Tomoe nage Sumi gaishi Ura nage Uki waza Yoko wakare Maki komi Ura otoshi
Tenbin Waza	Uki goshi O goshi Harai goshi Yama Arashi Hane goshi Koshi guruma	Tsuri komi goshi O guruma Ushiro goshi Utsuri goshi Sukui nage Obi otoshi
Tsumazukase Waza	Deashi Harai Tsuri komi ashi Hiza guruma Ko uchi gari Kosoto gari Ouchi gari Uchi mata	Osoto gari Osoto otoshi Osoto guruma Osoto gake Ashi guruma Okuri ashi Harai

Tab.4.3.1.1.d Koizumi Classification (1960)

Ashi Waza	***Koshi Waza***	***Kata Waza***	***Te Waza***	***Sutemi Waza***
O soto gari De ashi barai Hiza guruma Ko soto gake Ouchi gari Ko uchi gari Okuri ashi barai Osoto guruma Osoto otoshi Ko soto gari Sasae tsuri komi ashi Harai tsuri komi ashi Soto gake Kouchi makikomi Ashi guruma	Uki goshi Kubi nage Tsuri goshi Koshi guruma Harai goshi Hane goshi Ushiro goshi Tsuri komi goshi Utsuri goshi Uchi mata O goshi Ko tsuri goshi Guruma Yama Arashi Obi goshi	Kata seoi Seoi nage Kata guruma Seoi otoshi Hidari kata seoi Seoi nage	Taiotoshi Uki goshi Kuki nage Hiza otoshi Sukui nage Mochiage otoshi Sumi otoshi Obi otoshi Kata ashi dori Rio ashi Dori	Tomoe nage Yoko Tomoe Maki Tomoe Makkomi Yoko gake Tani otoshi Sumi gaeshi Uki waza Kani basami Yoko otoshi Hane makikomi Ura nage Yoko guruma Yoko wakare Tawara gaeshi

Tab.4.3.1.1.e, Kawaishi classification(1964)

Ateru Waza	Hiza guruma Sasae tsuri komi ashi O goshi Tsuri komi goshi Seoi nage Tai otoshi Tsuri goshi Tomoe nage
Karu Waza	O soto gari O uchi gari Ko uchi gari Ko soto gari Ko soto gake
Harau Waza	De ashi barai Okuri ashi barai Uki goshi Harai goshi Hane goshi Uchi mata

Tab.4.3.1.1.f, Fujiwara Classification (1970)

A. Geesink and G. R. Gleeson have synthesized other kinds of classification.
The former Dutch champion, in his work, emphasizes the dynamic role played by biodynamic chains, introducing the concept of action arm and action leg Geesink classify the nage waza by a continuous evolution of technical difficulties. (Tab. 4.3.1.1.g)
While the latter, English senior coach indeed the subtlest student of western judo ones, in his historical book "Judo for the West", makes a very creative classification based on his enormous theoretical and empirical knowledge.
This classification collects the throwing techniques under two groups:

First-Class of "turning" Uke's body around an obstacle (hip, leg, etc.) –
Second- Class of "striking" Uke's legs.

The next time in his book "All About Judo", Gleeson revised his classification, presenting a new and more interesting effort based on the shifting velocity of a couple of athlete's systems. In this system, the collocation of a technique is not stable but depends on shifting velocity. This notation makes sure that Gleeson was more interested in understanding the role of throws in a couple of athletes (see Competition Invariants) than to classify simply the techniques. (tab.4.3.1.1.h)

Tachi waza group	***action arm***	Uki goshi Koshi guruma Ushiro goshi O goshi I Seoi nage Utsuri goshi O goshi II Sukui nage Kata guruma O goshi III Te uchi mata
	action leg	Tsuri komi goshi Hane goshi Tai otoshi Ashi guruma Harai goshi Tomoe nage Uchi mata Sumi gaeshi
Barai Group	De ashi barai Okuri ashi barai Ko uchi barai Harai tsuri komi ashi O uchi barai	
Gari group	O soto gari O uchi gari Ko soto gari O uchi mata Ko uchi gari	

Tab.4.3.1.1.g, Geesink Classification (1967)

<table>
<tr><td rowspan="2">Lifting techniques</td><td>Subgroup 1 arms</td><td>O goshi O Tsuri goshi Utsuri goshi
Seoi nage Ko tsuri goshi Ushiro goshi
Morote seoi nage Tsuri goshi *Tai otoshi</td></tr>
<tr><td>Subgroup 2 leg</td><td>Hane makikomi *Uchi mata
Soto makikomi * Hane goshi</td></tr>
<tr><td rowspan="2">Rotating techniques</td><td>Pure rotation</td><td>Hiza guruma Tomoe nage
Sasae tsurikomi ashi Sumi gaeshi
Uki goshi Yoko wakare
Koshi guruma Yoko guruma

Tsuri komi goshi * Tai otoshi
Sasae tsuri komi goshi *Uchi mata
Uki goshi
Koshi guruma</td></tr>
<tr><td>Transport</td><td>De ashi Harai Uki otoshi
Osoto gari Uki waza
O uchi gari Sumi otoshi
Ko soto gari Yoko gake
Ko uchi gari

Okuri ashi harai Ura nage
Harai goshi *Hane goshi
Ko soto gake *Tai otoshi
Yoko otoshi *Uchi mata
Kata guruma</td></tr>
<tr><td>Trick techniques</td><td colspan="2">Sukui nage Kuchiki daoshi *De ashi barai Yoko gake
Morote gari Kibisu gaeshi Kani basami *Uchi mata</td></tr>
</table>

Tab.4.3.1.1.h, Gleeson Classification (1984)

Much less known but fascinating and intriguing is the fighting classification proposed in 1995 by Dr Sachio Ashida 8 Dan KDK founded on the effective way of the best utilization of force vector in competition Ashida proposed to classify all the Tachi waza techniques in two dynamic groups:
A) Lift and Thrust: for these techniques, Tori forces must significantly exceed the competitors defending force, which consist of his weight and combination of his shifting and reaction forces.
B) ***Lift and Wind*** for this group of techniques Ashida suggest that it is possible to apply the basic principle of hammer-throwing strictly connected to the centripetal force and angular momentum conservation.

Lift and Trust	***Lift and Wind***
O uchi gari	Seoi nage
Ko soto gari	Tsuri komi goshi
O soto gari	Uchi mata
Tai otoshi …..	Harai goshi…….

Tab.4.3.1.1.i, Sachio Ashida Biomechanical forces Classification (1995)

Based on dynamical principles of throwing, a not known classification was proposed and developed in Italy by Mr Tavolucci. This classification groups all techniques based on Japanese dynamical principles of throwing, which are the principles of motion applied or performed by Tori or undergone by Uke, then they are Nage, Otoshi, Tsurikomi, Gari, Harai, Gake, Guruma, Makikomi, Sutemi.

Nage	***Otoshi***	***Tsuri komi***	***Gari***	***Harai***	***Gake***	***Guruma***	***Makikomi***	***Sutemi***
Eri seoi nage Ippon seoi nage Morote seoi nage Tomoe nage Yoko Tomoe nage Ura nage	Tai otoshi O soto otoshi Tani otoshi Seoi otoshi Suwari seoi Waki otoshi Uki otoshi Sumi otoshi	Sasae tsuri komi ashi Uki goshi O goshi Tsuri komi goshi Sode Tsuri komi goshi Uchi mata Ushiro goshi	O soto gari Ko soto gari Ko uchi gari O uchi gari Kuchiki daoshi Morote gari	De ashi barai Ko uchi barai O uchi barai Harai goshi Okuri ashi barai	Ko uchi gake O uchi gake Ko soto gake O soto gake Yoko gake	Hiza guruma Koshi guruma Te guruma Yoko guruma Ashi guruma Tama guruma Kata guruma	Soto makikomi Uchi makikomi Ko uchi makikomi Harai makikomi Uchi mata makikomi	Sumi gaeshi Hikkomi gaeshi

Tab.4.3.1.1.j Tavolucci (?) Japanese dynamics Classification (1993)

In his books grips, Adams proposes a specific throws classification connected to the fight situation, already Vial and Roche and Fradet proposed but in a teaching way the approach to judo competition. Obviously, as a fighting man, in his pragmatic approach, Adams utilized the most important (for him) and applied to throw techniques in competition, but it is not in his intention to classify all techniques for the rational organization of the matter.

Forward throws under uke's grips
Tai otoshi, Seoi nage, Tomoe nage
Forward throws with uke's head control
Uchi mata, Hane goshi
Backward throws with uke's head control
O soto gari, Ko uchi gari
Backward throws inside uke's arms
O uchi gari, Ko uchi gari
Sided throws inside uke's legs circle
Yoko Tomoe nage, Sasae tsurikomi ashi
Throws on the side of uke's grips
O soto gari, Ko soto gari

Tab.4.3.1.1.k, Neil Adams fighting classification (1992)

Judo Canada, in 1990 published three profound and exciting books: "*The National coaching certification program*", the, first second and third level. These three books represent an excellent growing judo knowledge, starting from basic judo knowledge to the most advanced ones, like Sports physiology, mental training, and periodization.
The technical skill is studied more and more in deep in every book until the international level application. An exciting classification in the second level is presented in chapter IV, categorising judo techniques according to common biomechanical principles and concepts.

The classification is similar to Tavolucci work, but it is non-exclusive, and the same techniques are present in several groups based on they are performed.

Sweeping	***Floating***	***Fulcrum***	***Blocking***	***Reaping***	***Wheeling***	***Hooking***	***Sacrificing***
De ashi barai O uchi barai Ko uchi barai Harai tsurikomi ashi Okuri ashi barai Harai goshi Tsubame gaeshi	Uki goshi Tai otoshi Uki otoshi Sumi otoshi	Harai goshi Uki goshi Tai otoshi O goshi Koshi guruma Seoi nage Tsurikomi goshi Utsuri goshi Ushiro goshi Tsuri goshi Ashi guruma O guruma Uchi mata Sukui nage Ura nage Hane goshi	Tai otoshi Hiza guruma Sasae tsurikomi ashi O soto otoshi O soto guruma Ashi guruma O guruma	Harai goshi Ashi guruma O soto gari O uchi gari Ko uchi gari Uchi mata	Tsurikomi goshi O guruma Kata guruma Te guruma Sukui nage Tomoe nage Yoko tomoe Sumi gaeshi Obi tori gaeshi Yoko guruma	Tsubame gaeshi O soto otoshi Ko soto gake O uchi gake Ko uchi gake	Tomoe nage Yoko tomoe Sumi gaeshi Obitori gaeshi Uki waza Yoko otoshi Tani otoshi Ura nage Soto makikomi Hane makikomi Koshi makikomi Yoko gake Yoko wakare

Tab.4.3.1.1.l, Judo Canada Classification 1990

Another effort, not well known but very interesting and original, was produced by Andres Kolychkine Thomson, judo professor at the Medical Superior Institute in Cuba.
Mr Kolychkine made a considerable effort of revision of judo in term of a new didactic, some unique position is not very clear, like: "*Starting with basic elements, it is important to note that this new didactic approach singles out the* ***personality*** *of the basic elements like supports not only of throws but also as components of the complete tactic system with basic elements and throws; these basic elements are: Ukemi, shizen tai, grips, unbalance, shifting. However, defining the matter, we must consider the opportunity connected with time-space concepts, reaction forces, etc.* ***Sometimes these aspects are considered as basic technical elements that help judo execution, but they do not belong to judo, they belong to physics***" … (? "Author comment" physics try to understand and rationalize natural phenomena like Judo Throws, to help for a better execution)
Nevertheless, the work of Kolychkine is fascinating in its didactic and classificatory aspects. His classification is like the Kodokan classification (legs, hips, arms, and sacrifice techniques) with the introduction of a fascinating concept, the theory of Primitive and Analogous movements at the light of this theory, some movements can be considered, from **the Biomechanics point of view** as the example of the basic movement of a group of techniques. In contrast, the other's other throws can be easily obtained for an analogy from the previous basic ones'.

Ashi waza	***Primitive***	***Okuri ashi barai***	***Sasae tsurikomi ashi***	***O soto gari***	***O uchi gari***
	Analogous	*De ashi barai*	*Hiza guruma* *Ashi guruma* *Harai tsurikomi ashi*	*O soto otoshi* *O soto guruma* *Ko soto gari* *O soto gake*	*Ko uchi gari*
Koshi waza	***Primitive***	***Uki goshi***	***Kubi nage***	***Tsuri komi goshi***	***Ushiro goshi***
	Analogous	*O goshi* *O tsuri goshi* *Ko tsuri goshi*	*Koshi guruma*	*Sode tsurikomi goshi* *Harai goshi* *Hane goshi*	*Utsuri goshi*
Specially mixed movements		*Uchi mata*	*O guruma*	*Yama arashi*	
Kata waza	***Primitive***	***Ippon seoi nage***	***Morote seoi nage***	***Kata guruma***	
	Analogous	*Seoi otoshi*	*Eri seoi nage*	*Tamara guruma*	
Te waza	***Primitive***	***Tai otoshi***	***Uki otoshi***	***Sukui nage***	
	Analogous		*Hizi otoshi* *Sumi otoshi*	*Te guruma* *Ryo ashi dori*	
Ma sutemi	***Primitive***	***Tomoe nage***			
	Analogous	*Sumi gaeshi* *Ura nage* *Tawara gaeshi* *Kani basami*			
Makikomi					
Yoko sutemi	***Primitive***	***Uki waza***			
	Analogous	*Yoko otoshi* *Yoko guruma* *Yoko wakare* *Yoko gake* *Tani otoshi*			

Tab.4.3.1.1.m, Kolychkine Classification (1989)

This tentative it is an actual effort to single out the movement's similitude or Action Invariants inside the throws, during the time many masters in the world have reached the same point of view about one or more group of techniques like Snider brothers from Holland or Beaujean from France, but only Kolychkine pushed forward his study to complete a new defined didactic approach.
Also, the French Federation made a classification of nage waza techniques (limited to the green belt) grounded on the fundamental biomechanical principles singled out from the Author (for a better understanding of the following classification, it must refer to the ***Classification of technical actions in function of their complexity*** table shown in the next paragraph).

With more flavour of competition, I am considering a couple of athletes, by the extrapolation of the structural aspects of throws, in connection with the relative stability of Tori, the fall direction of Uke and the relative positioning between Tori and Uke.

Frontal uke's backward throws with one leg	*O soto gari, Ko soto gari, Ko uchi gari, O uchi gari*
Uke's forward throws by one's back with two separated legs	*Uki goshi, Tai otoshi*
Uke's forward throws by one's back with two joined legs	*O goshi, Seoi nage, Koshi guruma, Eri seoi nage, Morote seoi nage*
Uke's forward throws by one's back with one leg	*Harai goshi, Uchi mata, Ashi guruma*
Frontal uke's forward throws with one leg	*Hiza guruma, Sasae tsuri komi ashi*
Sweepings	*De ashi barai, Okuri ashi barai*
Sutemi	*Tomoe nage, Yoko guruma, Tani otoshi*
Throws with legs' grips	*Morote gari, Kuchiki daoshi*

Tab.4.3.1.1.n, Judo French Federation (FFJDA) Nage Waza Classification (1990)

Last but not least, we consider the old Russian Classification; in this country, the approach was very pragmatic; the first classification made by Andreev and Tumanian do not retain the Japanese names, but like Wrestling or Sambo, groups all throws by an action performed, introducing in the explication of each technique also the so-called tactic tasks: grips variation, combinations, parrying, counters, typical errors.

In the old Soviet Union, there were many national wrestling styles, and all these different ways of fighting based especially on Sambo or other styles with a very similar approach to freestyle wrestling were directly introduced in judo.

This is the reason for the different introduction of techniques and blossoming during the years sixty and seventy.

All judo throwing absorbed by this new pragmatic vision of the fight lost their Japanese flavour and name and were classified as number (like Kawaishi) or by action name.

We will use the Japanese nomenclature for the Russian classification for homogenizing reasons with the other categories shown.

Initially, in this classification, there are no Japanese names but only action descriptions in the Russian way, because, in this classification, there are many techniques outside the Kodokan classification, for some of them, we shall use the Roy Inman translation taken by his work on the shiai waza accepted into the BJA Syllabus.

Throws with hands grip to legs	Kata uchi ashi dori, Sukuinage, Morote gari, Soto kibisu gaeshi, Kata soto ashi dori
Sweepings	Harai tsurikomi ashi, Okuriashi barai, Ko soto gake, Ko soto gari, Ko uchi gake,
Hooking	O uchi barai, O uchi gake, Ko soto gake,
Legs throwing	O uchi gari, O uchi gake, O soto gari, Soto ashi dori o uchi gari
Tripping techniques	Tai otoshi, O soto gake, O soto otoshi,
Hip techniques	Harai goshi, Uchi mata,
Dragging down techniques	Kani basami, Hikkikomi gaeshi
Hips throws	O goshi, Koshi guruma, O soto makikomi
Back throws	Morote seoi nage, Suwari seoi, Sode tzurikomi goshi, tzurikomi goshi
Backward throwing techniques	Ura nage,
Sided throwing techniques	Yoko otoshi
Sacrifice techniques	Tomoe nage, Hikkomi gaeshi
Throws over the shoulders	Kata guruma, Tama guruma, Suwari kata guruma,
Backward overturning with the thigh	Mae Hiza ura nage, Ushiro hiza ura nage

Tab.4.3.1.1.p, (V.M.Andreev-G.S.Tumanian) Old Russian Classification (year??)

The need for classification grows around the world, and during these years, some new efforts born in different countries in the following two categories were presented in Croatia and Spain.
These classifications are both connected to the application in competition and the cognitive goal.

SUB-GROUP A1		**SUB-GROUP A2**
C1 ASHI GURUMA	C17 YAMA ARASHI	C7 OBI OTOSHI
C5 HIZA GURUMA	C16 UKI WAZA	C21 YOKO WAKARE
C14 UKI GOSHI	C18 YOKO GAKE	C11 SUMI OTOSHI
C6 KOSHI GURUMA	C4 HIKIKOMI GAESHI	C15 UKI OTOSHI
C28 O GOSHI	C13 TSURIKOMI GOSHI	
C2 HANE GOSHI	C19 YOKO GURUMA	
C8 O GURUMA	C36 NIDAN KOSOTO GAKE	
C3 HARAI TSURIKOMI ASHI	C20 YOKO OTOSHI	
C12 TAWARA GAESHI	C39 OKURI ASHI HARAI	

Tab.4.3.1.1.q Application in Competition, Throws Less important (Sertic, Seghedi) 2014

SUB-GROUP B1	**SUB-GROUP B2**	**SUB-GROUP B3**
C9 SOTO MAKIKOMI	C22 TOMOE NAGE	C32 OUCHI GARI
C26 SASAE TSURIKOMI ASHI	C23 SODE TSURIKOMI GOSHI	C34 UCHIMATA
C31 HARAI GOSHI	C24 MOROTE SEOINAGE	C35 KOUCHI GARI
C37 TANI OTOSHI	C25 IPPON SEOINAGE	
C33 OSOTO GARI		
C10 SUMI GAESHI		
C40 DEASHI HARAI		
C27 TSURI GOSHI		
C38 KOSOTO GARI		
C29 URANAGE		
C30 TAI OTOSHI		

Tab.4.3.1.1.r Application in Competition, Throws Most important (Sertic, Seghedi) 2014

In Croatia, was focalized a classification according to the Throws' importance in Competition. This result could be helpful to judo experts for selecting the most rational methods of technical and tactical preparation and establishing new and modern approaches to judo training.

	Acronym	*Movement structure*	*Dynamic leg direction*	*Dynamic leg zone*	*Throw space*	*Supporting base*	*Some Specific Judo Motor Skills*
1	Turn_F2	turn			forward throw	Two supporting legs	o goshi, uki goshi, koshi guruma, tsuri goshi, utsuri goshi, seoi nage, sode tsuri komi goshi, uchi makikomi, soto makikomi, tsuri komi goshi, seoi otoshi, tai otoshi
2	Turn_F1	turn			forward throw	One supporting leg	uchi mata, uchi mata makikomi, harai goshi, hane goshi, ashi guruma, o guruma, yama arashi, harai makikomi, uchi mata makikomi, hane makikomi
3	WT_IpExB1	without turn	ipsilateral leg direction	external zone	backward throw	One supporting leg	o soto gari, o soto gake, o soto otoshi, o soto guruma, o soto makikomi, o soto gaeshi
4	WT_IpInB1	without turn	ipsilateral leg direction	inner zone	backward throw	One supporting leg	ko uchi gari, ko uchi gake, ko uchi makikomi
5	WT_ClaInB1	without turn	contralateral leg direction	inner zone	backward throw	One supporting leg	o uchi gari, o uchi gake, o uchi makikomi
6	WT_ ClaExB1	without turn	contralateral leg direction	external zone	backward throw	One supporting leg	ko soto gake, de ashi harai, tsubame gaeshi, yoko gake, okuri ashi harai, o uchi gaeshi, ko uchi gaeshi,harai goshi gaeshi, uchi mata gaeshi, hane goshigaeshi, tani otoshi
7	WT_ClaExF1	without turn	contralateral leg direction	external zone	forward throw	One supporting leg	sasae tsuri komi ashi, hiza guruma, harai tsuri komi ashi
8	WT_2	without turn			forward or backward throw	Two supporting legs	ura nage, ushiro goshi, yoko otoshi (as kata guruma), sumi otoshi, obi otoshi, daki wakare
9	SP_FwBack	supine position			forward throw	back support	Tomoe nage, sumi gaeshi, hikikomi gaeshi, yoko tomoe nage, uki waza, yoko guruma, yoko wakare

Tab4.3.1.1.s Criteria and Group of techniques connected (Dopico. And Coworkers 2014)

This classification was born in Galicia to organize judo motor skills to **a)** facilitate the acquisition of a large number of movements (techniques) and to design a tool for acquiring significative learning through a classification based on motor criteria; **b)** use this as a resource to plan, control and optimize the training process; **c)** analyse the sport of judo from a tactical perspective.

Criteria for classification were: **a)** Movement structure position, **b)** Support base, **c)** Direction where the opponent is thrown, **d)** Direction of the dynamic leg, **e)** Applicability zone of the dynamic leg.

4.3.1.2 Cognitive motor learning arrangements

Technical improvement and perfection are grounded in building a proper motor system (correct movements, kinetics, kinematics, and learning).
A judo athlete's technical ability shall be a function of the correctness of his motor system, which during training will be better ever and ever thankful for the exercise.
Ajrijanc singled out the specific goals of technical training as:

1. Acquisition of basic techniques.
2. Lasting acquisition of technique.
3. A technical improvement as a function of an athlete’s capabilities.
4. Stabilization of technique as a function of difficult situations (stress, fatigue, emotional pressure)

For pupils, the learning system is connected to games because the boy's attentiveness is very low. And it is well known that, for boys and children, the better way to gain attention for learning is play and games. A well-built system based on games will produce tremendous and fast improvement in motor learning. With age, increasing will be possible to introduce an adult structured motor learning arrangement. For adult people, the instruction structure shall be built on interconnected and structured phases that shall improve both the conceptual knowledge and the technical motor knowledge that will be sufficiently flexible. In every technical training, it is possible to find four essential steps:

I. Phase (cognitive)
This phase is suited to let known the Sportive Rational Technique to the athlete by the instructor demonstration

II. Phase (experimental)
In this phase, the athlete must change the technical motor learning into body motion by practical experimentation. The instructor shall divide the movement to rectify the errors

III. Phase (stabilizing)
The meaning of this phase is to build a motor operant conditioning. This motor conditioning should be learnt by repetitions and variations method. The instructor shall blend the two ways to prevent stereotyping due to the repetition method and obtain the proper flexibility useful in situation sports.

IV. Phase (strategic)
During this phase, the instructor shall focus on the athlete’s situational adaptability and improve his inventiveness. This is the athlete’s capability to familiarise faster with the changing situations of the fight.
This is usually obtained by mistakes in statistical evaluation, competition control, tests, video analysis, and local strategy study.

4.3.1.2.1 Children area

The children area is a vast field for experimentations and specific applications.
Every country in these last twenty years faced with the children problem, the solutions are very different depending on the local cultural heritage and habits.
A complete analysis should surpass the limits of the book. We do not consider all the DVD operas but only writhed analysis, and then in this paragraph, among so many materials, they will be analyzed a few of the most fundamental and original approaches around the world (under author commitment).
The most organized and advanced country in this field is France, with a long history; if we see a single production, we could remember Adami and Couturier's work (1975). The first national organized teaching methodology was produced at the end of year 80, with the publication of the two books Approche Pédagogique du service de la recherché FFJDA 1985 – after Méthode Francaise d'enseignement du judo-jujitsu - FFJDA 1995, today the basis of the teaching evolution have been reorganized by Brousse and Co. on sound scientific and pedagogic foundations retaining and developing all the previous enormous experiences built in France by FFJDA.
In the following table, there is the example of the three classification criteria regrouping: 1) all techniques by the two basic biomechanical principles of functioning (Couple and Lever), 2) by the basic standing position (one or two feet), 3) by the relative Uke's position (forward, backward).

<table>
<tr><th></th><th>Backwards uke</th><th>Examples</th><th>Forward uke</th><th></th><th>Examples</th></tr>
<tr><td rowspan="3">Two legs' support</td><td>Spread Legs</td><td>Koshiguruma
Tai otoshi
Kubi nage
Soto makikomi
A</td><td>Forward Projection</td><td></td><td>Te guruma
Kuchiki daoshi
Morote gari</td></tr>
<tr><td rowspan="2">Tightly shut legs</td><td rowspan="2">Uki goshi
O goshi
Ippon seoi nage
Koshi guruma
Morote seoi nage
Eri seoi nage
Tsurikomi goshi
Sode tsurikomi
Ushiro goshi
D</td><td>Backwards Projection</td><td></td><td>Ura nage</td></tr>
<tr><td>With lifting</td><td></td><td>Kata guruma</td></tr>
<tr><td rowspan="4">One leg support</td><td rowspan="2">External Sweeps</td><td rowspan="2">Harai goshi
E</td><td rowspan="2">Forward or sided Projection</td><td>Standing</td><td>Hiza guruma.
Ashi barai
Sasae tsurikomi ashi
C</td></tr>
<tr><td>Falling down</td><td>Sutemi</td></tr>
<tr><td rowspan="2">Internal Sweeps</td><td rowspan="2">Uchi mata
F</td><td rowspan="2">Backwards Projection</td><td>Internal Sweep</td><td>O uchi gari
Ko uchi gari
B</td></tr>
<tr><td>External Sweep</td><td>O soto gari
Ko soto gariB.'</td></tr>
</table>

Tab.4.3.1.2.1.a France classification of technical actions in function of their complexity

Suppose the FFJDA is perhaps the leader federation in the children area with connected structures and centralized organization. In that case, English country shows a broad series of good books on children

teaching, many English thinkers like Gleeson or Sulman, Soames, and others gave some critical contribution to the children teaching but were original and single contributions not centralized as French federation.
Also, in Spain, there is not such a centralized situation like France, during these years, the most exciting proposal in Spain was a collaboration between Spain and Poland (2004) based on 911 surveys among nineteen countries the most active were Spain, Portugal, Italy, France, Poland, Venezuela, Colombia, Brazil and the United States. The result of the new go kyo proposal is shown in the following tables:

NIVEL I		
A	B	C
O SOTO GARI (OTOSHI) O-GOSHI DE ASHI BARAI KO SOTO GARI (GAKE)	O UCHI GARI KOSHI GURUMA SASAE TSURI K. ASHI OKURI A. BAR(LINEAL)	KO UCHI GARI SEOI NAGUE HIZA GURUMA OKURI A.B. (GIRO)

NIVEL II		
A	B	C
HARAI GOSHI TSURI GOSHI KATA GURUMA UKI WAZA	UCHI MATA TSURI KOMI GOSHI TOMOE NAGUE URA NAGUE	HANE GOSHI (ASHI G) USHIRO GOSHI UTSURI GOSHI YOKO GAKE (GURUMA)

EDAD	COLOR CINTURÓN	NIVEL
6 AÑOS	BLANCO AMARILLO	PARTICIPACIÓN+ UKEMIS
7 AÑOS	AMARILLO	NIVEL I GRUPO A
8 AÑOS	AMARILLO-NARANJA	NIVEL I GRUPO B
9 AÑOS	NARANJA	NIVEL I GRUPO C
10 AÑOS	NARANJA-VERDE	NIVEL II GRUPO A*
11 AÑOS	VERDE	NIVEL II GRUPO A**
12 AÑOS	VERDE-AZUL	NIVEL II GRUPO B*
13 AÑOS	AZUL	NIVEL II GRUPO B**
14 AÑOS	AZUL-MARRÓN	NIVEL II GRUPO C*
15 AÑOS	MARRÓN	NIVEL II GRUPO C**

Tab.4.3.1.2.1.b Spain result for children survey

Another exciting work performed on the same base: a collection of different teachers' opinions by Garcia Garcia and Vicente Carratala, in collaboration with Sterkowicz, produced the following teaching methodology based on the following technical points.

1. *The ease with which* tori *may achieve balance and* uke *imbalance*
2. *The ease with which* tori *may gain posture control*
3. *The ease in adjusting to space-time (precision)*
4. *The ease in achieving intersegmental coordination*
5. *The ease in attaining the correct direction in pushing and pulling actions*
6. *The ease with which* uke *achieves* ukemi *(falling without the risk of an injury)*

Aspect	Techniques that are easiest to perform	Techniques that are hardest to perform
The ease with which *tori* may achieve balance and *uke* imbalance:	O GOSHI KOSHI GURUMA TAI OTOSHI	TOMOE NAGE HIZA GURUMA
The ease with which *tori* may achieve the posture control:	O GOSHI O SOTO GARI KO SOTO GAKE	HIZA GURUMA KATA GURUMA
The ease in adjusting to space-time (precision):	O GOSHI O SOTO GARI KOSHI GURUMA	DE ASHI BARAI OKURI ASHI BARAI
The ease in achieving intersegmental coordination:	KO SOTO GAKE O GOSHI KOSHI GURUMA	TSURI KOMI GOSHI TOMOE NAGE
The ease in achieving the correct direction in pushing and pulling actions	O GOSHI TAI OTOSHI KOSHI GURUMA	KATA GURUMA O UCHI GARI
The ease with which *uke* achieves *ukemi* (falling without the risk of an injury):	O SOTO GARI DE ASHI BARAI O UCHI GARI	TOMOE NAGE KATA GURUMA

Tab.4.3.1.2.1.c Spain Breakdown of techniques according to ease with which they are performed.

The proposed methodology is presented in the next table :

Age	Belt colour	Programme
6	WHITE-YELLOW	MOBILITY/JUDO + UKEMI
7	YELLOW	O SOTO GARI (OTOSHI) O-GOSHI DE ASHI BARA* KO SOTO GARI (GAKE)
8	YELLOW-ORANGE	O UCHI GARI KOSHI GURUMA SASAE TSURI K. ASHI OKURI A. BAR (LINEAR)
9	ORANGE	KO UCHI GARI SEOI NAGE HIZA GURUMA OKURI A.B. (ROTATION)*
10	ORANGE-GREEN	HARAI GOSHI TSURI GOSHI KATA GURUMA UKI WAZA
11	GREEN	LEVEL II GROUP A**
12	GREEN-BLUE	UCHI MATA TSURI KOMI GOSHI TOMOE NAGE URA NAGE
13	BLUE	LEVEL II GROUP B**
14	BLUE-BROWN	HANE GOSHI USHIRO GOSHI UTSURI GOSHI YOKO GAKE (GURUMA)
15	BROWN	LEVEL II GROUP C**

Tab.4.3.1.2.1.d Garcia Garcia, Carratala, Proposed programme, taking the difficulty of learners' execution and age into consideration.

The Spanish Federation has developed a very complete and exciting teaching method for children between 6 to 14 years, essentially based on understanding movements connected to throwing technics.
One fascinating and complete contribution from the "Xunta Galiciana" the Galician Judo Federation authors, two eminent masters: Eduardo Galan Palla VI Dan and the Dr Vicente Carratalà Deval VII Dan is the judo for children book: "*Judo del descubrimiento a la formacion*" in which authors face at first with the social analysis connected to the initiation of Judo in Galicia, like the reasons for the families to introduce children into judo, the rights of athletes, for a second in-depth analysis of teaching phases at the light of pedagogy and the connection of matter.
For the third, the technical part is full of an exciting and original idea.

Tab.4.3.1.2.1.c. Judo technical content distribution for children ages (from Galan, Carratalà)

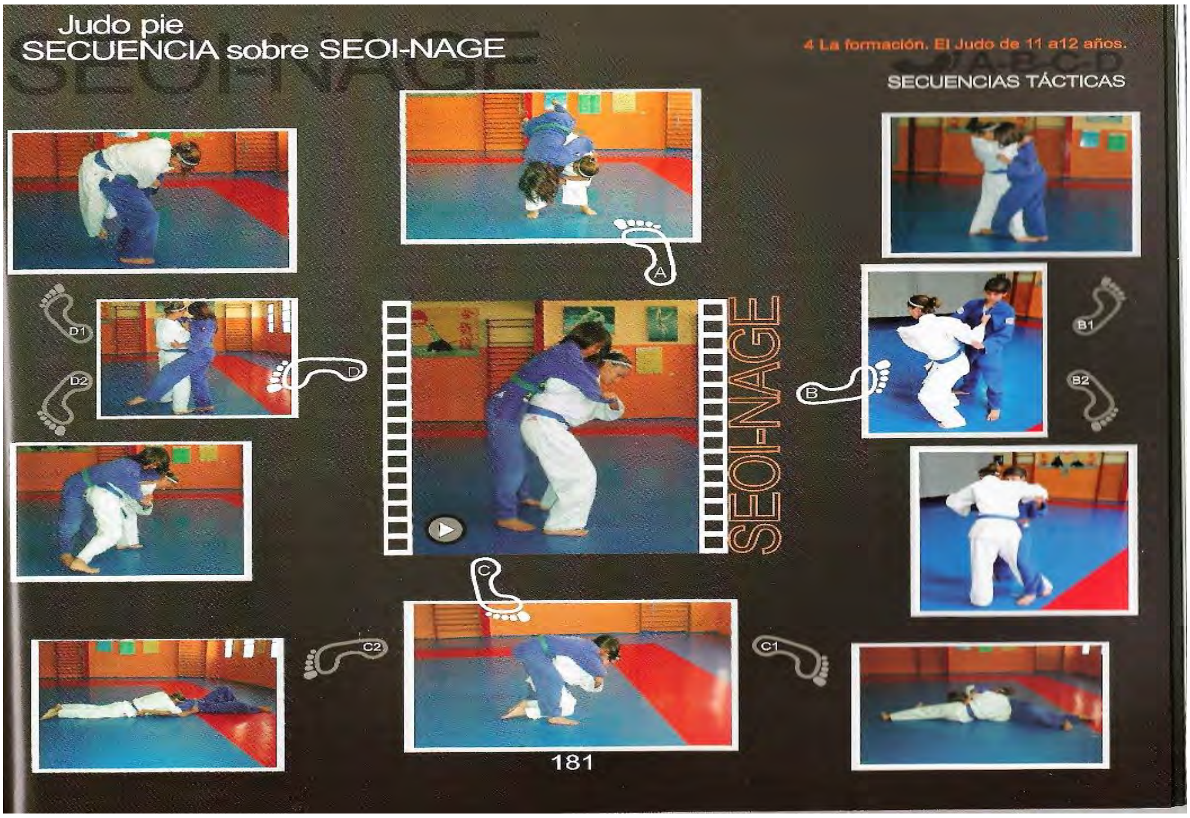


Fig.4.3.1.2.1.a Technical sequence for children on Seoi Nage (From Galan, Carratalà)

Fig.4.3.1.2.1.b, Technical sequence for children on Uchi Mata (From Galan, Carratalà)

Among other contributions, one of the most original ones is the organized work produced by Dr DI Frantisek Jahoda for the Austrian Federation in four books, the series “*Judo teaching system for children with judo ball”.*
It is a very original teaching system by a unique tool the judo ball is able to teach: Ukemi, grips, kansetsu, and barai or ashi waza, and other judo actions. And as it is easy to see agreeable not only for children

Fig.4.3.1.2.1. c.d.e. Austria, Judo ball methods for children

In the 6th International Science of Judo Symposium in Rotterdam 2009, some exciting papers were presented both by English and Italian People on children judo.
Challis (Anglia Ruskin University) gave an exciting study comparing two methods of teaching judo; (traditional Go Kyo and multi-skills application). A state if there is an improvement in children's motor ability (9-11 years) and which method was more valuable the results show that the trend in the modification of the multi-skill method was more robust, a result that conforms to the non-linear complexity of the human body.
In Italy same situation as England, during these years many interesting DVDs or books on children field, one for all *“The First judo”* by Capelletti 2002, all this shows the tension to solve a real problem in the judo world. Some years ago in 1996, an original teaching methodology for children was got ready, based on the biomechanical analysis of judo, taking into account the following considerations: the need to ensure logica1 and cultura1 continuity with the Classical Method (Go Kyo) by retaining the most valuable features of this approach; the need to set up a structure offering the maximum flexibility to learners (children) in such a way as to cater for differences in motor capability; the need to outline guidelines for instructors whereby rigidity and pre-established rules are kept to a minimum while highlighting personal skills and inventiveness.

Italian Biomechanical motor learning teaching (Monti-Sacripanti) 1996
The program was developed based on two particular didactic assumptions which continuously recur, especially in the most challenging period (1st year):
- Appropriate distribution of training and instruction;
- Innovative structuring is based initially on the Ne Waza and subsequently on the Tachi Waza.

The motor skills that the pupils must learn are furnished by the group as a whole, where the techniques are of equa1 value, not by the sequential order of the techniques.
In the latter case, it is assumed that the techniques are arranged to increase the difficulty of movement, whereas the Italian approach seeks to teach techniques with the same degree of motor difficulty in each group.
In specific terms, pair exercises in the form of games are used during the first year of instruction (initiation phase). Inventing "teaching games" proves to be very easy. A classical exercise can be transformed into a goal-oriented game by introducing practical tasks or aims and establishing rules to award victory.
In this case, however, the instructor must ensure the weakest pupil's gratification by playing with them. In this way, the group will improve more homogeneously, and pupils will not drop out through the inability to derive adequate benefit from the lessons' motor evolution.
The need to "camouflage" the exercises as games stems from the relative instability of attention span during childhood. Therefore, it is important not to demand concentration for unduly long periods but to exploit curiosity (interest in novelty) through suitable exercises variation.
At this age (6 years), play is a vital need and can promote learning.
The pupil will move gradually, from the phase of familiarization with the mat to the standing stage in the space of 6 to 8 months.
The initial techniques of Tachi Waza will then be learnt in 2-4 months. The schedule is thus as follows.
Initiation to Judo (1st year)
A) Familiarization with the mat (6-8 months) through gradual development (supine, prone, on all fours, kneeling on both knees, kneeling on one knee, crouching).
B) Familiarization with projections (2-4 months) through gradual development (from standing still, taking one step forward, in rectilinear movement, in lateral rectilinear movement, in a rotating motion, in free direction). After an initially passive period, Tori will come to guide the activity (tab. 1). The following five years are divided into two phases (basic preparation for pupils aged 8-10 and specialization for pupils aged 10-13). The technical program includes no fewer than 37 throwing techniques and 20 Ne Waza techniques, giving 57 techniques, not counting combinations. The method seeks to integrate the technical-classica1 Japanese education of technique mastery to absorb this substantial teaching and information load The well-known 6 phases (Tandoku renshyu, Sotai renshyu, Uchi komi, Yaku soku geiko, Kakari gheiko and Randori), with other details regarding directionality, kumi kata as a means of transferring energy. The biomechanical principles of the techniques and the more or less considerable importance of imbalance regarding the bio-mechanical group to which the technique belongs. The final phase of the program, which can rightly be described as competition preparation, involves
the careful and evolved study of several innovative concepts deriving from a biomechanical analysis, which can be labelled as follows;
1) Unified entry; 2) unified movement; 3) unified grip.

The intrinsic purpose of these concepts is that of providing pupils in the pre-competition phase with tools that can be developed into various techniques depending on the contingent "situation" produced in the closed bio-mechanical "pair of athletes" system.
This method for children, which is divided into the three phases of Initiation (for children aged 6 - 7), Basic Preparation (8 - 10) and Competition Preparation (11 - 13), presents various innovations and offers

pupils several advantages. During the 1st year, the initial activities on the ground and the focus on Ne Waza provide benefits in terms of "safety" concerning trauma:
1) The supporting musculature is free of improper tasks.
2) The complementary musculature enjoys general development and strengthening.
3) Pupils learn to overcome to fear of the "fall".
"Teaching games" are used to promote awareness of one's physical capacity - satisfy the desire for action - preserve the joy of learning - carry out technical instruction - carry out conditioning. Essential during this period is the specific introduction of Special Te Waza in kneeling on one knee position. These techniques ***Te Ouchi gari, Te uchi mata, Te ko uchi gari, Te o soto gari,*** sweeping uke's leg in kneeling position with the arm instead of own leg, made accessible not only the mechanical understanding of classical standing techniques but also are helpful and safe preparation for most of pick up used in real competitions

Initial programme on the ground	*Age for beginning judo courses*
6-7 years of age	*8-10 years of age*
1) Immobilisation	
2) Variants	
3) Methods of freeing oneself	
4) Overturning from prone and all-four position	
5) Attack from supine position	
6) Combat on the ground	
Standing	*Duration: 6 MONTHS*
7) Holds and shifts	
8) Rectilinear imbalances	
9) Fall-control techniques	
10) White-belt programme of throwing techniques with bilateral execution	
DURATION 1 YEAR /	
Initial training programme	

Tab 4.3.1.2.1.b, An Italian training program for children 1996

In the development of the Roku Kyo over the following years, the "open teaching" method seeks to give scope to the instructor's inventiveness and experience while ensuring the maximum respect for the pupil's character to combine the necessary growth of technical knowledge harmoniously with the total flexibility of application on the part of the pupil.
Time and application will make it possible to identify the less obvious limitations inherent in the method and the corrections required to ensure its adaptability to the ever-changing reality of a continually evolving sport such as judo.
After the first phase (half a year) on the ground, studying by ne waza games, this is pedagogical important to overcome the future fear of falling and to develop muscles without danger for the spine. The first interaction with standing techniques will be without grips because pupils naturally tend to tighten their arms. After some time, acquired the technical movement, it is possible to introduce grips in the lesson, without force, and after a just time with increasing strength. This is why de ashi barai is the first technique, and ko uchi barai is the second.

The Uke child is asked to crunch Tori, and Tori's foot rotates and sweeps with the other foot the advancing foot of Uke: first from outside (De Ashi) and after inside (Ko Uchi) rotation; and so on with the different techniques.
All the structure of the Italian pupils' progression is based on a biomechanical and pedagogical basis. Techniques are not sequential, and it is essential to teach each group whatever order because the important is the motor knowledge content in the whole group and not in each technique, each group is inter-connected to the increasing difficulties in motion, in weight charge for the skeleton, and in stress for the cardiovascular and respiratory system.

Roku Kyo - Standing and ground combat techniques *Traditional programme of instruction and development*	*Suggested duration: one year*
De ashi barai, Ko uchi barai, Tai otoshi, Eri seoi (with blocking), Sasae tsurikomi ashi, Hiza guruma, O soto otoshi (as blocking)	*Initial teaching programme 6-12 months* *White belt - pupils aged 6-8*
O uchi barai, Koshi guruma, Uki goshi, O goshi, Ippon seoi nage, Eri seoi nage	*Yellow belt - pupils aged 9-10*
Tsuri kumi goshi, Morote seoi nage, Osoto gari, Techniques of gari (O uchi, Ko uchi), Sode Tsuri komi goshi	*Orange belt - pupils aged 10-11*
Harai goshi, Uchi mata, Tani otoshi, Tomoe nage, Yoko Tomoe, Ushiro goshi Te guruma, Sukui nage	*Green belt - pupils aged 11-12*
Yoko guruma, Hane goshi, Tama guruma, Techniques of gakè (Ko uchi, O uchi, Ko soto, O soto), Okuri ashi barai	*Blue belt - pupils aged 12-13*
Harai tsurikomi ashi, Hikkomi gaeshi, Sumi gaeshi, Combinations and counter-techniques, shime waza, kanetsu waza, Bilateral repetition of programme	*Brown belt - pupils aged 13-15*
"Roku Kyo" modified for children	

Tab 4.3.1.2.1.c, An Italian training program for children 1996

In the last time, a considerable effort was made by EJU to unify the background of teaching methodologies utilizing the very advanced French experience for children with the definition of a European teacher, in connection to the National Federation and some European Universities, from France, England, Italy.

4.3.1.2.2 Adult area

Now all technical action didactic structures in judo for an adult are finalized to teach and ready the athlete to compete.
The classical Japanese technical training methodology (geiko) is a practical biomechanical approach to throwing dynamics. From this point of view, it is possible to state that this teaching method is firmans sound.
If we start analyzing the different exercises structured in the whole system, it is possible to recognize the increase in the teaching methodology's dynamical difficulty.
The primary technical drills and Skill Training are:

1. ***Tandoku renshyu*** (shadow training)
The athlete performs his attack in the void, envisaging the adversary's position.
This exercise can make more straightforward the technique of understanding, improving both speed and balance.
2. ***Sotai renshyu*** (free training without resistance)
It is the following step in technical training, during which both athletes help themselves better understand the main points of technical action utilizing a slow and soft attack and a driven fall without resistance if the attack is correct.
3. ***Uchi komi*** (to come into)
This is the first step of the dynamic training; understood the technical movement, Tori practices high succession and speed against a static Uke. This is the first step to understanding judo and getting into a habit of a couple of athlete's systems.
4. ***Yaku Soku Geiko*** (chance training)
Tori and Uke shift freely on the mat, and the entries are always soft. This step can let Tori understand the chance concept, improving technique and style, while Uke understands his grips' attack sensation. This kind of training could also be used in a specific prearranged stance to study particular situations.
5. ***Kakari Geiko*** (training with the opposition)
During this step, always in motion, Tori attack will be powerful, and Uke defence will be better. However, this Uke's defence will be not based on the solid opposition but timing and dodging.
As it is easy to understand, the Japanese methodology of technical training improves the Couple System's knowledge.
6. ***Randori*** (free fight)
It is the last step before the actual fight, there are no specific tasks, and both athletes are free to fight freely. During randori, every people must attack frequently and with sharpness, not being afraid to lose. The randori spirit is very different from the actual fight because it is always a study step about the couple systems' inner mechanics.
7. ***Shiai*** (real fight)
It is the actual fight, in which the only essential duty is to win, but it is also a challenging school in which everyone knows his physical and psychological limits and understands how to overcome them.

Generally, in Europe, it is utilized the ***Harre*** method to increase skill and coordination based on the following step:
To perform the technique in a difficult situation; to perform technique mirror-like; to perform the technique with a variety of speed and stance rhythm; linked techniques study; related counters; fights against an adversary with different weights; fights with a handicap.

Japan
The cognitive motor learning arrangements developed by Kano and co-workers called Go Kyo was built on the Cognitive Classification ground, in combination with some specific needs:

1. The degree of technical difficulties from more uncomplicated to difficult
2. The amplitude of Tori movements connected to the execution difficulty
3. Fall the difficulty of Uke connected to the throws.

This progression was reassessed, during the time, from the first 1893 to 1920 to the last 1967.
Different cognitive motor learning arrangements were produced for the High school judo 1974.
This fascinating method built by Mr Fujiwara 8° Dan Kodokan was the forerunner of the continuity method of Mr Geesink.
One old survey made in Japan in 1984 showed that Go Kyo was that time not used at all in the Japanese judo gym. But the training lessons were not unified or Kodokan connected. These five Principles (Go Kyo) to teach judo are not followed in the modern Japanese sports centre.

V Kyu	***IV Kyu***	***III Kyu***	***II Kyu***	***I Kyu***
Hiza guruma Tsuri komi ashi Uki goshi Tai otoshi De ashi harai Yoko otoshi O soto gari	Sumi kaeshi Ko soto gari O goshi Koshi guruma Seoi nage Tomoe nage Tani otoshi	Okuri ashi harai Harai goshi Ushiro goshi Ura nage Uchi mata Obi otoshi Hane goshi	Uki otoshi Uki waza Daki wakare Kata guruma Hikkomi gaeshi Tsuri goshi Soto makikomi Utsuri goshi O soto otoshi Tawara gaeshi	Yoko guruma Yoko wakare Uchi makikomi Ko uchi gari Ashi guruma Harai tsurikomi ashi Yama Arashi O soto guruma Yoko gake

Tab. 4.3.1.2.2 .a, (Kyu Go Kyo no Waza)Kodokan 1895

	V Kyu	***IV Kyu***	***III Kyu***	***II Kyu***	***I Kyu***
1	De ashi barai	Ko soto gari	Ko soto gake	Sumi gaeshi	O soto guruma
2	Hiza guruma	Ko uchi gari	Tsuri goshi	Tani otoshi	Uki waza
3	Sasae tsurikomi ashi	Koshi guruma	Yoko otoshi	Hane makikomi	Yoko wakare
4	Uki goshi	Tsurikomi goshi	Ashi guruma	Sukui nage	Yoko guruma
5	O soto gari	Okuri ashi barai	Hane goshi	Utsuri goshi	Ushiro goshi
6	O goshi	Tai otoshi	Harai tsurikomi goshi	O guruma	Ura nage
7	O uchi gari	Harai goshi	Tomoe nage	Soto makikomi	Sumi otoshi
8	Seoi nage	Uchi mata	Kata guruma	Uki otoshi	Yoko gake

Tab. 4.3.1.2.2 .b,(Shin Go Kyo no Waza) Kodokan 1920

	I Kyu	***II Kyu***	***III Kyu***	***IV Kyu***	***V Kyu***
1	De ashi barai	Ko uchi gari	Uchi Mata	Yoko guruma	Ura nage
2	Hiza guruma	Koshi guruma	Hane goshi	Osoto Guruma	Sumi otoshi
3	Uki goshi	Ko soto gari	Hanemakigoshi	Uki otoshi	Yoko wakare
4	Sasae tsurikomi ashi	O goshi	Harai Tsurikomiashi	Utsushi goshi	Oguruma
5	O soto gari	Seoi Nage	Tomoe nage	Uki Waza	Okuri Ashi Barai
6	Tsurigoshi	O Uchi Gari	Sukui Nage	Taniotoshi	Sumigaeshi
7	Taiotoshi	Ko Soto Gake	Ashi Guruma	Yoko Otoshi	Kata Guruma
8	Tsurikomigoshi	Haraigoshi	Ushirogoshi	Yoko Gake	Sotomakikomi

Tab.4.3.1.2.2.c Five Principles (Go Kyo) from Kyuzo Mifune 1956

VI Kyu -V Kyu	***IV Kyu***	***III Kyu***	***II Kyu***	***I Kyu***
withe-yellow	**orange**	**green**	**blue**	**brown**
Nage waza	**Nage waza**	**Nage waza**	**Nage waza**	**Nage waza**
De ashi barai	O goshi	Tsuri komi goshi	Ko soto gake	Yoko otoshi
Hiza guruma	O uchi gari	Okuri ashi barai	Ashi guruma	Hane makikomi
Sasae tsurikomi ashi	Seoi nage (ippon morote)	Tai otoshi	Harai tsurikomi ashi	Utsuri goshi
Uki goshi	Ko soto gari	Harai goshi	Hane goshi	O guruma
O soto gari	Ko uchi gari	Uchi mata	Tomoe nage	Soto makikomi
Basics of judo	Koshi guruma		Kata guruma	Ushiro goshi
Katame waza	**Katame waza**	**Katame waza**	**Katame waza**	**Katame waza**
Hon kesa gatame	Yoko Shiho gatame	Basic shime waza	Hadake jime group	Renraku waza
Kuzure gesa gatame	Kuzure yoko shiho gatame	Kata juji jime	Kata ha jime group	Kaeshi waza
	Kami Shiho gatame	Nami juji jime	Kata te jime group	
Makura gesa gatame	Kuzure kami shiho gatame	Okuri Eri groups	Morote jime group	Kuzure tachi waza
Ushiro gesa gatame	Tate Shiho gatame	Basic kansetsu	Ashi gatame group	Shiai
Kata gatame	Kuzure tate shiho gatame	Ude garami group	Waki gatame group	Renroku-renraku waza
		Juji gatame group	Hara gatame group	Kaeshi waza
Ukemi		Ude gatame group		
Kumi kata	Harairi kata	Hiza gatame group	Nage no kata	Nage no kata
Tsukuri kuzushi			Te waza	All series
Kake			Koshi waza	
Shintai		Shiai	Ashi waza	

Tab. 4.3.1.2.2 .d, Technical Program for teaching, Kodokan 1967

	1	2	3	4	5	6	7	8	9	10
Te waza	Seoi nage (704)	Tai otoshi (416)	Ippon seoi nage (126)	Kata guruma (75)	Uki otoshi (70)	Sukui nage (9)	Morote gari (8)	Seoi otoshi (3)	Sumi otoshi (2)	Hiki otoshi (1)
Koshi waza	Harai goshi (546)	O goshi (352)	Tsurikomi goshi (331)	Uki goshi (215)	Hane goshi (143)	Utsuri goshi (26)	Koshi guruma (17)	Tsuri goshi (5)	Koshi nage (3)	Ushiro goshi (2)
Ashi waza	O soto gari (498)	O uchi gari (452)	Ko uchi gari (345)	Okuri ashi barai (266)	Sasae tsurikomi ashi (247)	Uchi mata (213)	De ashi harai (195)	Hiza guruma (178)	Ashi harai (90)	Kosoto gari (42)
Katame waza	Kesagatame (702)	Kami shiho gatame (572)	Yoko shiho gatame (556)	Kata gatame (251)	Tate shiho gatame (147)	Juji gatame (10)	Ude garami (1)			

Tab. 4.3.1.2.2 .e, Japan technical teaching frequency in Gym (1984)

France

French country is after Japan the most important judo country, his federal organization is well known in the word, and the judo sport in this country is as participants' number into the first three places in this country with more than 5 million of participants in 2003.

Much work was devoted to children development, but elite judo is under continuous evolution (see all the French scientific studies and application in this book).

About adults, the cognitive-motor learning arrangements were developed at first by Mr Kawaishi, who assembled 61 techniques in a progression connected to the increasing Tori movement as space and difficulty of execution its classification clashes with its teaching arrangement

Today the era Kawaishi is historical memory. The FFJDA made a new Roku Kyo (6 lessons) at the national level, grounded on the following pedagogical principles.

1. ***Physical –Educational value of some basic motor learning as specific balances, potential motion combination, etc.***

2. ***Easier and less dangerous executions.***

3. ***Athletes' psychological development.***

This teaching arrangement retains the classical Japanese nomenclature with a further reorganization and the ne-waza progressive study.

Ashi Waza	***Koshi Waza***	***Kata Waza***	***Te Waza***	***Sutemi Waza***
O soto gari	*Uki goshi*	*Kata seoi*	*Tai otoshi*	*Tomoe nage*
De ashi barai	*Kubi nage*	*Seoi nage*	*Uki goshi*	*Yoko tomoe*
Hiza guruma	*Tsuri goshi*	*Kata guruma*	*Kuki nage*	*Maki tomoe*
Ko soto gake	*Koshi guruma*	*Seoi otoshi*	*Hizi otoshi*	*Makkomi*
Ouchi gari	*Harai goshi*	*Hidari kata seoi*	*Sukui nage*	*Yoko gake*
Ko uchi gari	*Hane goshi*	*Seoi age*	*Mochiage otoshi*	*Tani otoshi*
Okuri ashi barai	*Ushiro goshi*		*Sumi otoshi obi otoshi*	*Sumi gaeshi*
Osoto guruma	*Tsuri komi goshi*			*Uki waza*
Osoto otoshi	*Utsuri goshi*		*Kata ashi dori*	*Kani basami*
Ko soto gari	*Uchi mata*		*Rio ashi dori*	*Yoko otoshi*
Sasae tsurikomi ashi	*O goshi*			*Hane makikomi*
	Ko tsuri goshi			*Ura nage*
Harai tsurikomi ashi	*Guruma*			*Yoko guruma*
	Yama Arashi			*Yoko wakare*
Soto gake	*Obi goshi*			*Tawara gaeshi*
Ko uchi makikomi				
Ashi guruma				

Tab 4.3.1.2.2 .f, Kawaishi Teaching arrangement 1964

VI Kyu	***Nage Waza*** *O goshi* *Ippon seoi nage* *O soto gari* *De ashi barai* *Hiza guruma* *Uki goshi* ***Katame Waza*** *Hon kesa gatame* *Yoko Shiho gatame* *Ushiro gesa gatame* *Kami Shiho gatame* *Tate Shiho gatame*	III Kyu	***Nage Waza*** *Kata guruma* *Tomoe nage* *Ko soto gake* *Uki otoshi* *Ashi guruma* ***Shime Waza*** *Kata juji jime* *Okuri eri jime* *Gyaku juji jime* *Kata ha jime* *Nami juji jime* *Sode guruma* *Morote juji jime* *Ashi gatame* *Hadaka jime* *Kata te jime*
V Kyu	***Nage Waza*** *Tsuri komi goshi* *Sode tsurikomi goshi* *Harai goshi* *Morote seoi nage* *Sasae tsurikomi ashi* *Ko uchi gari* *O uchi gari* ***Katame Waza*** *Kata gatame* *Kuzure kesa gatame* *Kuzure yoko shiho gatame* *Makura gesa gatame* *Kuzure kami shiho gatame* *Kuzure tate shiho gatame*	II Kyu	***Nage Waza*** *O guruma* *O soto otoshi* *O soto makikomi* *Harai tsurikomi ashi* *Uki waza* ***Kansetsu Waza*** *Ude garami* *Juji gatame* *Ude gatame* *Hiza gatame* *Waki gatame* *Hara gatame*
IV Kyu	***Nage Waza*** *Tai otoshi* *Okuri ashi barai* *Koshi guruma* *Uchi mata* *Ko soto gari* ***Katame Waza*** *Kuzure yoko shiho gatame bis* *Kuzure makura gesa gatame* *Kuzure kami shiho gatame* *Kuzure tate shiho gatame*	I Kyu	***Nage Waza*** *Yoko otoshi* *Utsuri goshi* *Yoko guruma* *Ushiro goshi* *Te guruma* ***Ne Waza*** ***Shiai***

Tab. 4.3.1.2.2.g, French Teaching arrangements (Roku Kyo)

For the dan degree, the French federation FFJDA utilises the nomenclature accepted by the International Judo federation IJF shown in the following table.

Koshi waza	***Te waza***	***Ashi waza***	***Sutemi waza***
			Ma sutemi waza
Hane goshi	*Ippon seoi nage*	*Ashi guruma*	
Harai goshi	*Kata guruma*	*De ashi barai (harai)*	*Hkkikomi gaeshi*
Koshi guruma	*Kibisu gaeshi*	*Hane goshi gaeshi*	*Sumi gaeshi*
O goshi	*Kuchiki taoshi*	*Harai tsurikomi goshi*	*Tawara gaeshi*
Sode tsurikomi goshi	*Morote gari*	*Hiza guruma*	*Tomoe nage*
Tsuri goshi	*Obi otoshi*	*Ko soto gake*	*Ura nage*
Tsurikomi goshi	*Obitori gaeshi*	*Ko soto gari*	
Uchi mata	*Seoi nage*	*Ko uchi gaeshi*	
Ushiro goshi	*Morote seoi nage*	*Ko uchi gari*	***Yoko sutemi waza***
Utsuri goshi	*Seoi otoshi*	*O guruma*	
	Sukui nage	*Okuri ashi barai (harai)*	*Daki wakare*
	Sumi otoshi	*O soto gaeshi*	*Hane makikomi*
	Tai otoshi	*O soto guruma*	*Harai makikomi*
	Te guruma	*O soto otoshi*	*Ko uchi makikomi*
	Uchi mata sukashi	*O uchi gaeshi*	*O soto makikomi*
	Uki otoshi	*O uchi gari*	*Soto makikomi*
	Yama Arashi	*Sasae tsurikomi ashi*	*Tani otoshi*
		Tsubame gaeshi	*Uchi makikomi*
		Uchi mata	*Uchi mata makikomi*
		Uchi mata gaeshi	*Uki waza*
			Yoko gake
			Yoko guruma
			Yoko otoshi
			Yoko tomoe nage
			Yoko wakare
Osaekomi waza	***Shime waza***	***Kansetsu waza***	
Hon kesa gatame	*Ashi gatame jime*	*Ude hishigi ashi gatame*	
Kami Shiho gatame	*Gyaku juji jime*	*Ude hishigi hara gatame*	
Kata gatame	*Hadake jime*	*Ude hishigi hiza gatame*	
Kesa gatame	*Kata ha jime*	*Ude hishigi juji gatame*	
Kuzure gesa gatame	*Kata juji jime*	*Ude hishigi sankaku gatame*	
Kuzure kami shiho gatame	*Morote jime*	*Ude hishigi t e gatame*	
Kuzure kesa gatame	*Nami juji jime*	*Ude hishigi ude gatame*	
Kuzure tate shiho gatame	*Okuri Eri jime*	*Ude hishigi waki gatame*	
Kuzure yoko shiho gatame	*Ryo te jime*	*Ude garami*	
Tate Shiho gatame	*Sankaku jime*		
Ushiro kesa gatame	*Sode guruma jime*		
Yoko Shiho gatame	*Tsukkomi jime*		

Tab 4.3.1.2.2.g, IJF technical Nomenclature FFJDA: dan program.

England

Mr Koizumi, the British judo father, made a very original effort in the cognitive, technical classification. However, his step in the motor learning arrangement was not original. Until 1960, the British progression was very similar to Go kyo with the extension like Kawaishi method to six teaching levels.

Most original was the effort made by Gleeson in the field of cognitive classification, also from the fighting point of view, but in 1985 the didactic structure adopted in England was very far from Japanese and French one's the kyu number (for children) was 9 with 24 techniques, but for the first Dan the program was around 40 techniques ordered by sequential logic

.

9 kyu	***8 kyu***	***7 kyu***	***6 kyu***	***5 kyu***	***4 kyu***	***3 kyu***	***2 kyu***	***1 kyu***
Tai otoshi Ouchi gari	*Morote seoi nage Osoto gari*	*Ippon seoi nage Kosoto gari*	*Harai goshi Kosoto gari*	*Uchi mata Ko soto gake*	*De ashi barai Sumi gaeshi Sasae tsurikomi ashi*	*Okuri ashi barai Harai tsurikomi ashi Yoko guruma*	*Hiza guruma Makikomi Tani otoshi*	*Yama Arashi O guruma Ashi guruma*
Yoko Shiho gatame	*Kuzure yoko Shiho*	*Kami Shiho gatame Kuzure kami Shiho Juji gatame*	*Kesa gatame Okuri Eri jime*	*Kuzure kesa Ude garami*	*Tate Shiho Kuzure Tate Shiho*	*Kata gatame Juji jime*	*Mune gatame Waki gatame ushiro kesa*	*Makura kesa Sankaku gatame Ashi gatame Hiza gatame*

Tab. 4.3.1.2.2 .h, British Kyu Syllabus (1985)

Tachi waza				
O goshi Uki goshi Tsuri goshi Tsurikomi goshi Tai otoshi Ippon seoi nage Morote seoi nage Seoi otoshi	*Ashi guruma O guruma Harai goshi Hane goshi Uchi mata Harai makikomi Hane makikomi Soto makikomi*	*O soto gari Ko soto gari O uchi gari Ko uchi gari O uchi gake Ko soto gake O soto guruma Morote gari*	*De ashi barai Okuri ashi barai Sasae tsurikomi ashi Harai tsurikomi ashi Tsurikomim ashi Hiza guruma Uki otoshi Tomoe nage Sumi gaeshi*	*Kata guruma Koshi guruma Yama Arashi Tani otoshi Yoko otoshi Yoko wakare Yoko gake Uki waza*

Tab. 4.3.1.2.2.i. British Dan technical throwing knowledge (1985)

In modern times BJA revised all the British judo technical teaching organizations profoundly.

The most critical revolution grounded on the pragmatic English vision was introducing the technical motor learning arrangements of many new techniques coming from the Russian style.

The acceptance of these particular techniques does not consider in Kodokan classification (and in other any category as possible to see in the previous paragraph) but still present and applied at a high international level was the pragmatic and obvious recognition of the agonistic judo evolution.
If judo changes, for a logical consequence, teaching matter must change and broaden at all teaching levels.
This is the reason for which both Kyu and Dan knowledge organizations were broadened.
The significant improvements in the modern British kyu arrangement were the come back to the "six classical" lessons like Roku Kyo but with different contents, the increase in throws number, from 21 to 41 and the introduction of several modern throwing techniques, from Russian Style.
In the Dan Syllabus, this Cultural Revolution was connected with introducing the Kokusai Shiai Waza group, a collection of 25 modern techniques Japanese named by Mr Roy Inman and presented at IJF in 2007.
In modern times the English judo school is the only country that has improved judo technical knowledge at every level, from proficient to master.

6 kyu	***5 kyu***	***4 kyu***	***3 kyu***	***2 kyu***	***1 kyu***
O soto otoshi *De ashi barai* *Uki goshi*	*Tai otoshi* *Ippon seoi nage* *O uchi gari*	*Tsurikomi goshi* *O goshi* *Seoi otoshi* *Moroteseoi nage* *O soto gari* *Ko uchi gari* *Ko soto gake* *Ko soto gari*	*Harai goshi* *Uchi mata* *Sasae tsurikomi ashi* *Hane goshi* *Okuri ashi barai* *Morote eri seoi nage*	*Koshi guruma* *Tani otoshi* *Yoko guruma* *Tomoe nage* *Kata uchi ashi dori* *Soto kibisu gaeshi* *Kata guruma* *Morote gari* *Soto ashi dori ouchi gari* *Uchi kibisu gaeshi*	*Sode tsurikomi goshi* *Te guruma* *Ryo hiza seoi otoshi* *Sumi gaeshi* *Yoko gake* *Ko uchi gake mata makikomi* *Ushiro goshi* *Ura nage* *Uki otoshi* *Soto makikomi* *Yoko tomoe* *Kata hiza te ouchi gake ashi dori*
Kesa gatame *Mune gatame* *Kuzure kesa gatame*	*Tate Shiho gatame* *Yoko Shiho gatame* *Kami Shiho gatame*		*Ude gatame* *Waki gatame* *Jjuji gatame*	*Okuri eri jime* *Nami juji jime* *Gyaku juji jime* *Ude garami*	*Kata ha jime* *Hadaka jime* *Kata te ashi koshi jime* *Sangaku jime*

Tab. 4.3.1.2.2 .j, British Roku Kyo Syllabus (2005)

1st SET	*2nd SET*	*3rd SET*	*4th SET*	*5th SET*
Nage waza				
O goshi *Uki goshi* *Tsuri goshi* *Tsurikomi goshi* *Tai otoshi* *Ippon seoi nage* *Morote seoi nage* *Seoi otoshi*	*Ashi waza* *O guruma* *Harai goshi* *Hane goshi* *Uchi mata* *Harai makikomi* *Hane makikomi* *Soto makikomi*	*O soto gari* *Ko soto gari* *O uchi gari* *Ko uchi gari* *O uchi gake* *Ko soto gake* *Ko soto guruma* *Morote gari*	*De ashi barai* *Okuri ashi barai* *Sasae tsurikomi ashi* *Harai tsurikomi ashi* *Hiza guruma* *Uki otoshi* *Tomoe nage* *Sumi gaeshi*	*Kata guruma* *Koshi guruma* *Yama Arashi* *Tani otoshi* *Yoko otoshi* *Yoko wakare* *Yoko gake* *Uki waza*
Ne waza				
Hon kesa gatame *Kuzure kesa gatame* *Ushiro kesa gatame* *Makura kesa gatame* *Mune gatame* *Kata gatame*	*Hon kami shiho gatame* *Kuzure kami shiho gatame* *Hon yoko shiho gatame* *Kuzura yoko shiho gatame* *Hon tate shiho gatame* *Kuzure tate shiho gatame*	*Nami juji jime* *Gyaku juji jime* *Kata juji jime* *Tsukkomi jime* *Ryo te jime*	*Hadake jime* *Okuri eri jime* *Kata ha jime* *Sode guruma jime* *Koshi jime*	*Ude garami* *Juji gatame* *Ude gatame* *Hiza gatame* *Waki gatame*
Kokusai Shiai Waza				
Daki ko soto gaeshi *Soto kibisu gaeshi* *Uchi kibisu gaeshi* *Ryo hiza seoi otoshi* *Kata hiza tai otoshi*	*Morote eri seoi nage* *Kata soto ashi dori* *Kata uchi ashi dori* *Ryo ashi tomoe nage* *Kata hiza te ouchi gake ashi dori*	*Yoko tomoe nage* *Kata sode ashi tsurikomi goshi* *Soto mata seoi otoshi* *Ko uchi gake mata makikomi* *Kata eri sode tsurikomi goshi*	*Ushiro hiza ura nage* *Hiza soto muso* *Yoko kata guruma otoshi* *Mae hiza uranage* *Ryo hiza kata guruma*	*Morote kata tai otoshi* *Ashi Hara gatame* *Katate ashi koshi jime* *Soto ashi dori ouchi gari* *Kata sode seoi otoshi*

Tab. 4.3.1.2.2.k, British Dan Syllabus (2008)

Holland

The only original but today historic contribution to motor learning arrangments, to the author's knowledge, was organized in Holland by Mr Geesink but never adopted at the national level in this country. To understand the content refers to the Geesink Cognitive Classification

Initial phase Ne Waza, way to hold, ne-waza exercises, responsibility Tori vs Uke	Tachi waza action with an action arm
Kesa gatame group, lighter vs heavier Heavier vs lighter	Tachi waza group with action leg
Ne waza group with play arm	Barai group
Hishigi group	Gari group
Garami group	Renraku waza group
Shime waza group juji jime eri jime	Gonosen group
Tachi waza, responsibility Tori vs Uke, ukemi waza, shisei,	Nage no Kata

Tab. 4.3.1.2.2.l, Teaching motor learning arrangement Geesink (1967)

Australia

Also, in the far EST, judo is structured like Kodokan, but for Kyu with the increasing number and not decreasing like Japan.

The teaching arrangement is organized in five lessons Go Kyo with the following program in which there are shown only throws, to which must be added the same osae waza, shimewaza and kansetsu waza from Kodokan.

1 kyu	***2 kyu***	***3 kyu***	***4 kyu***	***5 kyu***
De Ashi Harai	*Ko Soto Gari*	*Ko Soto Gake*	*Sumi Gaeshi*	*O Soto Guruma*
Hiza Guruma	*Ko Ouchi Gari*	*Tsuri Goshi*	*Tani Otoshi*	*Uki Waza*
Sasae Tsurikomi Ashi	*Koshi Guruma*	*Yoko Otoshi*	*Hane Makikomi*	*Yoko Wakare*
Uki Goshi	*Tsurikomi Goshi*	*Ashi Guruma*	*Sukui Nage*	*Yoko Guruma*
O Soto Gari	*Okuri Ashi Harai*	*Hane Goshi*	*Utsuri Goshi*	*Ushiro Goshi*
O Goshi	*Tai Otoshi*	*Harai Tsuri Komi Ashi*	*O Guruma*	*Ura Nage*
O Ouchi Gari	*Harai Goshi*	*Tomoe Nage*	*Soto Makikomi*	*Sumi Otoshi*
Seoi Nage	*Uchi Mata*	*Kata Guruma*	*Uki Otoshi*	*Yoko Gake*

Tab. 4.3.1.2.2 .m, Australia Go Kyo grading

For the Dan grading evaluation in Australia, the candidate must be able to execute some additional techniques, in addition to Go Kyo waza, the Shimmeisho waza.

The Shimmeisho No Waza is made up of an additional 17 throws recognised by the Kodokan. These throws are in addition to the variations (Kuzure like Eri seoi or morote seoi) of those throws currently recognised within the Go Kyo No Waza.

Te waza	*Koshi waza*	*Ashi waza*	*Yoko sutemi waza*	*Shimmeisho no waza*
Morote Gari	*Dakiage*	*Tsubame Gaeshi*	*O Soto Makikomi*	*Seoi Otoshi*
Kuchiki Taoshi		*O Soto Gaeshi*	*Uchi Mata Makikomi*	*Obi Otoshi*
Kibusi Gaeshi		*O Ouchi Gaeshi*	*Harai Makikomi*	*Kouchi Gaeshi*
Uchi Mata Sukashi		*Ko Ouchi Gaeshi*		*Yama Arashi*
		Harai Goshi Gaeshi		*Sode Tsuri Komi Goshi*
		Hane Goshi Gaeshi		*O Soto Otoshi*
		Uchi Mata Gaeshi		*Ken Ken Uchi Mata*
				Hikkomi Gaeshi
				Tawara Gaeshi
				Daki Wakare
				Ichi Makikomi

Tab. 4.3.1.2.2 .n, Dan Grading Australia.(2006)

Canada

This country shows an exciting and advanced course for coaching divided into three levels. As remembered in the classifications.
The teaching methodology Roku kyo is similar to the classical Japanese in six Kyu.
Different is the program requested for the dan grading.

Te waza	*Koshi waza*	*Ashi waza*	*sutemi waza*	*Shimmeisho no waza*
Tai otoshi	*Uki goshi*	*Hiza guruma*	***Ma sutemi waza***	*Morote gari*
Seoi nage *Ippon seoi nage*	*Tsurkomii goshi* *Sodetsurikomi goshi*	*O uchi gari*	*Tomoe nage* *Ura nage*	*Kuchiki daoshi* *Kibisu gaeshi* *Uchi mata sukashi*
Kata guruma	*Harai goshi*	*O soto gari*	*Sumi gaeshi*	*Dakiage*
Uki otoshi	*Hane goshi*	*Sasae tsurikomi ashi*	*Hikkikomi gaeshi*	*Tsubame gaeshi*
Sumi otoshi	*O goshi*	*Harai tsurikomi ashi*	*Tawara gaeshi*	*O soto gaeshi*
Sukui nage	*Ushiro goshi*	*Okuri ashi harai*	***Yoko sutemi waza***	*O ouchi gaeshi*
Obi otoshi	*Tsuri goshi* *Ko tsuri goshi* *O tsuri goshi*	*De ashi harai*	*Uki waza* *Yoko gake* *Yoko guruma*	*Ko Ouchi Gaeshi*
Seoi otoshi	*Utsuri goshi*	*Ko uchi gari*	*Tani otoshi*	*Hane goshi gaeshi*
Yama Arashi	*Koshi guruma*	*Ko soto gari*	*Yoko wakare*	*Harai goshi gaeshi*
		Ko soto gake	*Yoko otoshi*	*Uchi Mata Gaeshi*
		Ashi guruma	*Hane makikomi*	*Obi tori gaeshi*
		Uchi mata	*Soto makikomi*	*O soto makikomi*
		O guruma	*Uchi makikomi*	*Uchi mata makikomi*
		O soto guruma		*Harai makikomi*
		Osoto otoshi		*Daki wakare*

Tab. 4.3.1.2.2 .o, Canada Dan Syllabus (2006)

Spain
Spanish Federation (Real Federacion Espagnola), with a well-developed Federation and many people at a very high level among coaching, researchers and athletes present a more classical program for the Dan grading; however, this program is now under revision, but the new program is not yet proposed, till now.

1st dan	***2nd dan***	***3rd dan***	***4th dan***	***5th dan***
Nage waza				
De ashi harai Hiza guruma Okuri ashi harai Sasae tsurikomi ashi Uchi Mata O soto gari O uchi Uki goshi Harai goshi Tsurikomigoshi Uki otoshi Tai otoshi Seoi nage Kata guruma	*Ko uchi gari Ko soto gari Ko soto gake Ashi guruma Koshi guruma Tsuri goshi Hane goshi Tomoe nage Ura nage Sumi gaeshi Yoko gake Yoko guruma Uki waza*	*Harai tsurikomi ashi O soto otoshi O guruma Ushirogoshi Utsuri goshi Seoi otoshi Sukui nage Kuchiki Taoshi Morote gari Sotomakikomi Uchimakikomi Yoko otoshi Tani otoshi*	*O soto guruma O soto gaeshi O uchi gaeshi Ko uchi gaeshi Sumi otoshi Kibisu gaeshi O soto makikomi Uchi Mata makikomi Hane makikomi Harai makikomi Tawara gaeshi*	*Hane goshi gaeshi Harai goshi gaeshi Uchimata gaeshi Tsubame gaeshi Yama Arashi Uchimata sukashi Obi otoshi Yoko wakare Daki Wakare Hikkomi gaeshi*
Ne waza				
Hon kesa gatame Yoko Shiho gatame Tate Shiho gatame Kami Shiho gatame Kata juji jime Gyaku juji jime Nami juji jime Hadaka jime Ude garami Ude hishigi juji gatame	*Kuzurekesa gatame Kata gatame Kuzure kami Shiho Okuri eri jime Kata ha jime Ude hishigi ude gatame Ude hishigi waki gatame*	*Ryote jime Tsukkomi jime Ude hishigi hiza Udehishigi hara*	*Kata te jime Sode guruma jime Ude hishigi sankaku gatame*	*Sankaku jime Ude hishigi ashi gatame Ude hishigi te gatame*

Tab. 4.3.1.2.2 .p, Spanish Dan Syllabus (2016)

Tips for Teachers
Teachers in e can facet many different situations. Optimization of judo helps the minimum degree of information that a teacher or a coach can give to his students or athletes to provide the correct information and a sufficient level of judo knowledge.
As seen in the first chapter, Judo is a dual situation sport, and its optimization is very complicated, but the best way both for coaches and teachers is to apply qualitative biomechanics with the help of Kano taught.
Qualitative Biomechanics helps find the right way to teach, dividing the judo situation into two main areas: club and competition.
It is easy to understand that teaching in a club is a ***Static*** situation organized to teach students to apply Judo techniques step by step from **static** to **dynamic** conditions.
Teaching in club amateur judo students is grounded on the Kano suitable methodology.
The main goal is to apply movements that save energy, and all judo techniques are energy-saving if used in the right way.
If we speak of athletes at the National and International Level levels, the goal is not energy-saving, but maximum effectiveness is the right way to win.
On these bases, it is possible to state the minimum right tools to apply in a club to train amateur students or athletes competing at National Level up to high-performance championships.

Tools for a Basic Club Training Methodology
For Conditioning Normal Judo Gymnastic
As Technical Training Classical Japanese Training Six Steps Sequence :
1) Tandoku Renshyu (shadow training)
2) Sotay Renshyu (free training without Uke’s resistance)
3) Uchi Komi (to come into)
4) Yaku Soku Geiko (Chance Training)
5) Kakari Geiko (Training with Uke’s opposition)
6) Randori (free fight without a winner)

Tools for a Basic National Level Methodology
For Conditioning Linear training with correct Periodization or Block Periodization
As Technical Preparation: Deep study of “Breaking Symmetry” in competition,
High specialization study of 1 or 2 Throws in various: “Fighting Situation”, Speed and Grips.
Classic Ne Waza,

Tools for High-Level Athletes
For Conditioning Non-Linear (undulating) training periodization and customized-specific training planning solution, it speeds up reflexes by visual training, Active Recovery, Increasing Attentiveness, etc.
As Technical Preparation “Useful” Grip fighting, Effective Connected throws (forward-backwards combinations), Study of useful complementary tools, Tokui Waza implementation/Variation, standing to lay connection, Ne Waza specialization, New Throws Construction, etc**.**
Psychological Strengthening
Match Analysis Deep Adversary scouting and constant analysis of own mistakes.

In this field is interesting the French Judo Federation's effort to integrate and connect the necessities of high-level judokas with the needs of young judokas, presented in Porec by Patric Roux and Baudry.
The approach is based on a similar experience take from Rugby (Lambertin) for one integrated physical and technical training.

The French Judo Federation built and developed a specific circuit training based on fundamental technical skills and variability.
This means that classical Japanese training steps were arranged in circuit training: tandoku renhsu, uchi komi & nage komi, kakari geiko & yaku soku geiko, randori, organized in circuits and alternated with simple physical exercises were utilized for integrated physical, technical training at each level.

Fig .4. 3.1.2.1. f.g.h Example of Integrated physical, technical training.

Another essential tool to discriminate the practice among young, National level athletes and High-Performance level in the French method is (in accord with the previous information on the ondulating methods) is the number of tasks and the order of tasks.

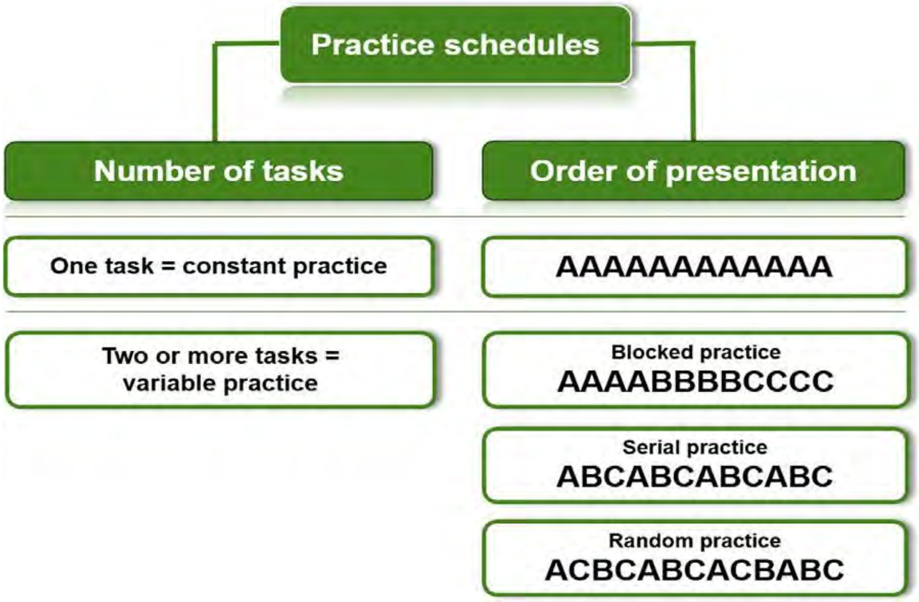


Fig .4. 3.1.2.1. i. Integrated physical, technical training order of tasks increasing the difficulty

But what kind of acquisition capability is connected to these different arrangements of tasks? It is interesting that from the simple to the complex one (from young to high athletes), this kind of training always lose plus the acquisition capability changing in one complex technical training, able to train diversification beneficial for high-level athletes, as shown in the following figure

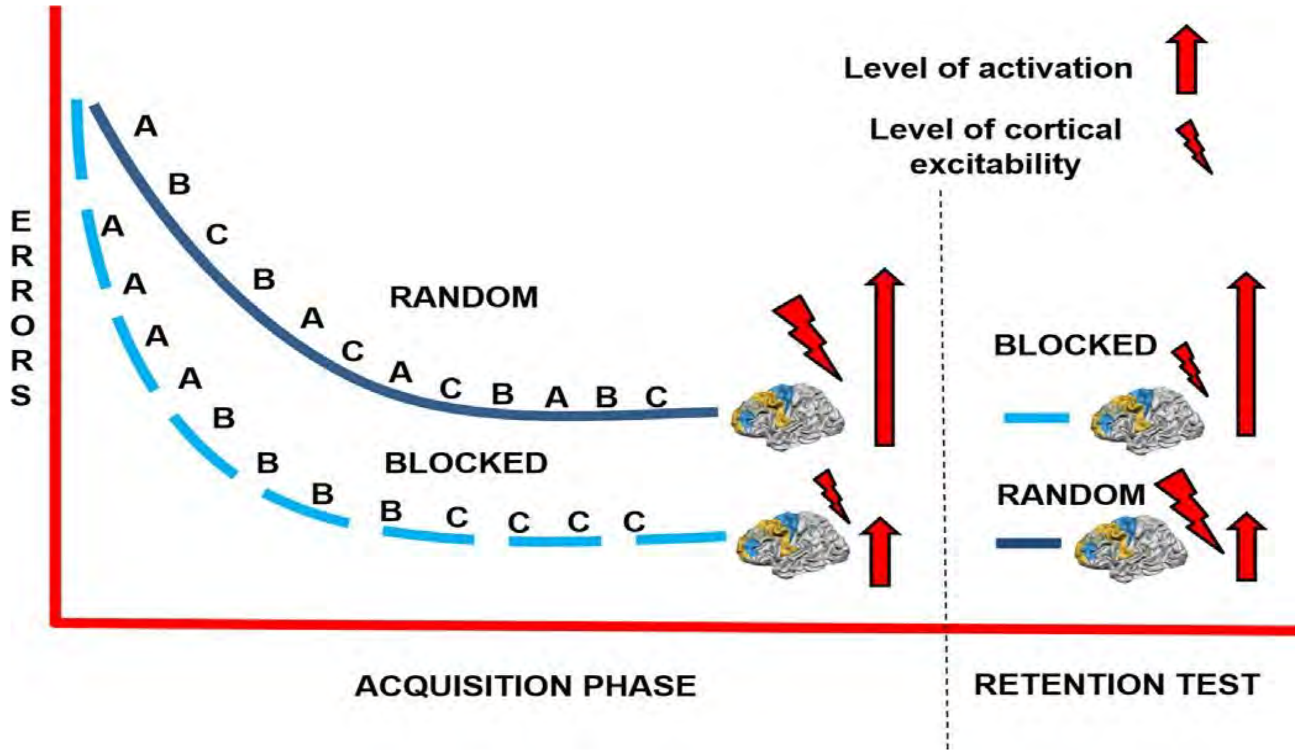


Fig .4. 3.1.2.1. i. Integrated physical, technical training order of tasks acquisition and retention (Lage et al. 2015)

4.3.2 Technical teaching methods for elite athletes' modern biomechanical approach

Pedagogy deals with the study of **teaching methods**, including education aims and how such goals may be achieved.
The teaching methodologies that a teacher chooses to use should be following the following teaching 'objectives'

- **Knowledge** refers to the cognitive domain.
- To know = pure theoretical knowledge of throwing
- To Know how = the application of the right movements to throw.
- **Attitudes** refer to the affective domain that includes 'learner's values, beliefs, biases, emotions, and role expectations that may influence competitions' management.
- **Skills** are the actual abilities to put the specific motor knowledge of throwing into practice (performance)**.**
- Show how = demonstrate the ability to use specific throwing or adopt particular attitudes to obtain an excellent position to throw in competition
- Do = demonstrate in their fight that they have acquired an excellent throwing capability

The teaching methodology approach based on biomechanics is grounded on the same pedagogical principles but different in content. It is full of in-depth advanced information, mainly about throwing techniques and their connection or execution. It is possible to understand that a proficient agonist is excellent and sufficient for the Go Kyo. But for advanced or elite athletes is better to specialize based on biomechanics. The information is given with a more complex methodology, progressive pedagogically, usually not sequential as the Go Kyo but more flexible and adaptable to athletes' different necessities. The paramount vantage obtained by Biomechanics is to single out most of the inner knowledge presents in judo. For example, Throwing's Biomechanical analysis has already shown us that all judo throwing is based on only two Physics Principles and applied by two tools.

1. The couple of forces
2. The lever

Or that Uchi Mata is the same Tori movement as O Soto Gari. While Khabarelli is the opposite Tori movement in the same sagittal symmetry plane (Gyaku Uchi Mata). This capability to summarise the problem from a more organic point of view lets us understand the better and useful information that can be achieved from Biomechanics to build an advanced technical teaching method. It is possible to approach the problem from two points of view: Experimental and Theoretical; in the following, we can give two exempla of these approaches.

- ***Experimental***

Today, in our knowledge, there is the French team of sport gesture mechanics at Poitiers University, the most advanced in experimental biomechanical studies on judo techniques.
This team works hard to build up a new technical progression or teaching methodology grounded on their laboratory's biomechanical knowledge. Some papers presented at eight JORRESCAM 2006 (Journee de Reflexion et de recherché sur le Sports de Combat et les Arts Martiaux) show their approach's background.

The connected utilization of Saga technology, 3D camera, and force platforms can give complete Kinetic and Kinematic information on throwing techniques' complex motion.
During these experiences, the interaction forces were analysed into the Couple of Athletes Systems and singled out the common essential elements of the Rational Sportive, Throwing Techniques. (See: Action Invariants 8.2 and Biomechanics 5.2.1).
Evaluating the articular efforts produced by muscles acting the motion focalises the attention both on specific muscular preparation and on articular safety as prevention of accidents.
The results confirmed the well know biomechanics theorem or the ***"Motion through the kinetic chains theorem***" (see also the Grips Paradox), which states:
"Every motion or action is connected to force/energy transfer from soil to legs, through waist and trunk from arms to hands." or, in scientific words, starting from soil: "from distal to proximal by waist and trunk from proximal to distal".
The importance of kinetic chains, both inferiors and superiors, and their optimized correlation by "core" is the basis of an excellent technical movement.
The other important finding was the exact step by step analysis of first legs and waist rotation and after the trunk harms rotation during the tsukuri phase.
It is fascinating that the time evolution analysis of forces for right-sided athletes gives information on the simultaneous starting of pull with a bit stronger constantly left arm and shoulder overcome only by a bit higher peak from the right side in the throwing instant. In the following figure, it is reported the time evolution of forces applied by grips.

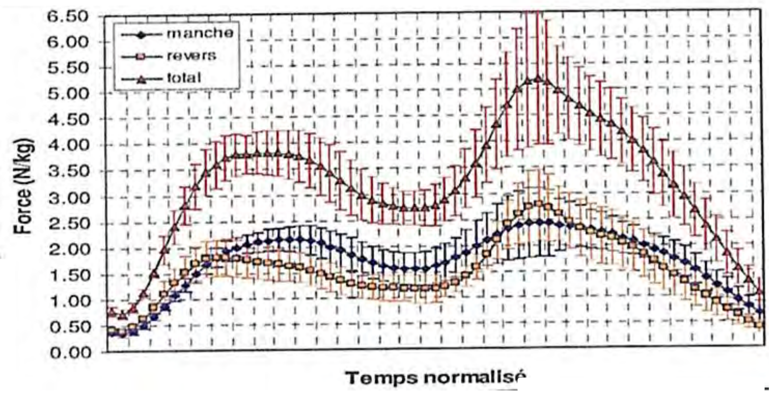


Fig. 4.3.2.a Evolution of grips forces in time

The results of this in-depth biomechanical analysis of judo throw, in connection with the "Action Invariants" identified, gave the right direction to the French researchers to build two crucial learning areas in the teaching methodology: the first area is connected to the evaluation of technical skill of the athletes (for each throw) by specific motion assessment analysis as shown in the following table.

Throw:	Suwari Seoi	*Absent*	*Present low*	*Present mean*	*Present good*	*Excellent*
Kuzushi	***Pre-pivot inclination***					
Tsukuri	***Vertical bending down***					
	Horizontal bending down					
	Hips and shoulders twisting					
	Post pivot inclination					
Kake	*Trunk-hips flexion*					
	Forward propulsion					
	Shoulder hips closure					

Tab. 4.3.2.a, Example of proposed control sheet for French judo players.

The second one is connected to the teaching methodology's pedagogy, by some specific training methods and, most importantly, by focusing on the main elements for learning judo. See the following figures.

Fig. 4.3.2 .b.c.d.e.f, Example of training developed on the Biomechanical data: Athlete's need to acquire the proper body's inclination

In a recent exciting work by Cadiere, Trilles and Colin, "*The main elements for the learning of judo*" (***2015 EJU Poster exhibition)*** were presented the main results in this area of long biomechanical studies performed in France. the result was the determination of four mechanisms that can set practical actions in judo both in Tachi waza and Ne waza.
This work also focuses on integrating these mechanisms in a teaching method adapted to different ages: young adults and children. Specifically, these researches try to find the mechanisms of action to define the teaching content and performance criteria for a judo teaching method.
In the following figures, the superior kinetic chains allow adjusting: the degree of control, the space of conduct of the adversary, the unbalance, the distance of fight, and obtain information from the opponent. And the primary trilogy of throwing techniques.

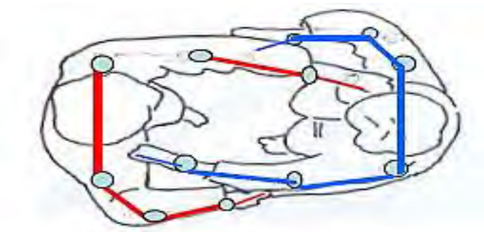


Fig.4.3.2.g Horizontal Kinetic Chains

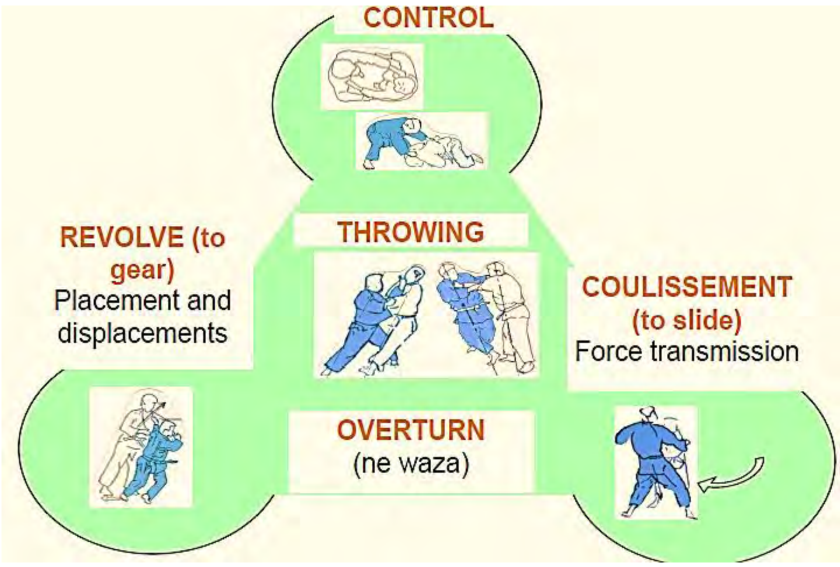


Fig.4.3.2.h. Trilogy of throwing system.

- ***Theoretical***

The second approach, followed mainly by the author, is connected to the academic system.
The so-called: global method.
This method sees the teaching problem as a whole and tries to build an advanced pedagogical structure, which is founded on a factual biomechanical basis.
The method focalized on technical growing will be longer in time, but aimed at the whole team growth, solitary personal study is good, but the danger should be the possibility of a stereotyped not evolving approach to the subtle and evolving competition problems.
The global method usually is more flexible and should be possible to use, with every kind of elite athlete well suited with few "ad hoc" adjustments.
Suppose we see the general structure of this method. In that case, we must remember that we are speaking about a particular type of knowledge (both theoretical and experimental) specific for overcoming the "situations" occurring in competitions, and the right goal aimed must be the harmonic growth of the whole team of elite athletes. For teaching/learning 'knowledge of Throw," the following steps are suitable:

1. Theoretical advanced Biomechanical explication of throws
2. Interactive execution with different partners both as Tori and Uke on the same technique
3. Analysis of execution by different direction forces for throwing with the same tokui waza.
4. Audiovisual materials with feedback (for, e.g. CD ROM, videotapes)
5. Case studies
6. Individual research (breaking symmetry study, different grips, different timing, different shifting velocity, different action invariants, different competition invariants)
7. Group discussion and evaluation by different points of view
8. Special Thematic Randori

The following are suitable for learning about 'attitudes to throw':

1. Exploration of personal attitudes (application of technique at preferred pace and competition invariants)
2. Group discussion and evaluation from different points of view.
3. Promotion of attitudes such as 'openness' and not a standardized technical approach
4. Mat work: different renzoku and renraku, connection Tachi waza –Ne waza

The following are suitable for teaching/learning skills:

1. Simulations as phantom training
2. Supervised throws application
3. The technical evolution of tokui waza
4. Videotaping real competitions and applications for feedback.
5. Checklists and handouts as guidelines for good practice
6. Group discussion and evaluation by different points of view
7. Top Competitions.

The final phase of the programme involves the careful and deeper study of a number of innovative concepts. Deriving from the biomechanical analysis, this can be labelled as follows;

1) Multipurpose entry. - Connected to the Action Invariants and breaking symmetry study
2) Unified movement. -Connected to the physical throwing principles (Lever or Couple)
3) Multipurpose grip. - Connected to the Competition Invariants, breaking symmetry study.

The goal of these concepts is to provide elite athletes in competition with special tools very flexibles that can cover a wide range of different situations; it means that these tools can be developed into various techniques depending on the specific "situation" produced in the biomechanical "Couple of athletes" system.
The particular teaching methodology for fight competition is shown in the following diagram both: cognitive and motor learning principles and pedagogical principles.

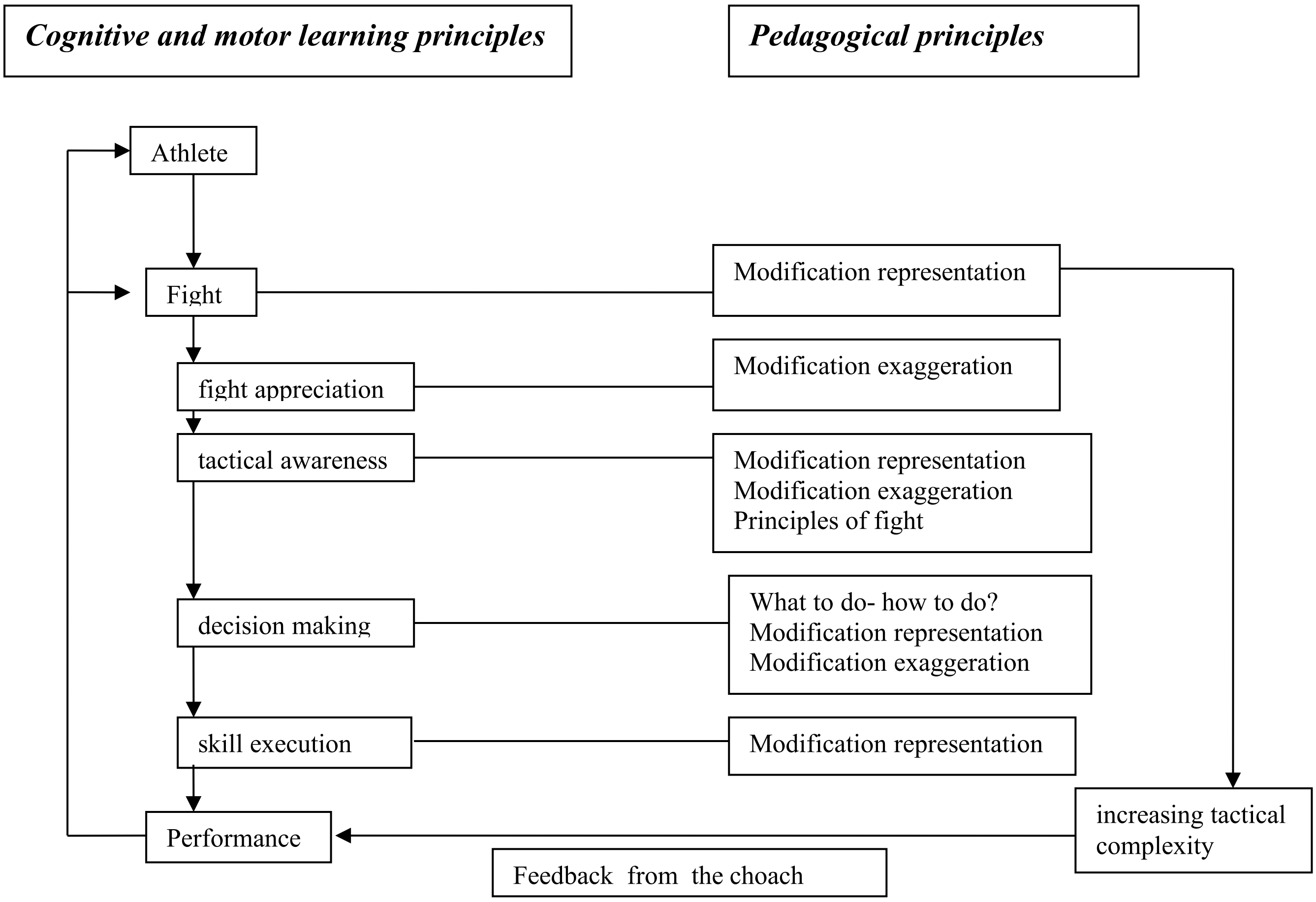


Fig. 4.3.2.g, Fighting Technical Acquisition

Chapter 5 Biomechanics of Throwing Techniques. (*Tachi waza*)

5.1.1 Biomechanics of Falls Control (*Ukemi*)

In practice Judo application, there is essentially the theoretical and practical learning of fall control to prevent accidents and the body's traumas.
In this optics in the Biomechanics Laboratory of Florianopolis Santa Catherina (Brazil), was demonstrated by Saray and co-workers studying Seoi on a different kind of Tatami, that, even though these impacts were of short average duration (0.01 s), they were in limits considered the producer of severe injuries (acceleration >250g).
Mainly in the Athletes' fists and ankles, the results exceeded the limits considered safe.
Ukemi Techniques were introduced in judo by Dr Kano to can evolve ju-jitsu techniques-in Sports techniques, mainly in judo schools or clubs are studied five kinds of Ukemi.

Fig.5.1.1.a Judo Ukemi as Japan Classic classification

The Ukemi techniques are grounded on a prominent and clever biomechanical mechanism: "***Energy absorption/dissipation by angular momentum conservation***" in order to prevent the body's traumas.
This mechanism becomes manifest through two phases:

1. **Dissipative phase**
2. **Impulse/reactive phase**

The first phase is connected to the translational kinetic energy absorption by transforming the kinetic rotational energy.
The last phase is connected to the dissipation by the use of a cushioning ground reaction force.
An old Japanese Study on Ukemi (Studies on reflex action in judo Ikai 1958) stated that when the Athlete's body is thrown during the fly, it passes through four phases.
If we connect these results with the biomechanical phases, we obtain a clear situation of what happens in the Athletes' bodies during fly and in the landing phase
.

a) First Impulse/reactive phase: Unconscious

The postural neck reflexes generate increasing in muscle tone of superior biokinetics chains.

b) First Dissipative phase: Unconscious

The vestibular reflexes generate extension and divarication of inferior biokinetics chains, with a consequent increase of moment of inertia, slowing the fall.

c) Second Dissipative phase: Conscious

The Athlete conscious curve is the body rectifying both lordosis and kyphosis to secure the spine from traumas.

d) Second Impulse/reactive phase: Conscious

The last part of translational energy is fast cushioned by the ground reaction force of stroke on the ma

$$Total\ \ Kinetic\ \ energy = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

$$because\ \ the\ \ angular\ \ Momentum\ \ shall\ \ be\ \ conserved$$

$$I_1\omega_1 = I_2\omega_2$$

$$1) If \quad I_2 \rangle I_1 \Rightarrow \omega_2 < \omega_1$$

$$2) Then \quad \frac{1}{2}mv_1{}^2 + \frac{1}{2}I_1\omega_1{}^2 > \frac{1}{2}mv_2{}^2 + \frac{1}{2}I_2\omega_2{}^2$$

$$3) from \quad \frac{1}{2}mv_1{}^2 + \frac{1}{2}I_1\omega_1{}^2 - \frac{1}{2}I_2\omega_2{}^2 = \frac{1}{2}mv_2{}^2$$

$$4)\ energy\ \ decreases$$

$$5)\ Angular\ \ momentum\ \ is\ \ conserved$$

$$6) if \qquad \frac{1}{2}mv_2^2 \equiv Fdr \cong Fdt \equiv I_2\Delta\omega$$

$$7) Then \qquad Fdr - Fdt = 0 = Stop$$

In the last time in Japan, also Computer came into Judo Ukemi teaching: Minatami and Yamamoto from Hokuriku and Kanazawa Universities produced special software for Ukemi e-learning, with video help.
In this study, it is concluded that the utilization of the personal computer and video could improve performance and perfect students' skills in understanding various types of ukemi, and that system had the capability of increasing students' desire to improve their skills.
Students could understand the forms and classifications of ukemi through the program.
The use of the personal computer makes the image of ukemi skills evident and easy to understand. In the video, students can see not only their mistakes but also monitor their positive progress.
In the following figures, it is possible to see that also in competition, and classical Ukemi is effective, Yoshida throws Aljmanjov with a powerful Hidari Seoi Otoshi. (suwari Seoi)

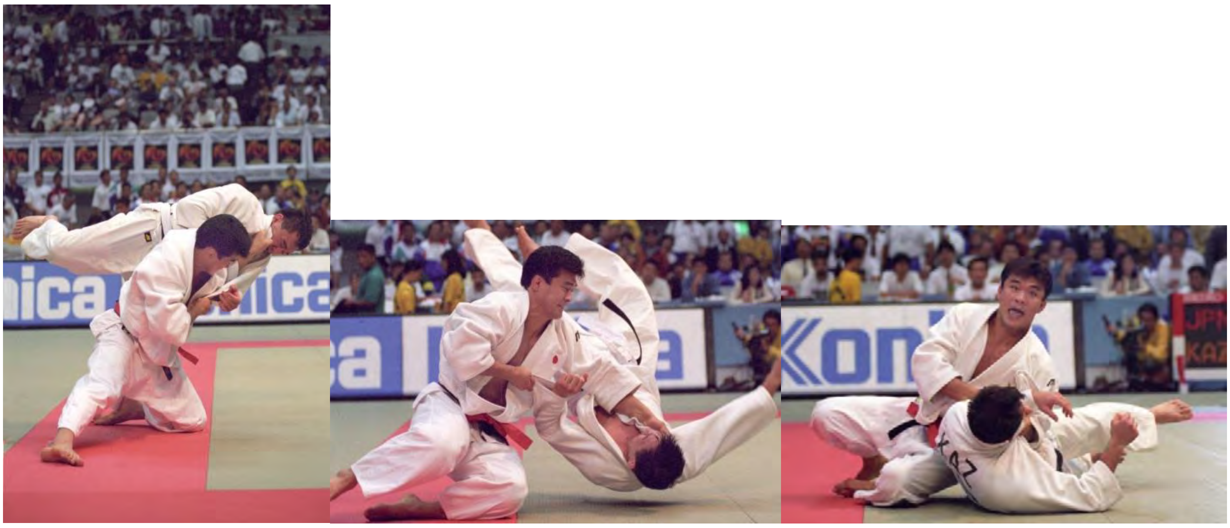


Fig. 5.1.1.b.c.d, classical ukemi in competition (Finch)

During the years from the second edition, 2010, many scientific works were performed in the world, and some applied to the Biomechanics of Ukemi. Among the most interesting, we report the position of Koshida and Coworkers used to study the kinematic differences between experienced and novice judokas in Ushiro Ukemi derived by O Soto Gari application.

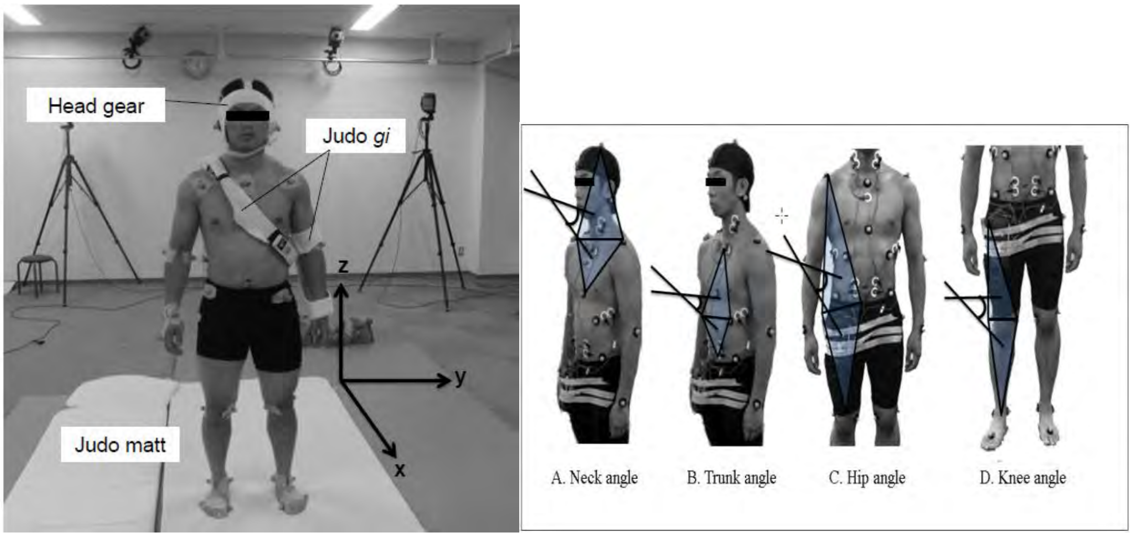


Fig 5.1.1.e.f Layout of the research and repere points with angles on uke body (Koshida 2014)

The results showed that despite significant differences between novice and experienced judokas in the angles of the Uke body during falls and in hip movement patterns, and also in neck movement patterns and trunk angle–time plots; in the end, there were only small effect sizes.
Other exciting research was performed during the second "***Teaching and Coaching EJU Master***" held in Rome to obtain results connected to the actual contact surface of the body on different (soft or hard) Tatami.
This surface is connected to the pressure received by internal organs of Uke at the end of the Falling trajectory. The research showed for the first time, in a quantitative way, that in both cases, pressure received by the internal organs of Uke is slight and well absorbed by the body.

In fact, remembering the easy form of internal pressure $P = \frac{F}{S}$ with F impact force of the body on the Tatami surface and S contact surface of the body on the Tatami. All the results showed that internal transferred pressure was not significant in terms of the potential danger to the internal organs.

Fig 5.1.1.g.h.i Layout of research and Japanese thermal camera utilized

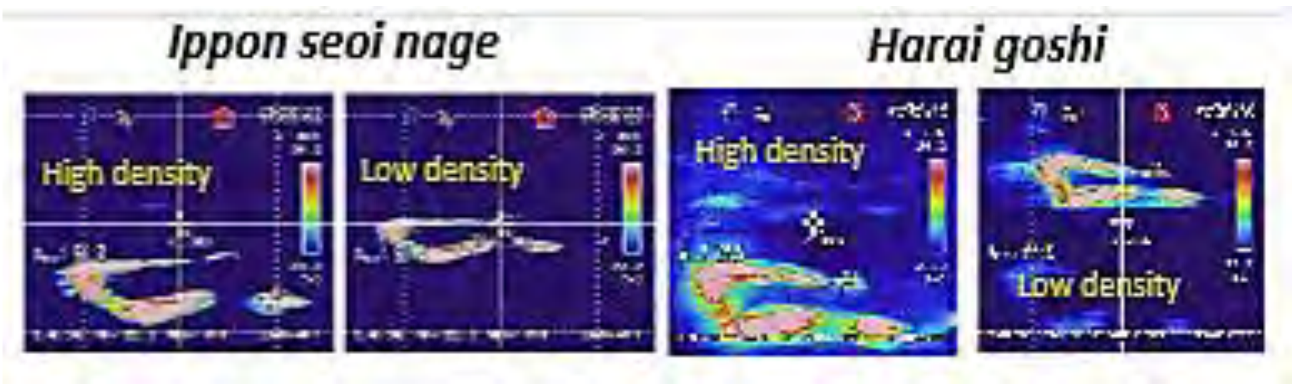


Fig.5.1.1.l.m.n.o Impact bodies surface results for two throws on soft and hard Tatami (Capelletti and Coworkers 2013)

5.1.2 Non-Orthodox Falling Techniques (*Agonistic Ukemi*)

In the last years, during international fights, to stop adversary scoring, many competitors introduced a non-orthodox system of falling based on turn-out, mainly on the hand with straight harm. Other forms were based on the falling in the bridge to avoid Ippon.
This kind of approach based on avoiding scoring falls was based on the powerful muscular preparation and on Athletes' somersault increasing capability.
But this new way was on the edge of safety because the risk to have traumas or fractures consequently to this method grows speedily.
In this field, a fascinating paper opened new ways both to theoretical and experimental researches, from Romania Barbuceanu and Stanescu proposed a biomechanical model of two different defective falls in order to understand the inner mechanisms of traumas, establishing the mean external loads and the internal mechanical tensions and also estimating the tolerable biomechanical limits of the supra-solicited zone. One of the dangers analyzed was the clavicle fracture

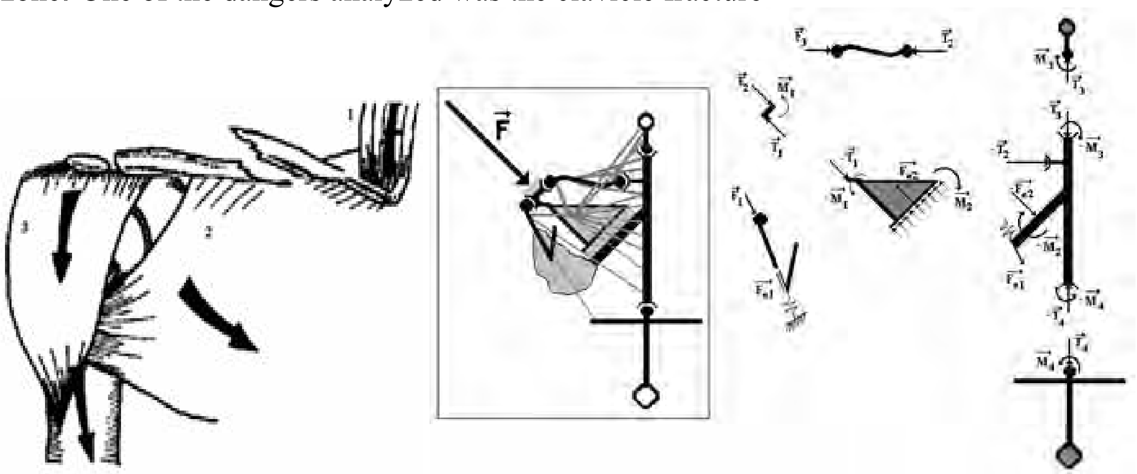


Fig 5.1.2. a Biomechanical representation of shoulder fall with the element isolation

Under the following biomechanical model:

$$
\begin{aligned}
&T_2 = F_3 - R \\
&T_1 = F_2 \\
&F_e = F_2 + R\sqrt{3} \\
&N \geq \frac{F_1 - R}{\mu} && \mu \cong 0.5 \\
&M_1 = F_2 d_1 && d_1 \cong 0.05m \\
&M_2 = \left(F_2 + R\sqrt{3}\right) d_2 && d_2 \cong 0.15m
\end{aligned}
$$

T_1=6.5kN; T_2=4.5kN; $F_e \approx$10kN; N $\geq$9kN; M_1=0.32Nm $M_2 \approx$1.35Nm

The right end of the paper introduces a new way and limitations of such studies.
Obvious, because this study is entirely new, the methods and the results may be criticized; but these models can be directions for future studies. It remarks that our results are in concordance with the experience.

5.1.2.1 Turnouts: In search of new ways

In a complete open-mindedness, Gerald Lafon, US master coach, proposes an original and different approach to judo learning by unorthodox Ukemi.
The approach was founded on the statement that classical Ukemi rarely were applied in real competition, and there was better not to fall at all or at maximum to land on one's feet, not to give a score to the adversary.
He classifies three groups of unorthodox Ukemi, named turnouts skill:

Under- and Over-Rotation -Skills
For the most part, these skills occur without the benefit of a point of contact with the ground and usually result in landing on the side of the body and infrequently face down.
Typically, these skills are done after forwarding throws and minimize scores rather than eliminate them.
These skills use mostly body control to speed up (over-rotate) or slow down (under-rotate) the rotation of the body. An excellent example of an under-rotation skill is called the back-leg turnout.
This skill seeks to keep most of the back off the mat to minimize the score.
Turn Away and Turn In- Skills
These skills are done after throws that take Uke towards his back, i.e. O soto gari, Ko uchi gari or Tani otoshi.
As the name implies, Uke turns away or into Tori to prevent from being thrown straight onto his back. These skills usually minimize scores.
Scoot-Around -Skills
These skills are the most spectacular in Judo. They almost always have a point of contact with the ground and result in landing on one's feet or fours. Scoot-around skills typically involve around off, head roll, elbow roll or handstand and usually result in eliminating a potential score.
They are mostly done after forwarding throws or sutemi waza.

Although, as Mr Lafon said, the primary purpose of turnouts was to minimize (or eliminate) scores in competitive Judo, turnouts have also the added benefit for all students of Judo, competitive and non-competitive alike, of accomplishing the following;

- ***Turnouts provide another means of falling safely onto a surface.***
- ***Turnouts allow a player to be in a position to counterattack after being airborne.***
- ***Turnout training increases kinesthetic awareness.***
- ***Turnouts help develop an entire category of athletic abilities that traditional methods don't.***

In the following figures, we can see some turnout Ukemi training, in a club, by G. Lafon. source *Judoinfo.com*

Fig.5.1.2.1a.b.c.d, Unorthodox Ukemi (G.Lafon)

But the refereeing rule changed in the time, and this way to stop the score, in the end, was not considered. In the following figures, we can see. The tentative of turnouts to stop a morote-gari attack Howey-Cho and a continuous reversing awarded, by the result in Franklin vs Lomax.

Fig.5.1.2.1.e.f.g,h. Unorthodox ukemi in competition and in Rio Olympics (Finch, Zahony, Gabii)

5.2 Biomechanical classification of judo throwing Techniques

This previous historical survey through various categories introduces the attempt to rationalize the matters in a scientific way, looking for the basic physical principles of Nage Waza.
A biomechanical analysis of judo throwing techniques in the sense of ***Rational Sportive Techniques*** must be dealt with in the following steps: firstly, by simplification and secondly by generalization.
As a simplification principle for the problem of classes of forces involved, at first, we can use the differential method pointed out by Dr Kano: the subdivision of the throwing movement in three steps:
1° Tsukuri (preparatory movements aimed at throwing out of balance Uke's body);
2° Kuzushi (the unbalancing action); and
3° Kake (execution of movements aimed at throwing), and later we shall analyze the motion of Uke's body cutting out secondary forces.
Then we generalize the classes of forces, putting out the inner physical principles of standard judo throwing techniques.
This method applied to Nage Waza. is able to group 77 throwing techniques (40 Kodokan go kyo and 37 others) under two dynamic principles only.
It is correct to remark that this is one of many possible biomechanical classifications, and we select it for its valuable simplicity and immediateness. **This simple and basic classification, applied first to static conditions, singles out Tori best forces use, without Uke opposition,** like the Kano classification.
It comes very handy to find the «General Principles", first to define two corollaries on the direction of forces (Static Analysis), and then to analyze Uke's body flight paths (Dynamical Analysis) and their symmetries. Then considering Uke's body as a rigid body, it is possible to state.

Static Analysis

Principium of resolution of forces.
These two corollaries determine the whole directional problem of static use of forces to execute throws.

Unbalance

1) Forces are effective and can be applied, on the horizontal plane, on the whole, round angle (360°).

Unified under these terms are the biomechanical problems of forces employed for unbalancing Uke's body. (Tsukuri-Kuzushi steps).

Throws

2) Forces are effective and can be applied, on the vertical plane, nearly for the width of a right angle (90°).

Determined under these terms are the biomechanical problems of forces employed for throwing Uke's body. (Kake step). Actual limits of throwing forces can be obtained with an angle of nearly 45 degrees, up or down a horizontal line, because the resistance caused by Uke's body structure or by force of gravity, beyond these angles, allows throwing again but with more waste of energy.

Dynamical Analysis

Principium of the composition of forces - Study of flight paths and their symmetries
If in space the composition of forces obeys, at the same time, the previous static two corollaries, the solution of dynamical problem (considering time) goes through the study of flight paths and their symmetries.
Trajectories along which Uke's body moves during flight following throwing can be collected under two simple types or their composition: Circular paths and Helicoidally paths.

A) Circular Path Spherical Symmetry
For throwing techniques in which the limbs of Uke's body follow a circular path

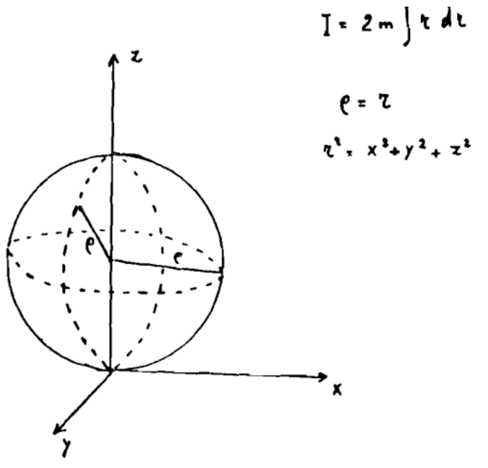


Fig 5.2.a Sphere

The radius of circumference coincides with the distance r from the rotation axis of inertial momentum. These techniques have spherical symmetry and circumference. That is, the “geodetic line” of a sphere (the shortest line between two points) is the path of minimum work, then the trajectory of the least waste of energy that extreme parts of Uke's body can cover.

B) Helicoidally Path: Cylindrical Symmetry
For throwing techniques in which Uke's body follows a helicoidal path, the bending radius of the helix is proportional to distance r from the rotation axis of inertial momentum.
These techniques have cylindrical symmetry, and the helix that is the «geodetic line» of a right cylinder is also the path of minimum work or the trajectory of the least waste of energy that Uke's body can cover.

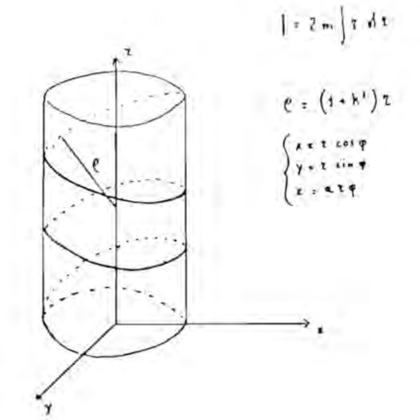


Fig.5.2.b, Cylinder

If we think both of the two corollaries on the direction of forces (Static Analysis) and of the study of trajectories followed by Uke's body (Dynamical Analysis), it is possible to state the two dynamical principles of biomechanical classification, which show the inner mechanisms of throwing techniques.

A) Techniques where Tori makes use of a couple of forces for throwing Uke.
B) Techniques where Tori makes use of a physical lever for throwing Uke.

Movements that seemingly make different throwing techniques, in appearance but not in biomechanical essence, can be collected in Tsukuri - Kuzushi stages and other preparatory actions (Taisabaki).
We think this classification, grounded on clear scientific criteria, is very suitable to give an easier understanding of physical principles linking judo throwing techniques.
A) Techniques of a couple of forces.
In the first group, we found all throws produced by sweeping away legs and pulling or pushing Uke's body in the opposite direction simultaneously. The techniques of "Group of a couple of forces" can be classified by parts of Tori's body which apply a couple of forces on Uke's body. Namely: two arms, arm and leg, trunk and leg, trunk and arms, two legs.

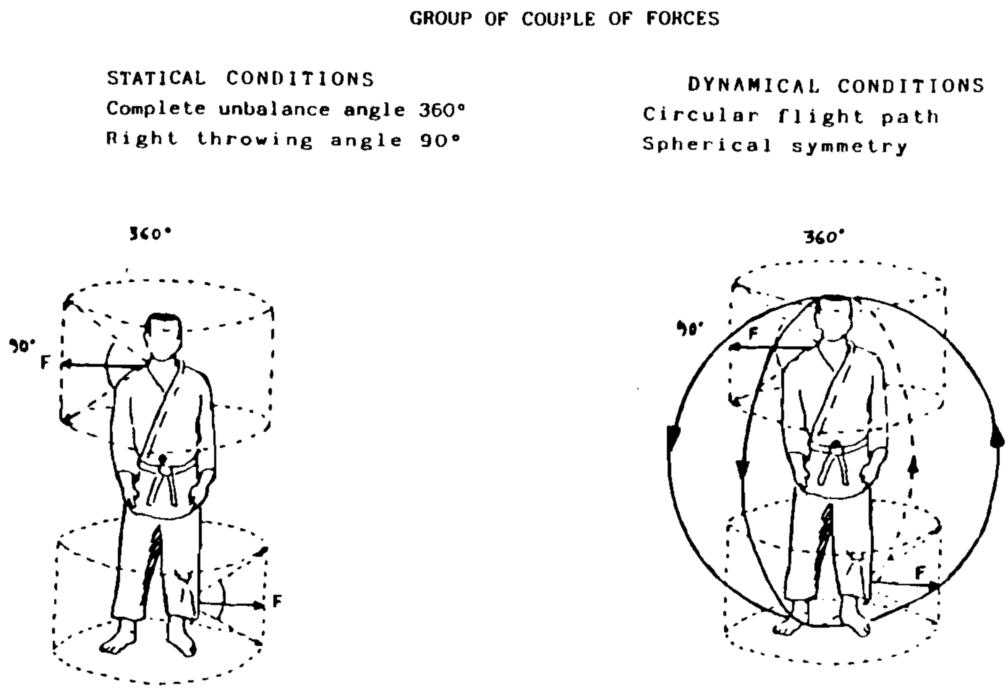


Fig.5.2.b, Couple of Forces Group

This biomechanical classification is able to show new likeness not evident in standard techniques. The asymmetry face-back of the human body explains astonishing examples of biomechanical likeness: O Soto Gari, Uchi Mata and Harai Goshi are the same Tori's movement, that is a couple of forces on Uke's body. As easily we can see in the next three sequences showing Inoue demonstration at Bath University.

Fig.5.2.c.d.e.f.g.h.i.j.k.l.m.n, Equivalence of Tori's movement in couple techniques (Finch.)

It is very interesting to note that most throws of a couple of forces (the ones applied by Tori standing on one leg) can be led to only one Tori's basic action: rotation on coxo-femoral articulation with three degrees of freedom each of it, lying into the three symmetry planes of the human body.
First: rotation of trunk-leg set on coxo-femoral articulation around a horizontal lateral-lateral axis of rotation. (motion lying in the sagittal plane)

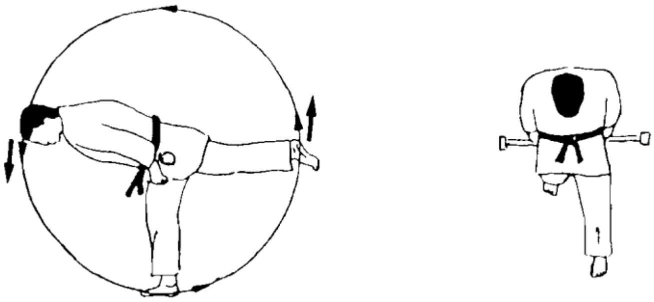


Fig.5.2.p, Motion in a sagittal plane

Second: rotation of trunk-leg set on coxo-femoral articulation around a horizontal lateral-lateral axis of rotation. (motion lying in the sagittal plane) inverse direction

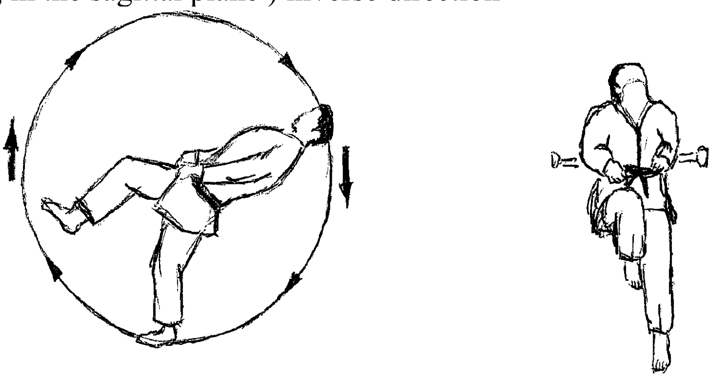


Fig.5.2.q, Motion in a sagittal plane

Third: rotation of trunk-leg set on coxo-femoral articulation around a horizontal anteroposterior axis of rotation. (Motion lying in the frontal plane)

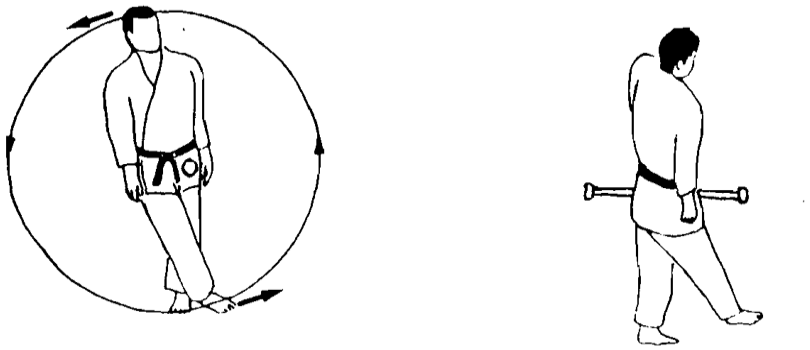


Fig.5.2.r, Motion in a frontal plane

Fourth: rotation of trunk-leg set on coxo-femoral articulation around a vertical axis of rotation. (Motion lying in the transverse plane)

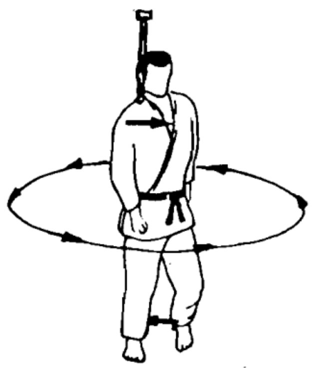


Fig.5.2.s, Motion in Transversal plane

This points out the fundamental role played by COXO-FEMORAL ARTICULATION in this group and entails that this athlete's articulation must be provided with great flexibility.

B) Techniques of the physical lever

In the second group, we found all throws produced by turning Uke's body around a stopping point (hip, leg, foot.). The techniques of “Group of physical levers” can be classified by the length of the arm of the lever applied on Uke's body. Namely: minimum arm (fulcrum under Uke's waist), medium arm (fulcrum under Uke's knees), maximum arm (fulcrum under Uke's malleola), variable arm (variable fulcrum from the waist down to Uke's knees) Because in this group throws of “minimum arm” are energetically unfavourable (greatest force applied), that clears why, for competition, people like more to turn them in throws of the variable arm, pulling down fulcrum under Uke's waist more and more. That means less waste of energy.

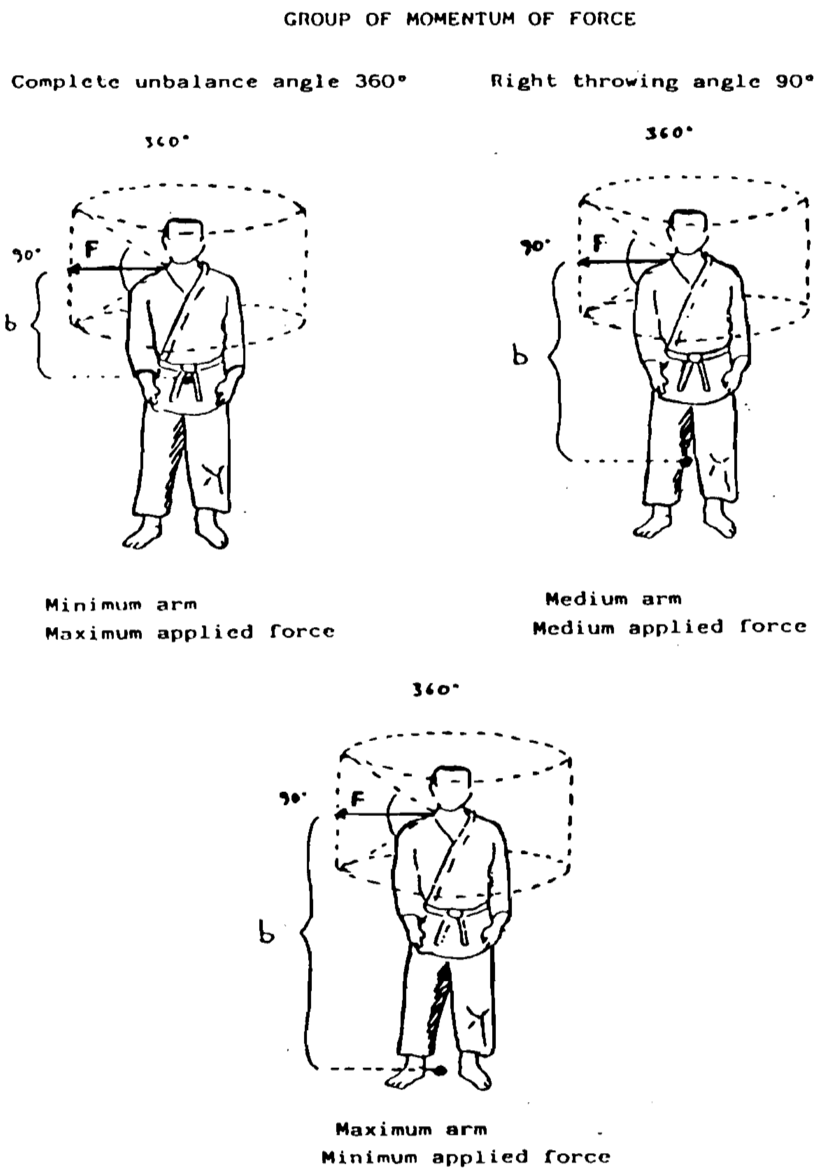


Fig.5.2.t, Physical Lever Group

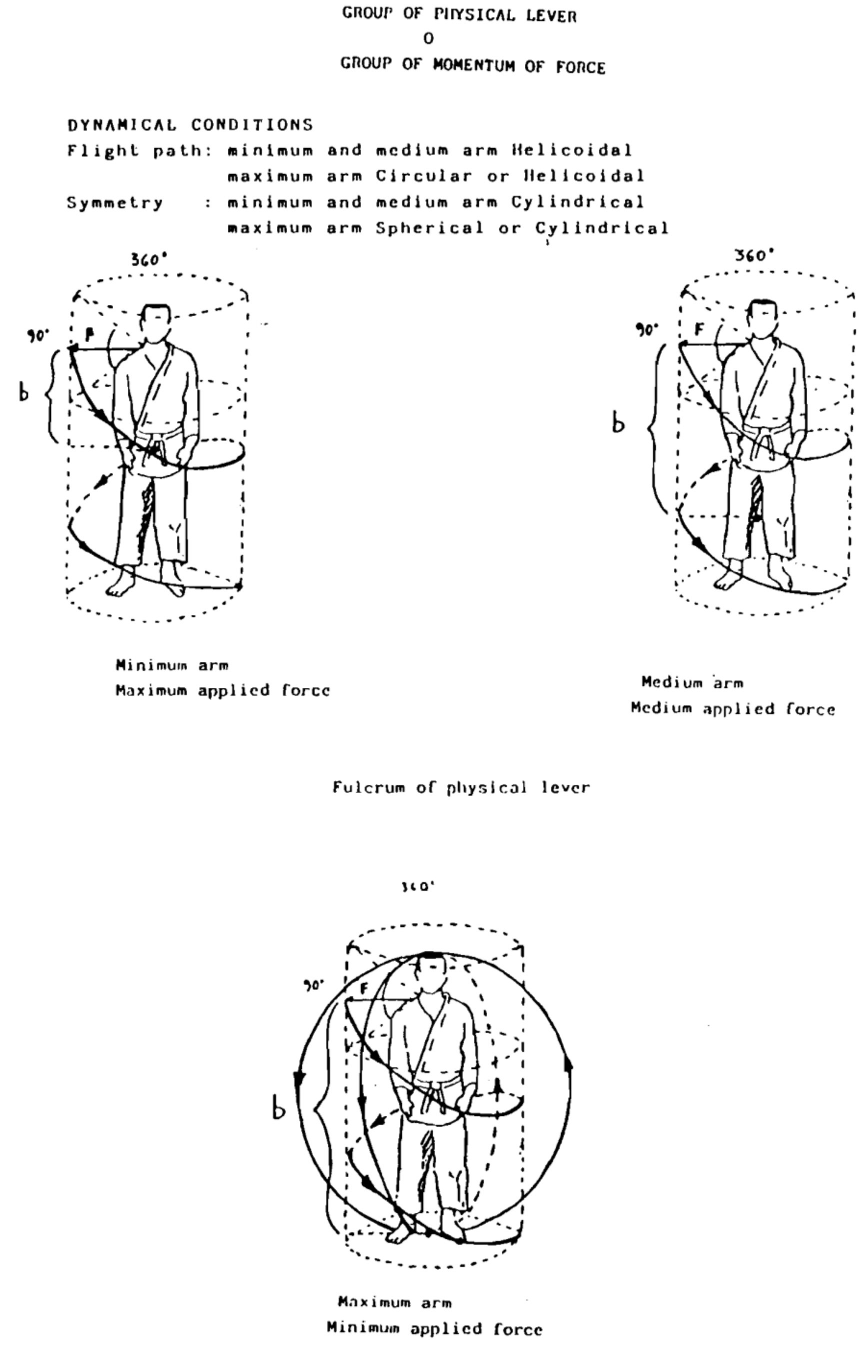


Fig.5.2.u, Physical lever Groups with Sutemi

Again, this biomechanical classification shows, in this group, likeness examples: classical Ashi Guruma and Hiza Guruma are the same techniques applying a lever of the medium arm on Uke's body.
It is very interesting to note that most throws of the group of the lever can be led to only one Tori's basic action if we do not consider the several Tori's legs positions: rotation of trunk on waist around a generic variable axis of rotation

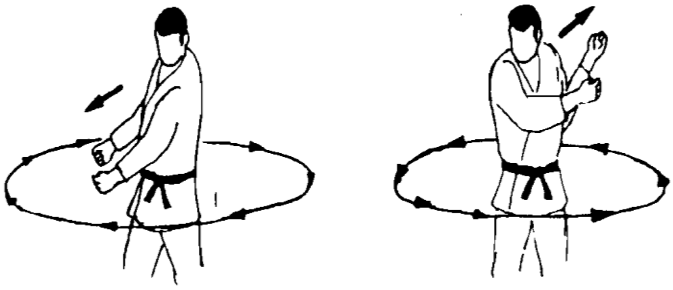


Fig.5.2.v Motion in transverse plane

Also, the body-abandoning techniques must be classified as throws of “Group of physical levers” with the maximum arm; in this case, the stopping point (fulcrum) is given by friction between foot and mat (tatami). Although they are more favourable energetically speaking, the starting force (bodyweight falling down) is applied with an angle greater than 45° (see II° corollary of static analysis).
That is, matters need high, directional help by arms or legs for rightly throwing Uke's body.
In the light of our analysis, we think the clarification of basic physical principles and the evidence of basic action, proving the leading role of Tori's pelvic belt, can be useful for a better understanding of inner mechanisms and for looking at new improvements in training theory, which should prevent erroneous methods and possible damages in the join.

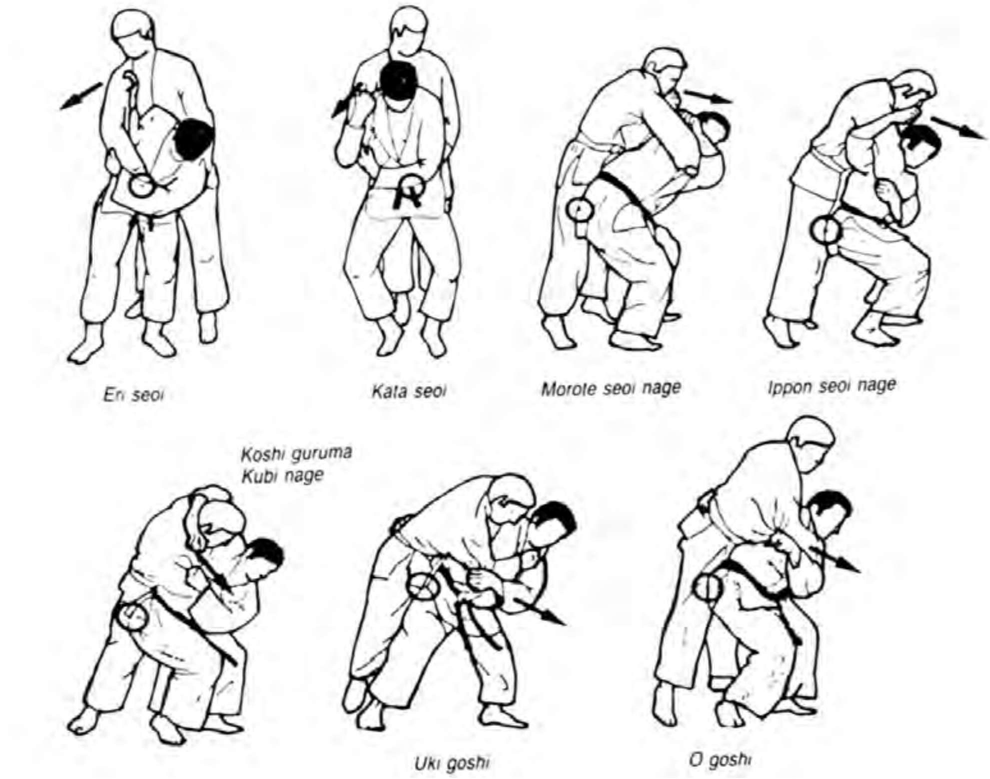
Techniques Of Couple of forces Couple applied by	Arms	Kuchiki daoshi Kibisu Gaeshi Kakato Gaeshi Te Guruma	
	Arm/s and leg	De Ashi Barai Okuri Ashi Barai Ko Uchi Barai O Uchi Barai Tsubame Gaeshi Ko Uchi gari Ko Soto Gari	O Uchi Gari Ko Uchi Gake Ko Soto Gake Harai Tsurikomi Ashi Yoko Gake O Soto Gake O Uchi Gake
	Trunk and legs	O Soto Gari O Soto gruruma Uchi Mata Okurikomi Uchi Mata Harai Goshi Hane Goshi Hane Makikomi Yama Arashi	O Tsubushi O Soto Otoshi Ko Uchi Sutemi Harai Makikomi Ushiro Hiza Ura Nage Gyaku Uchi Mata Daki Ko Soto Gake (Khabarelli)
	Trunk and arms	Morote Gari	
	Legs	Kani Basami	

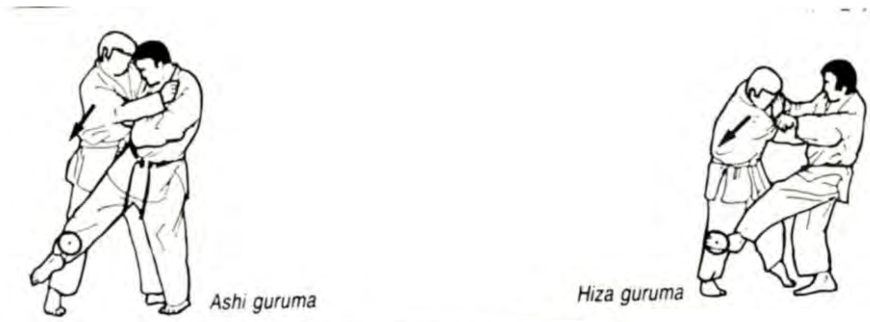
Tab.5.2a. Techniques based on a couple of forces

<table>
<tr><td rowspan="4">Techniques
Of
Physical lever
Lever applied with</td><td>Minimum Arm
(fulcrum under Uke’s waist)</td><td>O Guruma
Kata Guruma
Tama Guruma
Obi Otoshi
Tawara gaeshi
Makikomi
Sukui Nage
Ushiro Goshi
Utsuri Goshi</td><td>Ura Nage
Ganseki Otoshi
Uchi Makikomi
Soto Makikomi
Momo Guruma
Kata sode Ashi Tsuri.
Daki Sutemi</td></tr>
<tr><td>Medium Arm
(fulcrum under Uke’s Knees)</td><td>Hiza Guruma
Ashi Guruma
Hiza Soto Muso
Soto Kibisu Gaeshi</td><td></td></tr>
<tr><td>Maximum Arm
(fulcrum under Uke’s malleola)</td><td>Uki Otoshi
Yoko Otoshi
Sumi Otoshi
Suwari Otoshi
Waki Otoshi
Tani Otoshi
Tai Otoshi
Dai Sharin
Ikkomi Gaeshi
Sumi Geshi
Yoko Kata Guruma
Uki Waza
Uke Nage</td><td>Yoko Guruma
Yoko Wakare
Seoi Otoshi
Hiza Seoi
Obi Seoi
Suso Seoi
Suwari Seoi
Hiza Tai Otoshi
Tomoe nage
Ryo Ashi Tomoe
Yoko Tomoe
Sasae Tsurikomi Ashi</td></tr>
<tr><td>Variable Arm
(variable fulcrum from the waist To the knees)</td><td>Tsuri Komi Goshi
Sasae Tsurikomi Goshi
Ko Tsurikomi Goshi
O Tsurikomi Goshi
Sode tsurikomi Goshi
Uki Goshi</td><td>O Goshi
Koshi Guruma
Kubi Nage
Seoi Nage
Eri Seoi Nage
Morote Seoi nage</td></tr>
</table>

Tab.5.2.b. Techniques based on a physical lever

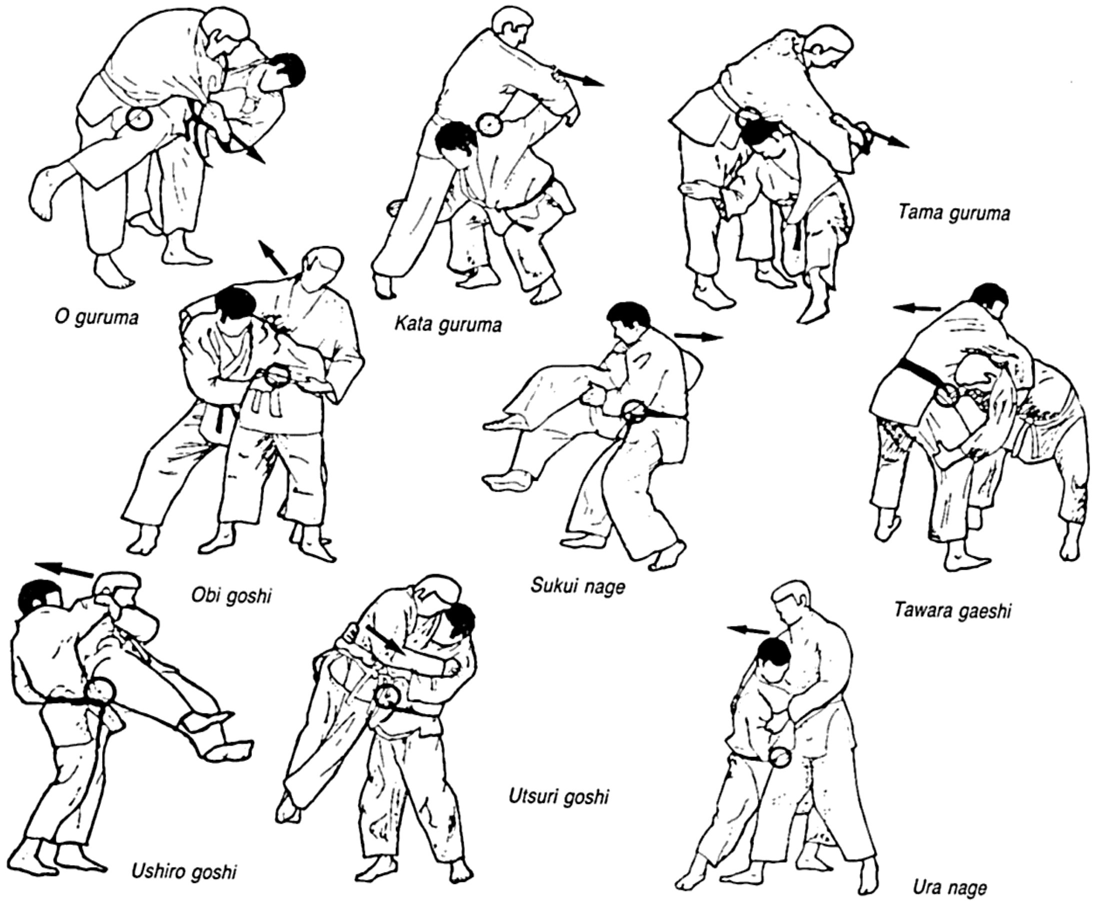
57 Techniques of Physical Lever in the function of the arm length

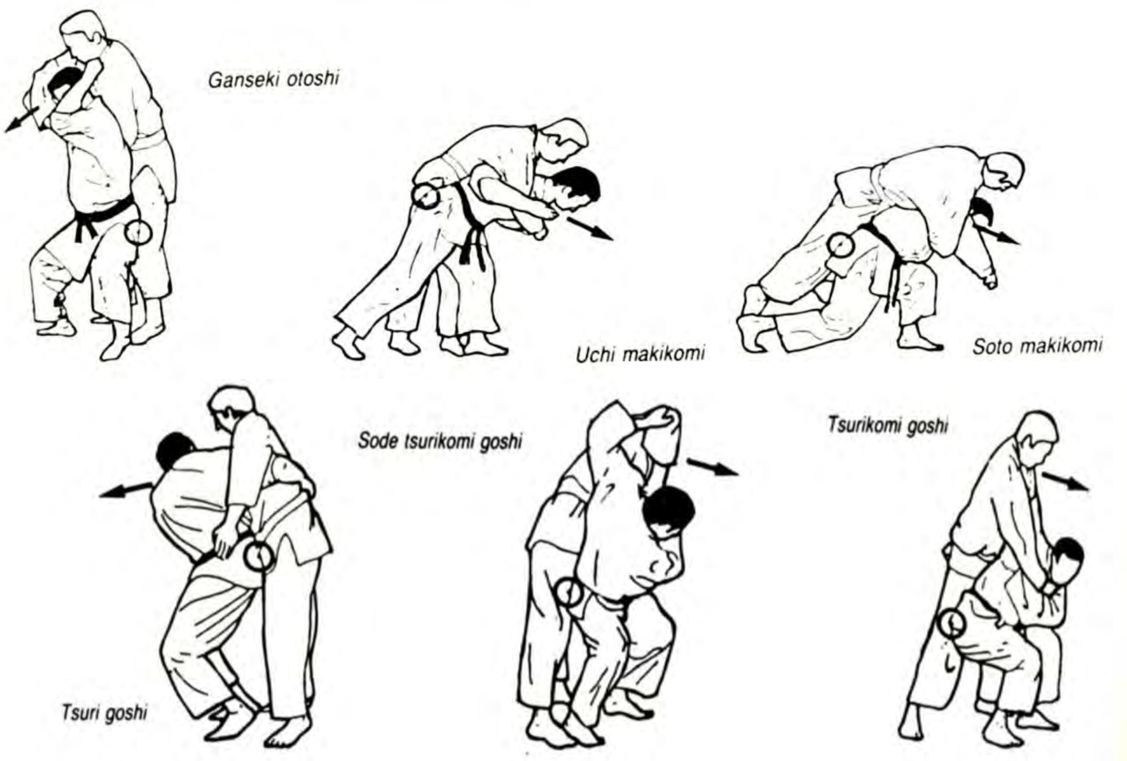


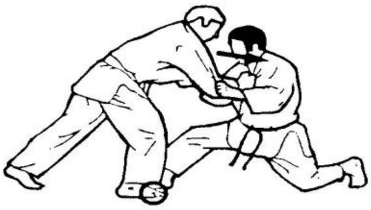


Soto Kibisu
Gaeshi

Hiza
Soto
Muso


O guruma
Kata guruma
Tama guruma
Obi goshi
Sukui nage
Tawara gaeshi
Ushiro goshi
Utsuri goshi
Ura nage


Ganseki otoshi
Uchi makikomi
Soto makikomi
Sode tsurikomi goshi
Tsurikomi goshi
Tsuri goshi


Uki otoshi


Tai otoshi


Sumi otoshi


Yoko otoshi

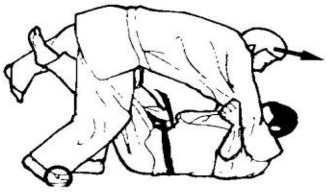

Yoko guruma


Uki waza


Tani otoshi


Yoko wakare


Tomoe nage


Sumi gaeshi


Hikkomi gaeshi


Waki otoshi

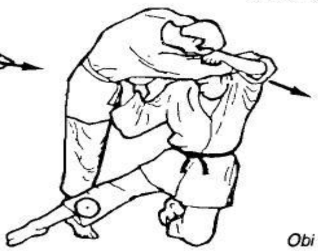

Dai Sharin


Sasae tsurikomi ashi

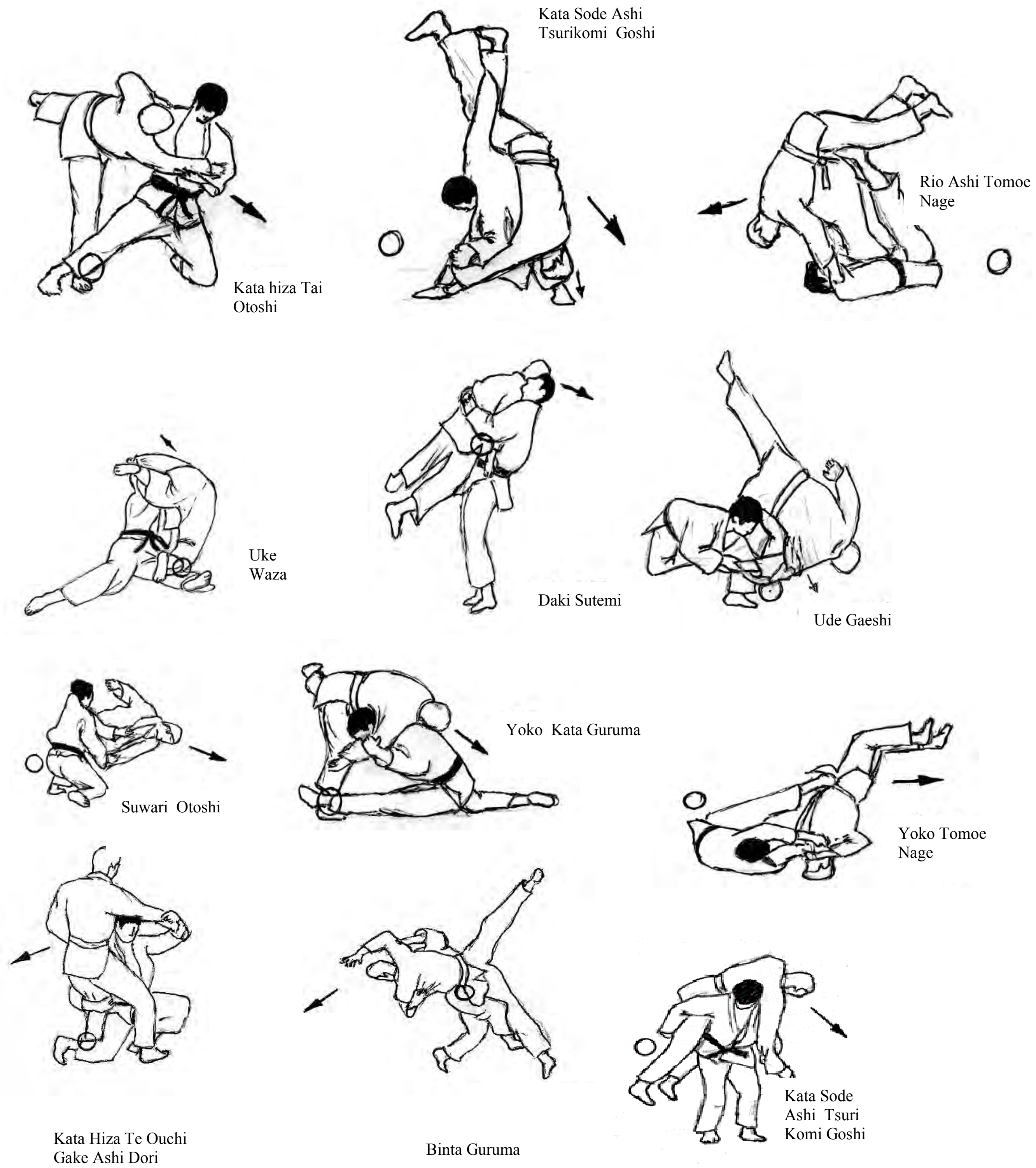

Seoi otoshi


Suwari seoi


Suso seoi

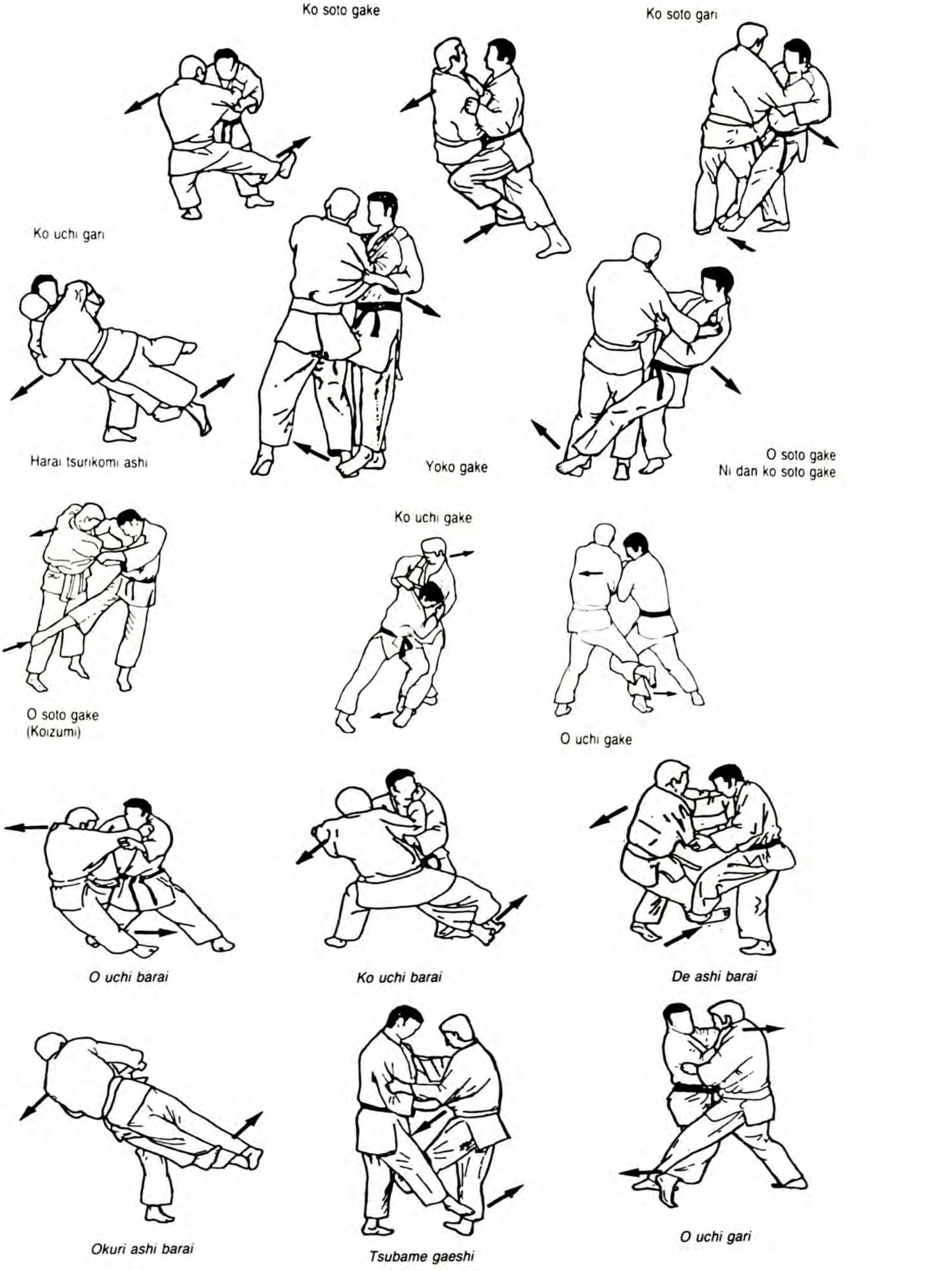

Obi seoi

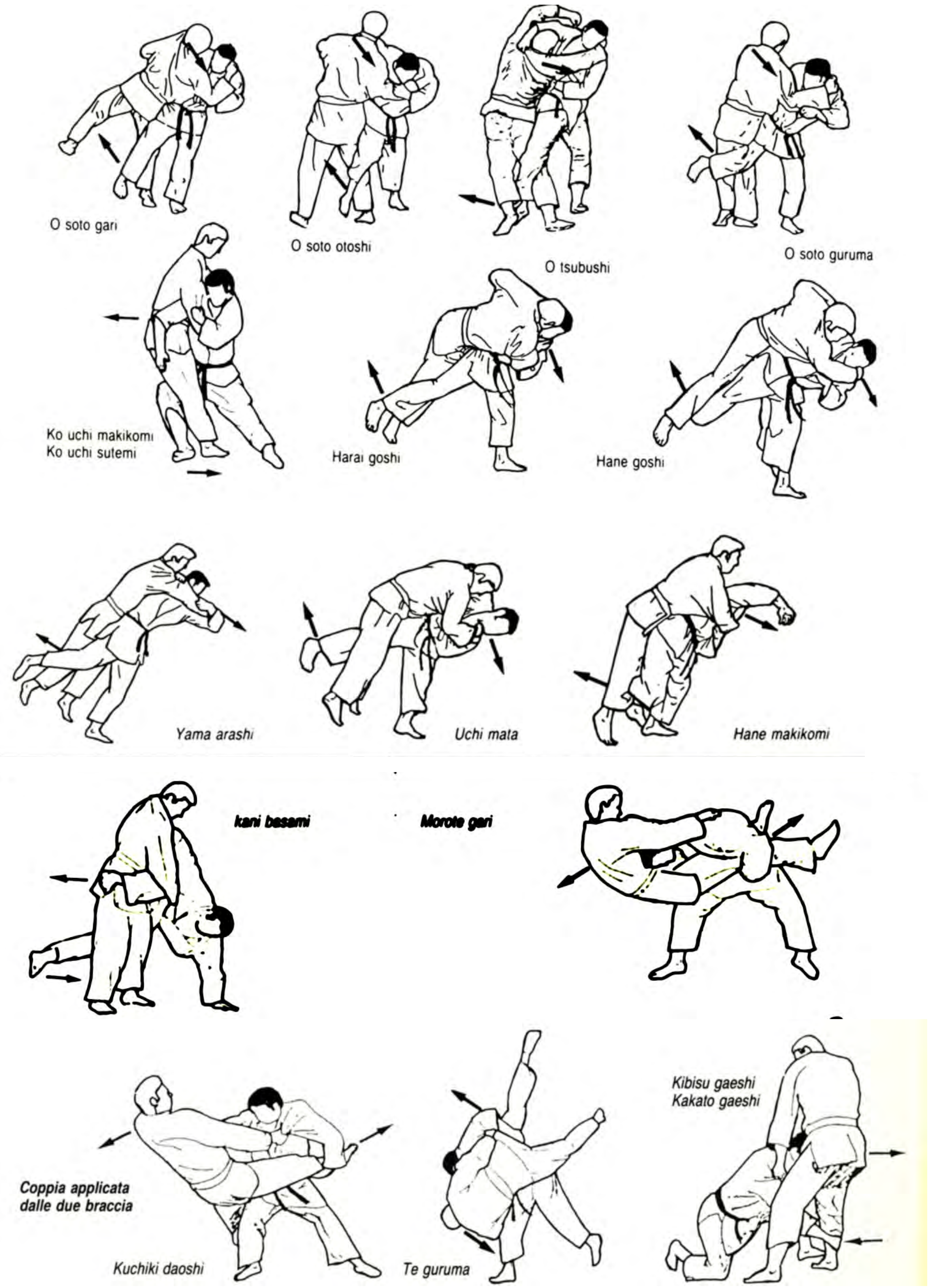

Hiza seoi



The non Kodokan Names were proposed by Roy Inman as agonistic Innovative techniques in his document Classification of Innovative International Competition Techniques (Shin Kokusai Shiai Waza 2005)

33Techniques of couple of forces in the function of body part applying forces




O soto gari
O soto otoshi
O tsubushi
O soto guruma
Ko uchi makikomi
Ko uchi sutemi
Harai goshi
Hane goshi
Yama arashi
Uchi mata
Hane makikomi
kani basami
Morote gari
Coppia applicata
dalle due braccia
Kuchiki daoshi
Te guruma
Kibisu gaeshi
Kakato gaeshi

Ushiro Hiza Ura Nage

Kata Uchi Ashi Dori

Daki Ko Soto Gake

.

The non-Kodokan Names were proposed by Roy Inman as Innovative agonistic techniques in his document Classification of Innovative International Competition Techniques (Shin Kokusai Shiai Waza 2005)

5.3 New Vision in Throws (Classic, Innovative and Chaotic Throws)

Before defining the concepts “Innovative Form” and “New or Chaotic Form” jūdō throwing techniques, it is important to consider that many countries have made and are still making new technical contributions to *Kōdōkan* jūdō. The motivation towards victory and the ability to overcome opponents represent the root of this evolution (without implying either a positive or pejorative meaning and merely using the term in the sense of “changes over time”).

In a previous paragraph already was performed the revision of Kano’s Educational Kernel (Kuzushi, Tsukuri, Kake), now it was for the first time studied the Judo Throws evolution in time around the world Tatami, defining these steps of changing from Classical Throws, to Innovative Throws, and to Chaotic Throws.

Then we Define ***Classical Throws, All the throwing movements as shown in Kano’s Go Kyo 1922 and Kodokan’s Go Kyo 1985***.

The last Kodokan Go Kyo or technical classification, Daigo 2005, is not considered because the Japanese author analyzes many variations of the Classical Techniques that in our definition are under the Innovative form of throws.

Fig. 5.3.a.b.c.d.e. Classical Throws: Lever Group- Morote Seoi Nage; Lever Group-Morote Otoshi. Couple Group- a Rare example of Hane Goshi in competition.

Fig. 5.3.f.g.h.i.l.m: Couple a perfect Classic Uchi Mata with Uke rotation into Sagittal plane.

To increase the effectiveness of throws, in real competition, athletes' bodies must collide with each other. In effect, because it is difficult if not impossible to fit in, during competition in the position that people train itself normally in *uchi komi* or *nage komi,* applying forces in classical directions, in that way borne the ***Innovative Techniques 2005*** (Roy Inman), that are defined as :

"Innovative Throws" are all throwing techniques that keep alive the formal aspect of Classic Jūdō throws and differ in terms of grips and direction of applied forces only.

Fig 5.3.n.p.q. Innovative Throws: Lever Group- Seoi, Tai Otoshi; Couple Group-Uchi Mata

Innovative Throws are variations (***Henka)*** of classical *Kōdōkan* throwing techniques, which are either Couple of Force-type or Lever-type techniques biomechanically speaking, while it remains easy to recognize still a well-known basic traditional technique (*gokyō* throwing techniques) in them. However, there are other "non-classic" solutions applied in competition and which are different from 'Innovative' (***Henka*** **Throws**), which we define as "***Chaotic Forms.***" 2010

Oftentimes these ***Chaotic Throws*** are mainly limited to the class of lever group.
When one analyses these types of throws more in-depth, then the real difference between the goals of kuzushi/tsukuri in both biomechanical groups of throws will be clarified.

" Chaotic Throws" are characterized by the application of different grips positions which applying force in different (nontraditional) directions while simultaneously applying (stopping points) in non-classical position, utilizing "no rational" shortening trajectories (longer or different than the usual) between athletes.

These techniques are not named as the classical ones, and this is one of the greater difficulties to describe them in a classical way. From there, the question arises whether it is necessary to use a new name for different throws? About the names of classic jūdō throws, it is appropriate to consider the words of Kazuzō Kudō, one of the last students of Jigorō Kanō, in his book “Dynamic Judo Throwing technique” he said: “*Jūdō names fall into the following categories:*

1. *Name that describe the action:* ***ō-soto-gari, de-ashi-barai, ō-uchi-gari-gaeshi.***
2. *Names that employ the name of the part of the body used:* ***hiza-guruma, uchi-mata.***
3. *Names that indicate the direction in which you throw your opponent:* ***yoko-otoshi.***
4. *Names that describe the shape the action takes:* ***tomoe-nage*** *(‘tomoe’ is a comma-shaped symbol).*
5. *Names that describe the feeling of the techniques:* ***Yama-Arashi, Tani-Otoshi.***

Most frequently, jūdō techniques names will use the content of one or two of these categories.”.

Biomechanics instead gives no names but helps the understanding, clarifying the mechanical action of the tool utilized for these techniques. In such a way, names are superfluous. The main thing is to understand the inner mechanism and to apply it in whatever situation.

The chaotic form of Throws:

Fig 5.3.q.r.s.t. Chaotic Throw: Lever Group -No name;

Fig5.3.u.v.w.z.aa.bb.cc.dd. Couple Group-No name; u,v,w. Lever Group-No name z,aa Couple Group-No Name; bb,cc, Lever Group -Reverse Morote Seoi Nage.

5.4 Biomechanics Analysis of some selected Throws

From the Second Edition of this book, many studies around the world were performed in many different laboratories on judo throwing techniques. During these years, despite Historical Nations as Japan and France, many interesting and strong groups of researchers born in some countries like Spain, Brasil, Poland and Portugal, but also some other countries show interesting individualities like America, Austria, Bosnia, Croatia, Egypt, England, Germany, Korea, Romania, Russia, Serbia, Italy, and others.

Judo throws are not only the most effective and esthetic part of judo but also the most complex ones. Researchers try always to grasp the inner part of these movements by deeper and deeper studies.

During these years, various researchers first scattered and without contact, thanks to the continuous efforts dell'EJU education, through its annual Poster competition, found a moment of contact and confrontation that increasingly goes to benefit research on judo. The important point is the ability to provide the scientific information obtained not only with fellow researchers but also with the final users: teachers, coaches and athletes.

Practically every throw is already analyzed, but from the competition statistics, many studies are focalized on the most frequent throw applied: Seoi and Uchi Mata.

The great importance of Seoi in high-level competition and his high effectiveness in the real contest is the main reason for many studies performed around the world in these last sixty years.

An overview of some worldwide researches will be developed to show how many details and from how many different points of view these techniques were studied in so many universities' laboratories.

So many different fields of researches show that to understand Judo Sport, belonging to the class of dual situation sports, is a very difficult and multi-complex task.

Worldwide study on Uchi Mata and his family (Couple Group throws by Trunk Leg) are numerous as studies on Seoi Family, but the main difference is that the Japanese heritage in Couple techniques was so heavy that many works were too focalized in small particular without a powerful common vision like Biomechanical point of view.

Despite this handicap, many data obtained (especially for Uchi Mata) are very interesting.

The specific concentration of the researchers on Uchi Mata is understandable because the statistical frequency and effectiveness of this throw in the competition are high than the Seoi, as it is possible to see from the following table. In the following, we try to show some interesting researches from around the world.

FRA		JPN		URSS		Autres	
Uchi-mata	25,5 %	Uchi-mata	15,8 %	Uchi-mata	11,4 %	Suwari-seoi-nage	13,8 %
O-uchi-gari	11 %	Suwari-seoi-nage	13,3 %	Seoi-nage, Kata-guruma	9,6 %	Uchi-mata	13,4 %
O-soto-gari	7,7 %	Ko-uchi-gari	10,7 %	Suwari-seoi-nage	7 %	O-uchi-gari	8,7 %
Sode-tsuri-komi-goshi	7,4 %	O-uchi-gari	9 %	Kuchiki-daoshi	7,7 %	Ko-uchi-gari	7,4 %
Ko-uchi-gari	7,4 %	O-soto-gari	7,3 %	O-soto-gari	7,4 %	Seoi-nage, Kata-guruma	7,4 %
Kuchiki-daoshi	7,4 %	Tomoe-nage	6 %	Sode-tsuri-komi-goshi	7 %	Hara-goshi	7 %
Suwari-seoi-nage	5,3 %	Seoi-nage, Kata-guruma	5,1 %	Tai-otoshi	7 %		

Tab. 5.4.a Percentage of throws utilization of French, Japanese and Russian Athletes.

Kinematics and Kinetics Parameters
The first official study published on Judo Throwing Biomechanics was Kinetic of Judo by Matsumoto and Ikai Kodokan Bulletin N°1 1958.
This is one of the complete biomechanical approaches to judo Throwing, the paper gives data about eight throws analyzed by photographs, but it is easy to understand that probably there were more throws analyzed.
This paper shows the perfect organization of Japanese Judo in preparation for the Tokyo Olympics 1964. In this paper, the distinguished Prof Y. Matsumoto analyzed with his friend Ikai all the Judo Throws Kinetics: centres of mass motions, angles of projection, landing velocities, Impact forces, the study of Tsukuri Kuzushi phases, and the relation between the effectiveness of the tricks and centre of mass. All the paper is a very deep analysis of every throwing phase, most interesting and a master paper for the following researchers. In the next figures, we can see some of the results obtained for Seoi and Hiza Guruma (not quite utilized but perhaps one of the Geesink's Tokui Waza?)

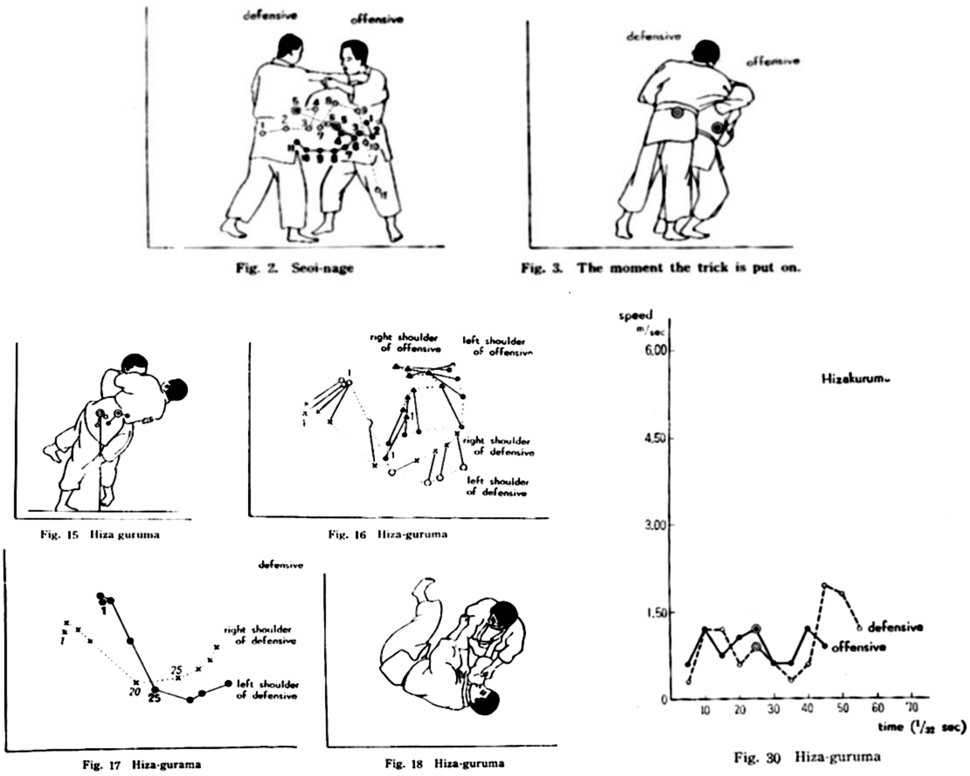


Fig.5.4.a.b .c.d.e.f.g, Japanese old kinetic studies on techniques (1958)

Technique	Landing vel. m/sec	Landing angle	Angle offensive	Impact kgm/sec
Seoi-nage	3.37	74	30	239~249
Katakuruma	5.18	70	65	315~336
Haraikoshi	4.90	70	0	299~318
Tsurikomikosh	7.00	60	60	445~518
Hizakuruma	1.95	68	0	130~140
Osotokari	1.98	90	0	146~146
Tomoenage	5.89	42	68	291~436
Ukiwaza	6.02	40	60	249~391

Tab.5.4.b, Japanese old Kinematic studies

The first Japanese work (published in the US) on the biomechanics of judo throwing, with specific Ergometers, was produced by Shukoh Haga and Kiyomi Ueya; these two authors published a similar work on Female Judo in the Bulletin of Kodokan 1984. The name of the American Paper published in the US in 1997 (about after ten years) was “Techniques of nage waza of judo Biomechanical study.”
The goals were to find data on velocity, force and power of the techniques applied, mainly Harai Goshi, Tai Otoshi, and Ippon Seoi Nage.
The very interesting result was the demonstration that a better thrower (Tai Otoshi) applies more force, power and speed than a lesser skilled thrower. The result was: velocity 1.8 m/s; 2.43 m/s; Force 112 N, 362.9 N; and Power 260 W, 443.2 W.

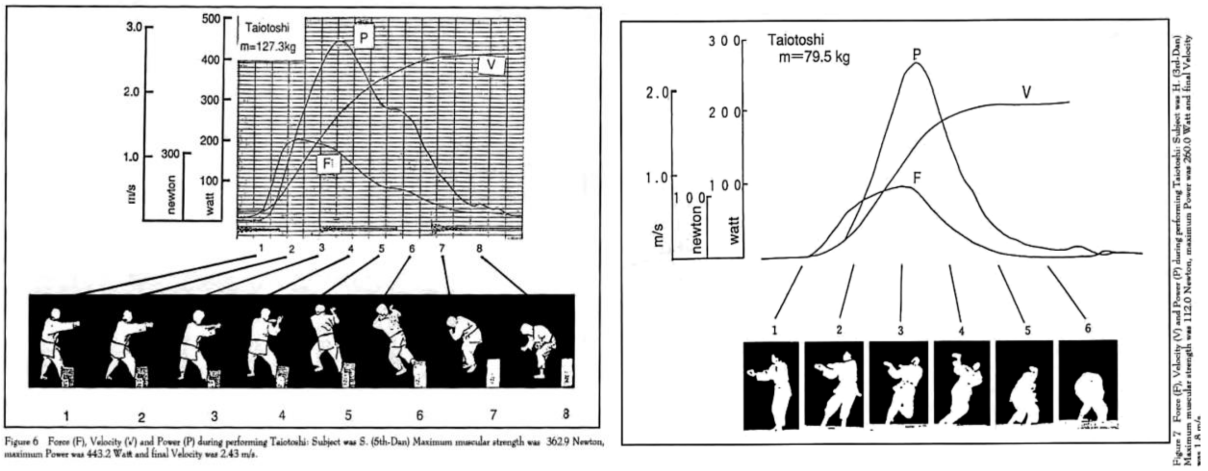


Fig.5.4.h.i, First Biomechanics Japanese Study published in the US.

Very few papers came from Russia; Kovalenko e Kukhitiy (2007) performed a biomechanical evaluation of all the throwing over the back in judo, analyzing different variants of performance.
The aim of the research was to find a common technical base to increase the more convenient technical-tactical skill of the athlete

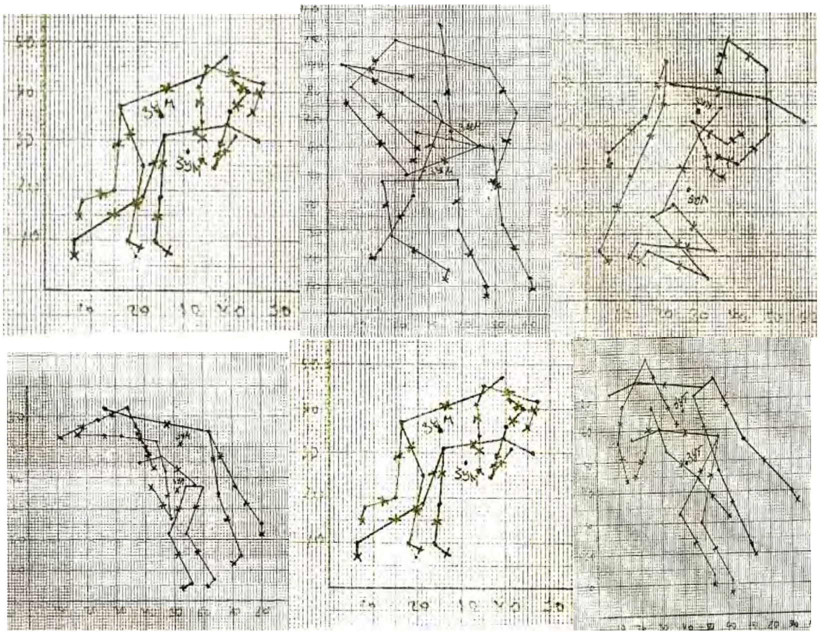


Fig.5.4.k.j.l.m.n.o, Russian Biomechanical Study

From the US, very deep and clever studies were made by Imamura and others, some papers also in connection with Japanese researchers (Iteya and others). The analysis of O Soto Gari, Harai Goshi and Seoi, was mainly performed by these authors, with very interesting findings.
The most original ones were the proposition of *“The Theory of Reaction Resistance.*”

During his studies on kuzushi - tsukuri phases, Imamura found a so-called reaction resistance movement, and this movement was a sideways motion away from Tori pulling hands in middle-lateral direction or for O soto gari to push in forward direction lessening the Centre of Mass.
Imamura proposed that these actions (less evident during the real fight) are unconscious reactions applied by Uke against Tori to stop the Kake phase.
Other findings by Imamura and co-workers are connected to the evaluation of the greater degree of collision for the couple forces techniques Harai goshi and O Soto gari, respect to the skill to apply Seoi Nage, which is connected to the physical lever group with helicoidally trajectory into the cylindrical symmetry.
In the following figures, there are shown the peaks of reaction in the negative versus for Harai, o Soto, and Seoi Nage.

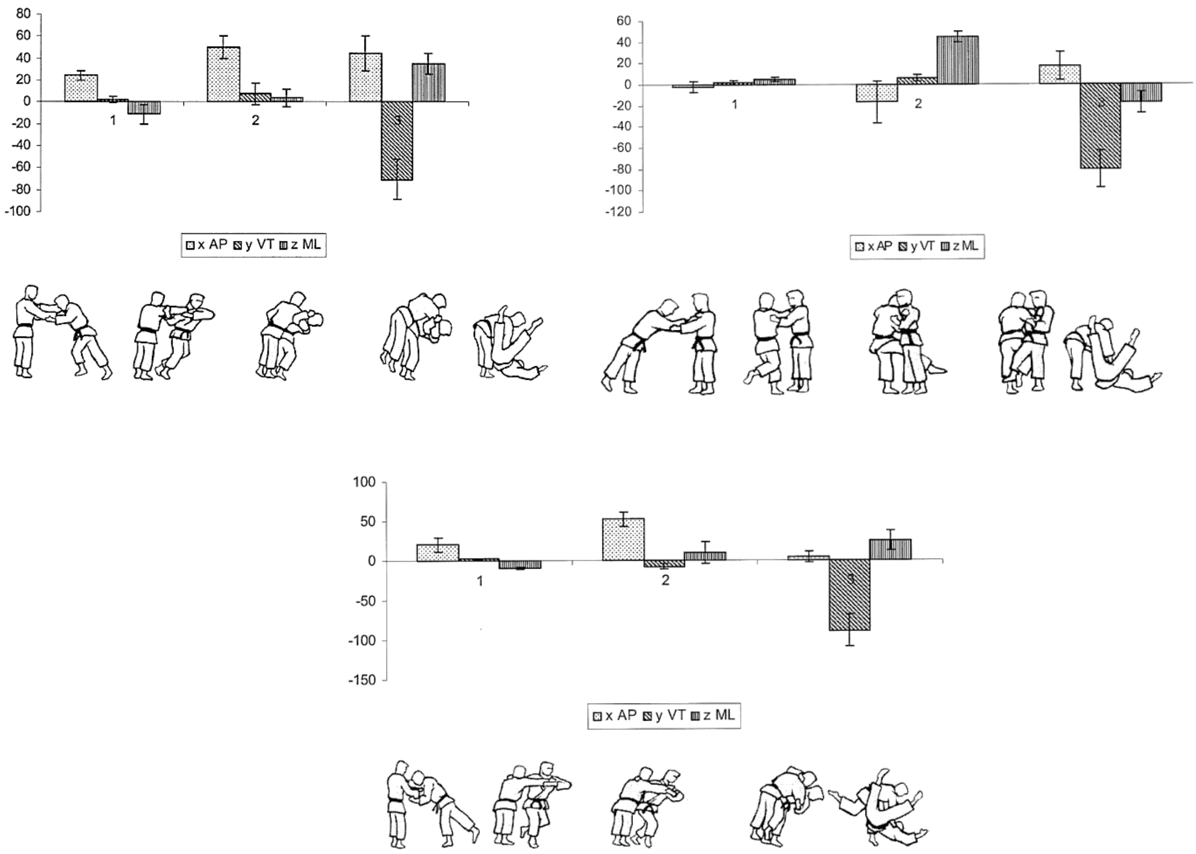


Fig.5.4.p.q.r, US Biomechanical Study

Other findings were produced in Germany by Vieten and co-workers, which tried to connect the effectiveness of throws with the linear momentum transferred by Tori to Uke. In the following figures, there are some of the main results of the Hane Goshi and Harai Goshi comparison.
The two situations Uke pushing and Uke pulling but moving forward shows clearly that in the pulling but moving forward situation, the applied Tori momentum is greater at the state of both techniques, while in the pushing situation, Tori utilizes a part of Uke push applying a smaller start momentum to the adversary.

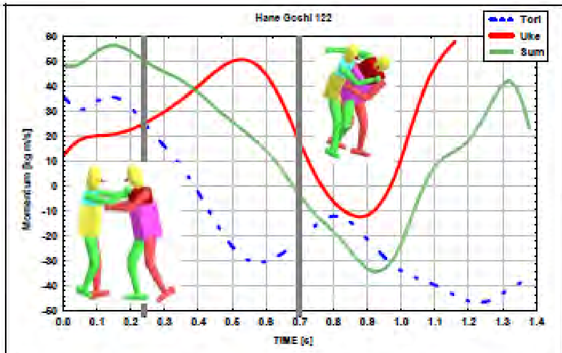


Figure 2: Momentum of a *Hane-Goshi* Throw, Uke pulling but moving forward

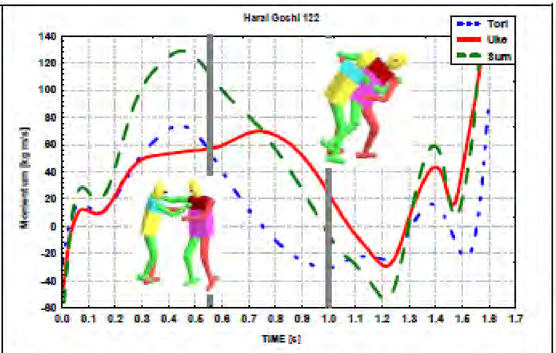


Figure 3: Momentum of a *Harai-Goshi* Throw, Uke pulling but moving forward

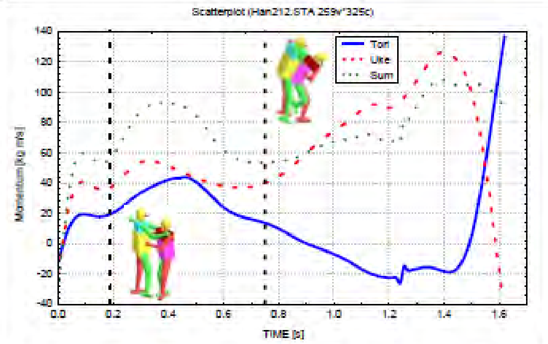


Figure 6: Momentum of a Hane-Goshi Throw; Uke pushing

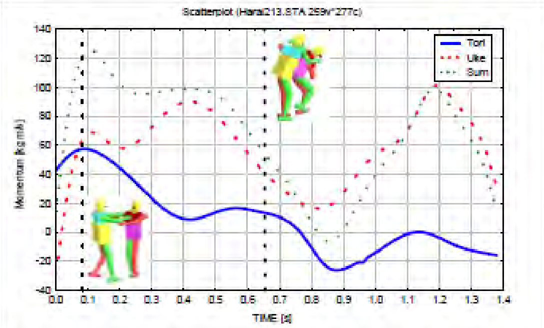


Figure 7: Momentum of a Harai-Goshi Throw; Uke pushing

Fig.5.4.s.t.u.v, German Biomechanical study

In nineteen eighty-four, a complete study on Uchi Mata was performed by Hashimoto and co-workers by two high-speed cameras and a force platform synchronised.
Some of the interesting results are shown in the next figures. The peak force from film and platform were correspondent between 2%, and the result was roughly 1.5 the summation of body weight of Tori and Uke. And the momentum evaluated at ground contact for Uke in the following sequence 1) right upper extremity, 2) right lower extremity, 3) trunk left-side, 4) head; with the following impulses 31.5 kg; 118 kg; and 73.7kg.

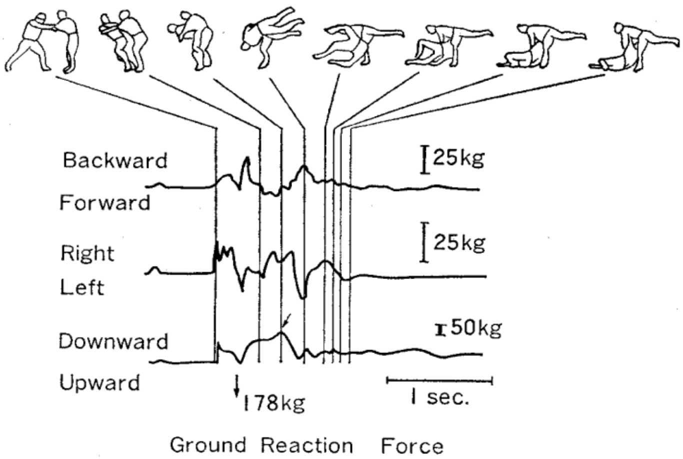


Fig.5.4.w.Japanese modern Biomechanical study

In the following figures, we can see respectively: the single COM displacement, relative both to Tori and Uke, the time variation of the tridimensional velocity vectors, the relative and general system.

COM motion in time recalculated by film and the last the change of momentum of biomechanical chains of the athlete.

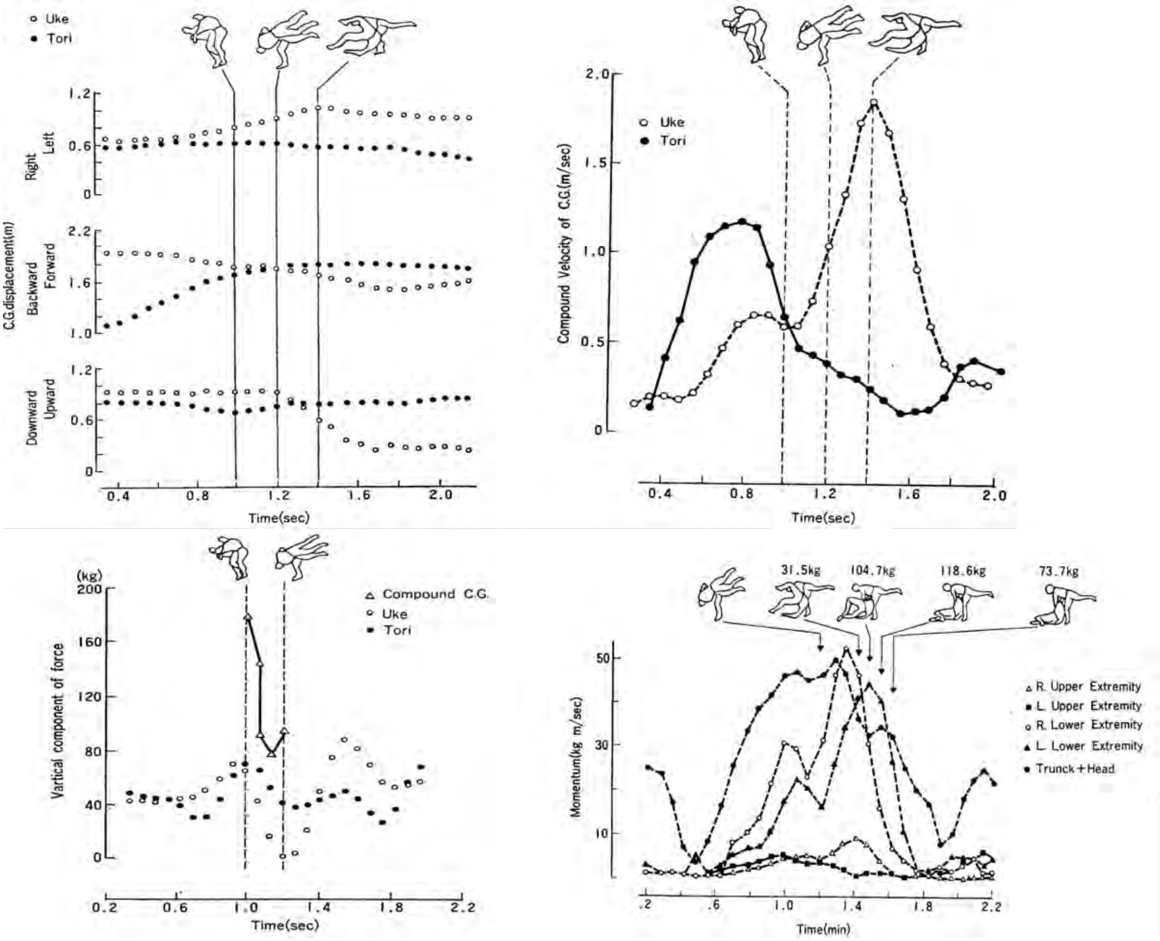


Fig.5.4.x.y,z,aa,.Japanese modern Biomechanical study

Aoki, Hashimoto and co-workers made one deep study on seoi nage by two synchronized cameras analyzing the films obtained by motion analyzer software.

The main results were that the GRF was about three times the Tori body's weight, and they also calculated the impact force for each segment of the Uke body on the mat, ranging from 60 kg to 496 kg. In the following six figures, we can see respectively the shift of COM of both athletes, the time evolution of tai kanzenkei kaku (angle in a forward bent balance) and hiza kansetsu kaku (knee angle), the forces acting during time into Tori's soles during the first and second half of nage phase, the power speed and force applied by Tori, and last the summary of the forces done for seoi nage movement.

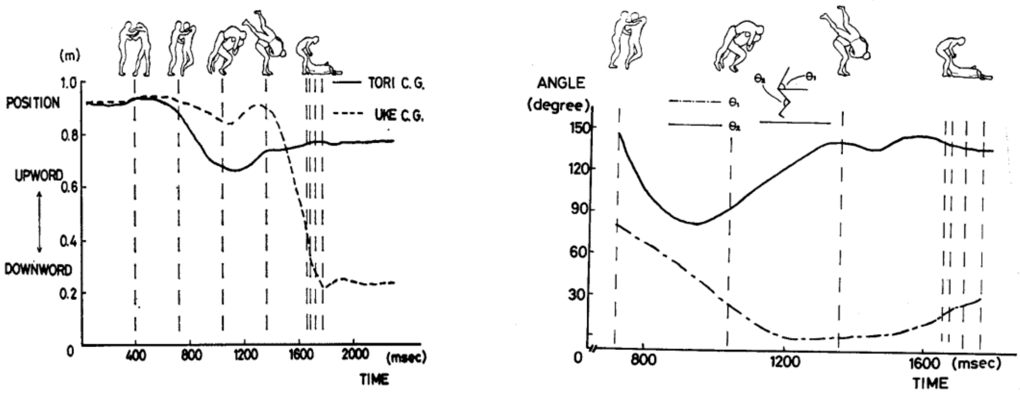


Fig.5.4.aa,bb.Japanese modern Biomechanical study

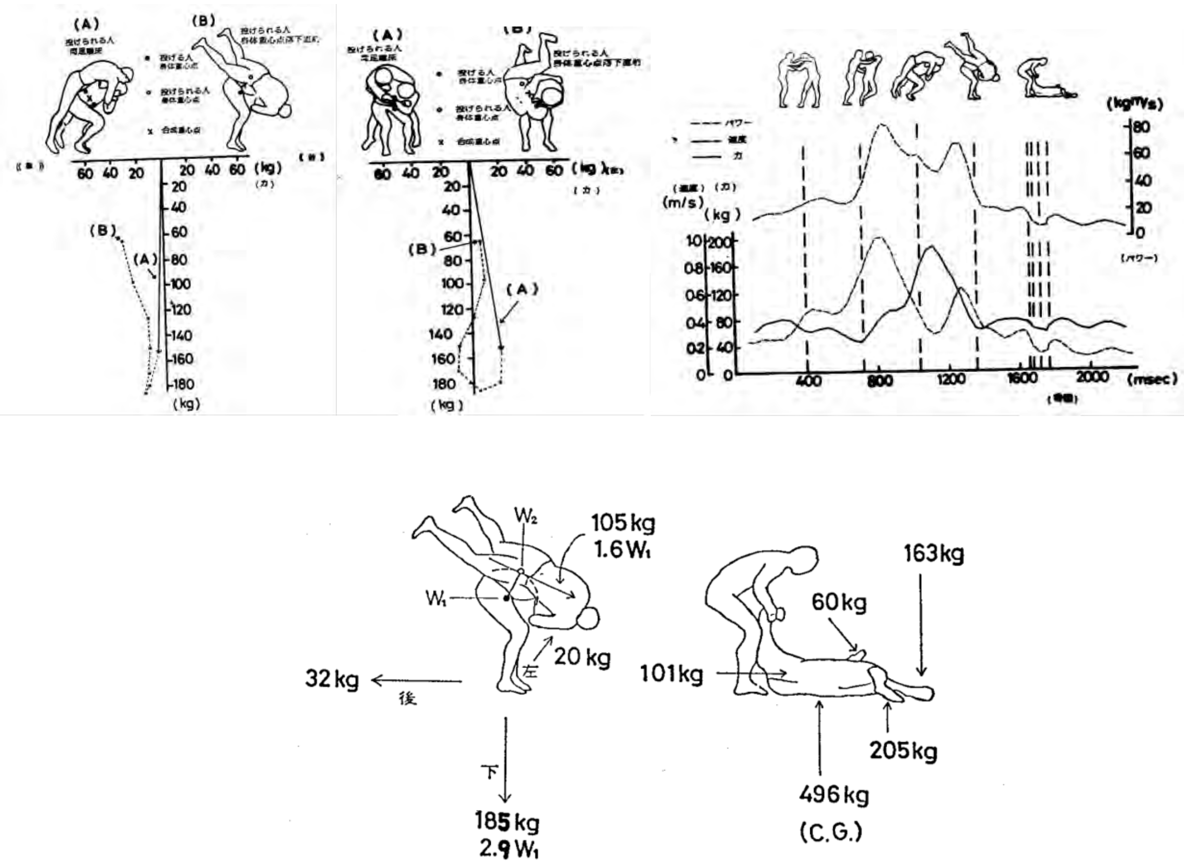


Fig.5.4.cc,dd,ee,Japanese modern Biomechanical study

From Austria, Hassmann and coworkers performed: Judo performance test using a pulling force device simulating a Seoi Nage throws 2011

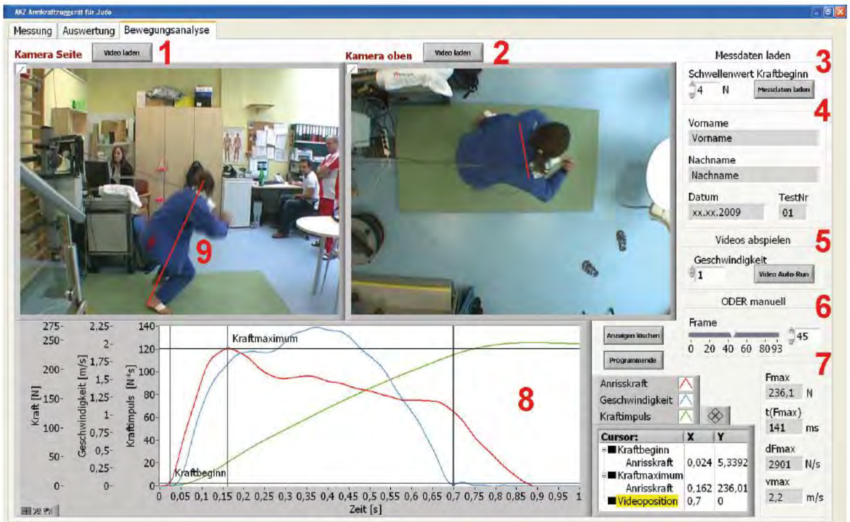


Fig.5.4. ff. The layout of the performance test simulating Seoi Nage

Spain Carretero & Lopez Elvira : *Impacto producido por la tecnica Seoi Otoshi . Relacion con anos de practica y grado de judo* 2014

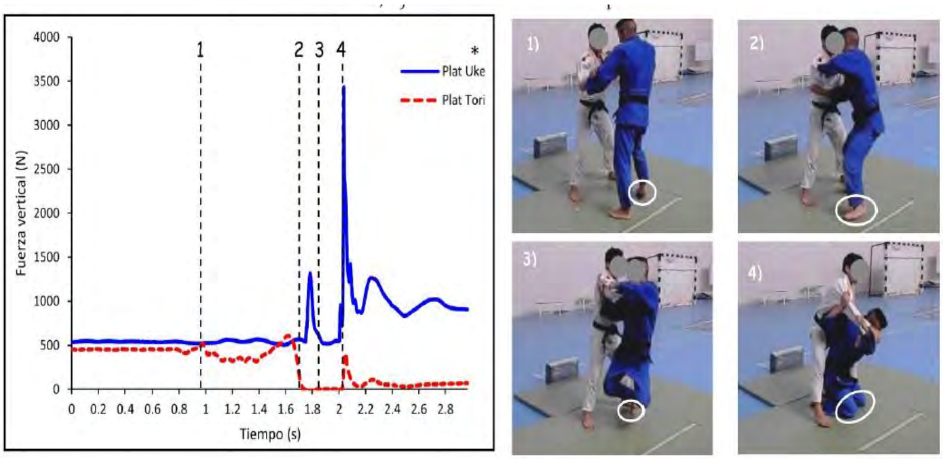


Fig.5.4.gg. Knee Impact in Suwari Seoi [34]

Egypt Ibrahim Fawzi Mustafa, *Force impulse of body parts as a function for prediction of total impulse and performance point of Ippon Seoi Nage skill in judo* 2010

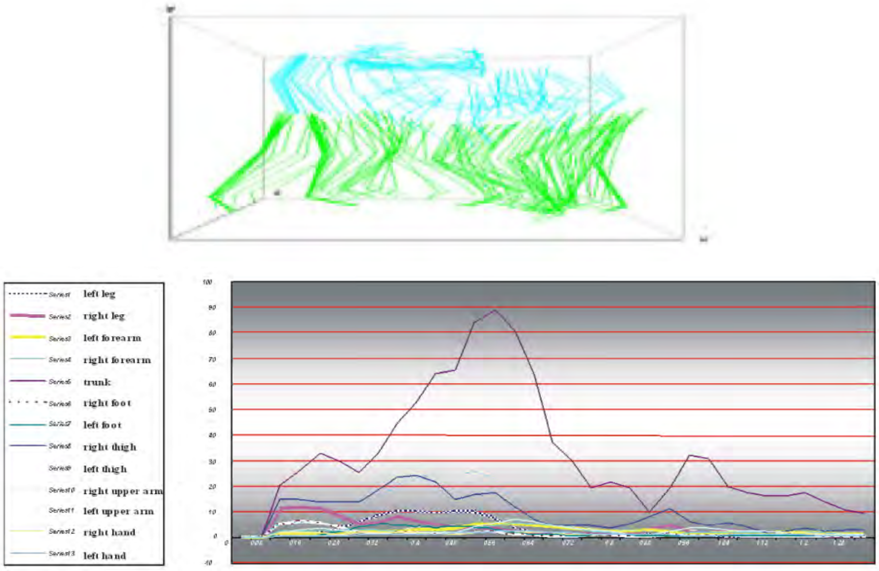


Fig.5.4.hh. Graph of partial forces and total impulse of Seoi performance.

Korea   Ji Tae & Seong- Gyu: *A kinematic analysis of Morote Seoi Nage according to the Kumi Kata types in Judo* 2006

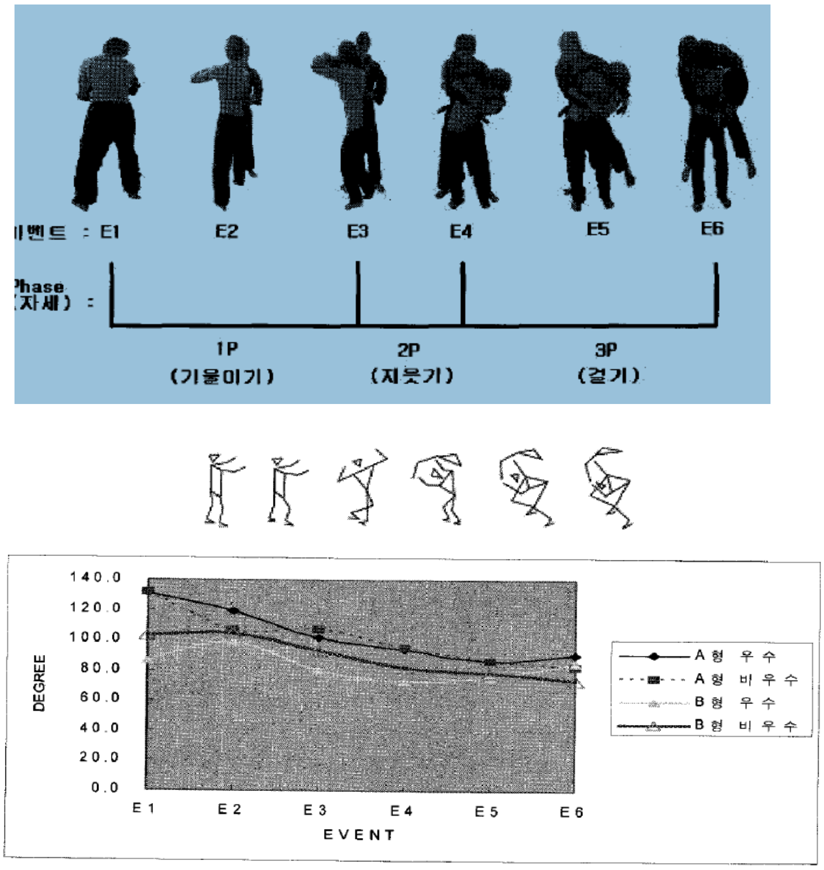


그림 6. 맞잡기 유형간의 집단별 공격팔 팔꿈치각의 변화

Fig. 5.4.ii.ll Layout and Attack Angle in Morote Seoi Nage [

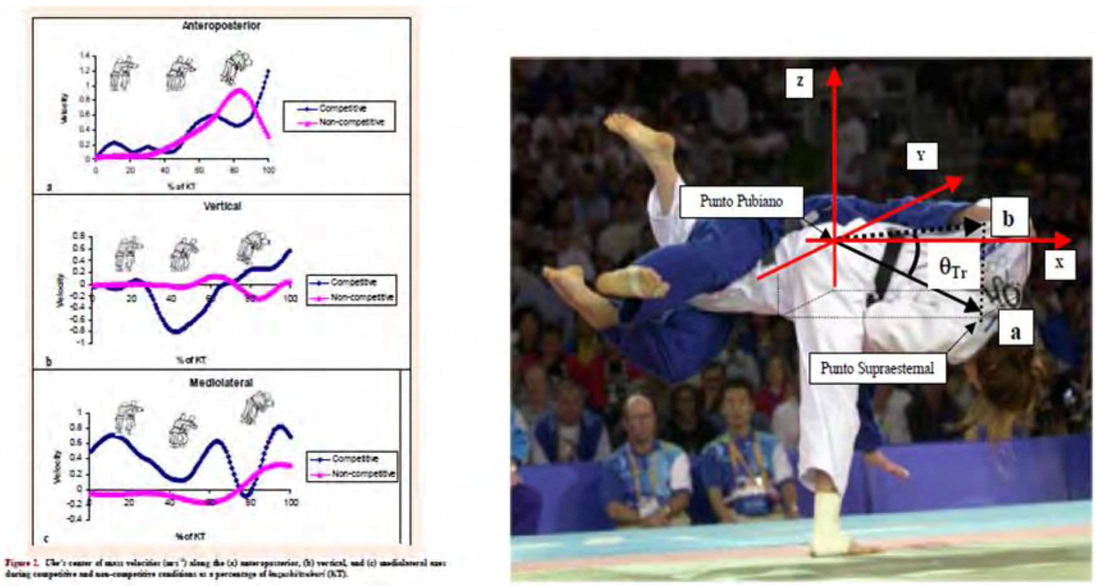


Fig.5.4.mm.nn Spanish thesis on Uchi Mata way of attack

During this time, very advanced biomechanical studies on Judo throws were performed at Poitiers University. This team, utilizing the most advanced scientific tools like Vicon System, Force Transducers, advanced software and so on, has developed the most interesting and original results on the biomechanics of Judo Throws such as global mechanical energy, joints power, force components, apportioning of the moments among knees, hips, and trunk during Kuzushi- Tsukuri-Kake phases and so on. (see Action Invariants) and (Biomechanical Teaching Methods)

The following figures are shown some results connected to Suwari Seoi and Uchi Mata studies. Some interesting data are connected to the time development of grips forces during throws as it is possible to see the left arm in Suwari Seoi works harder than the right unless, in the throwing action, different is the action of the left arm in Uchi Mata because always the right arm works harder during the whole throw execution. The tables, there are shown the relative data to the peak force applied to the sleeve and collar.

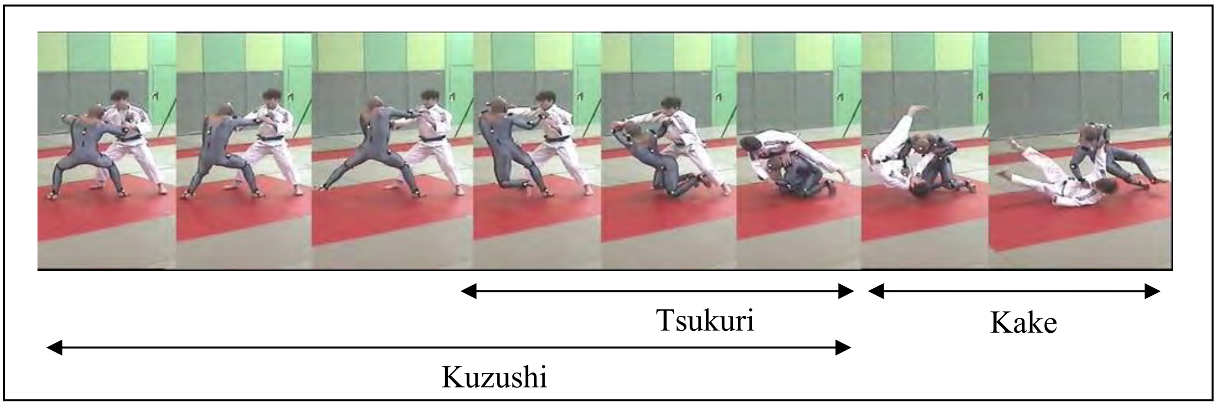


Fig.5.4.pp.French advanced Biomechanical study

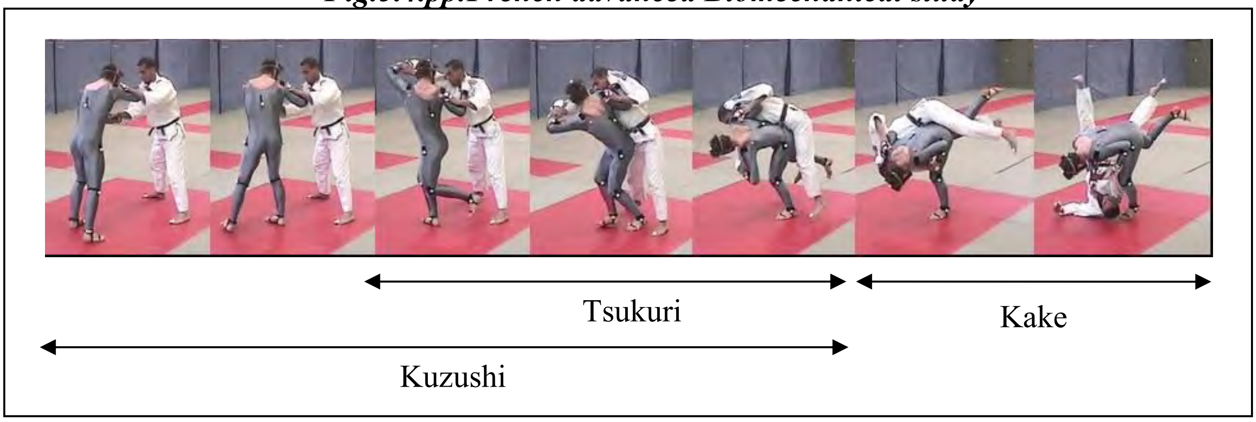


Fig.5.4.qq, French advanced Biomechanical study

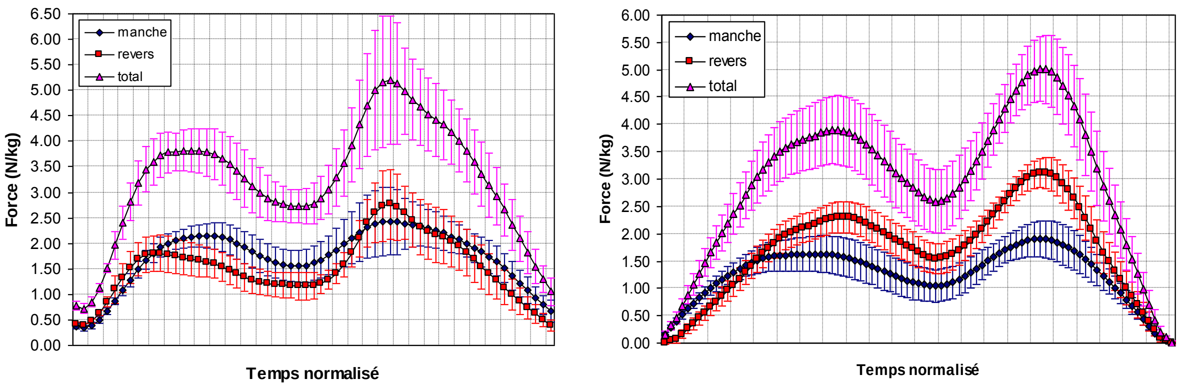


Fig.5.4.rr.French advanced Biomechanical study Time Forces evolution

	MSN group	Position of the sensors	Peak 1 (N/kg)	Plateau (N/kg)	Peak 2 (N/kg)
Table 1	**Average joining forces**	Collar	1,7 ± 0,3	1,2 ± 0,3	2,7 ± 0,6
		Sleeve	2,1 ± 0,2	1,6 ± 0,3	2,5 ± 0,6
		Global	**3,8 ± 0,5**	**2,8 ± 0,6**	**5,2 ± 1,2**

Tab.5.4. c Results of French studies

	UM group	Position of the sensors	Peak 1 (N/kg)	Plateau (N/kg)	Peak 2 (N/kg)
Table 2	**Average joining forces**	Collar	2,3 ± 0,3	1,6 ± 0,3	3,1 ± 0,3
		Sleeve	1,6 ± 0,3	1,1 ± 0,3	1,9 ± 0,3
		Global	**3,9 ± 0,6**	**2,7 ± 0,6**	**5,0 ± 0,6**

Tab 5.4. d. The result of French studies

The last figure shows one of the most interesting results obtained by the Poitiers group (Trilles, Blais and others) the ***Effective Sportive Technique*** effect on the rotation because each athlete in the same technique (Suwari Seoi) performs the turning motion in their own way, these different styles are shown by the different peak numbers in the figures.
It is possible to see different styles of performance, one, two or more peaks of rotation.

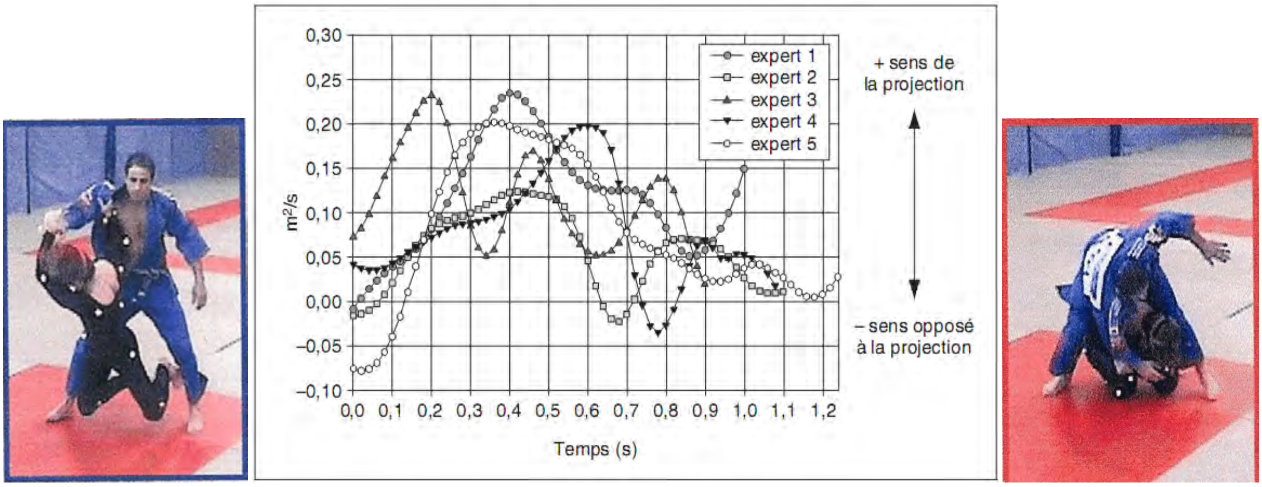


Fig. 5.4.ss. Effective Sportive Technique effect, Different rotation peak numbers

This is the experimental demonstration of the existence and difference between the Rational Sportive Techniques (as an ideal immutable model) and the Effective Sportive Techniques (as personal variation applied by different Athletes) that is able to obtain important sportive results.
The differences among effective variations depend not only on anthropometric differences but also on the actual situation in competition and with a personal style in performing judo skills.

An interesting attempt to analyze the difference between heavier and lighter attack velocities (called in the study speed performance) was performed by Almansba and co-workers in 2008. The result was that the throwing speed was different between the two categories.

1. The lighter had more speed in Seoi Nage
2. The heavier had more speed in Uchi Mata
3. No difference in O Soto Gari

These experimental results are in agreement with the theoretical study performed by the author in 1990 (see appendix I) in which the frequency of attack was evaluated inversely proportional to the square root of Mass of the athletes, directly to the square root of their Oxygen consumption and of their Efficiency of attack (page 439) $f = \frac{1}{2\pi^2 r}\sqrt{\frac{2\eta O_2}{m}}$ and the difference in change of velocity would be $\langle v(t)v(t')\rangle = \frac{2}{m}\eta O_2 e^{-\frac{\mu}{m}(t-t')}$ directly proportional to Oxygen and Efficiency and inversely to Mass (page 437)—utilizing the parameters used in the research: weight < 66 Kg and < 73 Kg, these two quantities are numerically very similar.

Considering for simplicity the same efficiency of each attack, the difference in mean weight and in mean oxygen consumption for each technique gives us the result that the overall difference is only around 0.8%.

This value is too small to justify a clear quantitative difference over the mean value for all three techniques without analyzing deeper efficiencies' fluctuation value and values' difference in oxygen and weight for each athlete.

Energy Cost

The first complete work on throws energy cost was conducted by Yoshizo Matsumoto of the Tokyo University in 1957-8. These pioneering works were conducted with Douglas bags for the calculation of the MRR (Metabolic Relative Rate). $MRR = \frac{O_2^{exs.} - O_2^{rest}}{O_2^{basal}}$

In the following figures, we can see Prof Matsumoto during the researches applied to all Judo techniques, both throws and holding (Tachi Waza-Osae Waza), and some of the results obtained.

Techniques	Average of offensive	Average of defensive
Defensive attitude	18.2	13.5
Uchimata	2.9	2.6
Osotogari	3.5	2.7
Ouchigari	4.0	2.8
Sutemiwaza	3.6	3.5
Seoinage	4.0	3.5
Ashiharai	2.9	2.4
Hanegoshi	4.3	3.4
Attitude directly prior to Newaza	18.5	17.7
Yokoshihokatame	18.4	30.2
Kuzurekamishiho-katame	21.0	29.9

Fig.5.4.tt. Old Japanese studies on Oxygen consumption

By these results, it is possible to see in accordance with the biomechanics findings that the mean energy consumption for couple throws is smaller than lever throws and that for Tachi Waza, the offensive consumption is greater than the defensive ones, in contrast with Ne waza in which it is possible to see the greater energy consumption of the defensive situation respect to the offensive ones.
The most actual and complete analysis of throws energy expenditure was performed by Franchini and co-workers (2008) that analyzed three specific different techniques (Seoi Nage, Harai goshi and O uchi gari). The overall measurements were performed with more modern and up to data tools like the Italian Kosmed K4 in connection with the contribution of the anaerobic alactic system.
The kinetics of post-techniques oxygen consumption or, in other words, the post-technique breath-to-breath VO_2 data were fitted to an exponential model

$$VO_2(t) = \overline{VO}_2(t_{rest}) + A\left[e^{-\left(t/\tau\right)}\right]$$

$$W_{aas} = A \cdot \tau$$

$$\text{with } W_{aas} \text{ as contribution of anaerobic alactic system}$$

Their interesting findings were shown in the following tables with the comparative results of Sugiyama and Kajitani 1995

	Seoi nage KJ/throw	O uchi gari KJ/Throw	Harai goshi KJ/Throw
Sugiyama 1995	8.12 (3.3)	5.31 (0.33)	
Franchini 2008	13.65 (4.3)	11.85 (4.95)	12.9 (4.55)

Tab.5.4.c, In Franchini, is also considered the alactic and lactic contribution, not considered in Sugiyama

These results confirm the energy expenditure differences among couple and lever techniques, showing the energy convenience for the first group. Many other kinds of research confirm these data. Two more types of research are shown in the next figures:
Franchini and coworkers: *Energy expenditure in different judo throwing techniques* 2008

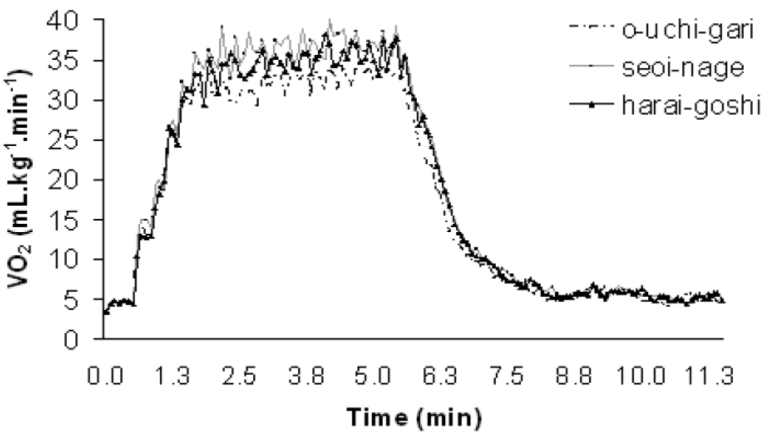


Table 1: Oxygen uptake, heart rate and blood lactate responses for three judo throwing techniques.

	Seoi-nage	*Harai-goshi*	*O-uchi-gari*
VO_2 (mL.kg^{-1}.min^{-1})	33.71±5.68 **	32.28±5.10	29.97±6.10
Heart rate (bpm)	146±14	140±11	139±16
$[La^-]_{rest}$ (mmol.L^{-1})	0.94±0.26	1.02±0.51	0.90±0.33
$[La^-]_{peak}$ (mmol.L^{-1})	1.80±0.56	2.02±1.33	1.73±0.88

VO_2 = arithmetic mean of oxygen uptake during 5-min activity for each technique; $[La^-]_{rest}$ = blood lactate concentration before each technique; $[La^-]_{peak}$ = highest blood lactate value measured 1, 3 and 5 min after the completion of 5-min of activity for each technique (one throw each 15s); ** significantly different from *o-uchi-gari* (P < 0.01)

Fig.5.4.uu. Metabolic results among different throws

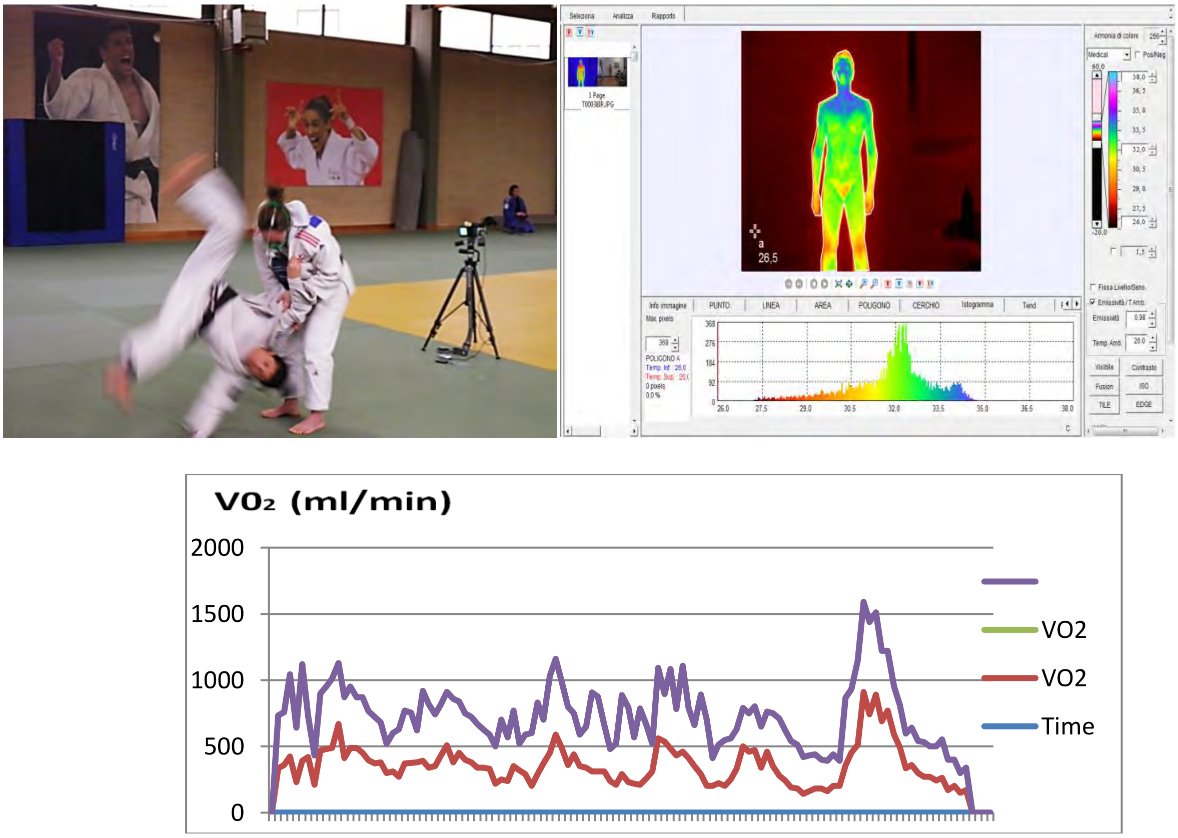


Fig 5.4.vv.ww.zz. Differences between Seoi and Uchi Mata by metabolimeters and thermal camera

Groups	Judo -Throws	K Joule
	Uchi Mata	4,2
COUPLE	Ashi Arai	3,6
	O Soto Gari	4,3
	Ippon Seoi Nage	5,3
LEVER	Koshi Guruma	5,8
	Tai Otoshi	4,9

Tab 5.4.d Difference in Metabolic absolute values of throw biomechanics groups (1980 Sacripanti)


TAMAS ZAHONYI


LCL

Chapter 6 Biomechanics of Groundwork Techniques (*Ne Waza*)

Today with the changes accepted into the referee regulation book, ne waza or ground fight is more important than many years ago. The biomechanical situation laying down on the Tatami is very different from a standing situation because, in the latter situation, a couple of athletes closed system is an isolated physical system, in stable equilibrium, while every single athlete is not more isolated and in unstable equilibrium.

Different physical conditions lying down on the mat; in this situation, each athlete is in stable equilibrium, and if there is one competitor over the other (without grips), the first is a bit more unstable than the latter. (The superior COM is higher than the other COM).

Nevertheless, this different biomechanical condition is able to narrow the application of the potential force because, in this stable situation, it could be applied only physical levers to turn or reverse the adversary.

During ground fighting, like standing fighting, practically infinite situations can happen, and it is impossible to describe the ground fighting in every specific particular.

The most important principle is to move your own body before attempting to move the opponent; this means that personal mobility, also in groundwork, like standing fighting, is the most important parameter like attack velocity in the standing situation.

With better mobility, there is almost always a solution to any situation, whereby swivelling, rolling, moving out of the way, etc., the athlete achieves easily, rapidly and effectively, what can be performed. Inversely he achieves only with great effort and slowly by moving the opponent primarily.

Technical actions are grouped in ne waza judo in three big families Oase waza (Holding), Shimewaza (Choking), and Kansetsu waza (Armlock).

If we compare it to the Tachi waza, Osae waza are like Throws in standing position, because if somebody remembers, both Choking and Armlocks are also allowed in standing position.

During groundwork, renzoku and renraku waza are present with different meanings. In ne waza fighting, very often the combinations are more complex than Tachi waza because usually, it is most effective to change the type of technique in a fluent continuous way from osae to shime, to kansetsu and so on, as the better opportunity that makes they useful and effective depending from the bodies' relative position and the real necessities of the specific situation.

The relaxation and the relatively slow velocity of the attack increasing do not make groundwork easier than standing techniques; both have the same difficulties although, from a different point of view, both show the same principles about mobility, hips freedom of movement, control over the adversary, unbalance, and relaxation.

Many books are specialized on ne waza from the most interesting we can consider the book of Feldenkrais "*Higher judo" groundwork*, Valin "*Judo au Sol*", Beaudoin "*Ne Waza*", Awazu "*Metode de Judo au Sol"* Flamand Gilbert " *Judo Champion*", Vismara "*Judo Competizione*", Kudo "*Judo In Action*", Okano "*Vital Judo*", Kashiwazaki "*Fighting Judo*", Harrison "*Judo On the ground",* Adams & Carter "*Olympic Judo "groundwork techniques*

In the next paragraphs will be shown only the ***cognitive classification of the Rational Sportive Techniques*** and not the ***cognitive-motor learning arrangements*** because in judo, in the author's knowledge, there is not a separate and structured cognitive arrangement about this topic, but they are introduced by Dr Kano as complementary techniques in the previous arrangements.

6.1 Holds Physical principle and Classification (*Osae Waza*)

Holds (Biomechanical principles and Conceptual classification)

Considering the ***Rational Sportive Technique*** model of hols, the biomechanical principle, which is at the basis of the Osae Waza classification, is very clear and easy to understand.
It is the physical principle that assures that if the exerted pressure by Tori over Uke supine down on the mat is greater than an amount R equal to the maximum reaction force that Uke can produce, the control will be effective and lasting.
The only external force acting on the coupled system will be the gravity force, which acts on the Tori body's mass will produce the weight that will work as pressure on the Uke body's surface, locking it on the mat.
One should always remember that the words" immobilization" and "holding" do not describe the actual state of affairs-they convey the idea of finality and fixity that do not exist in action.
An immobilization is dynamic and constantly changing all the time.
0sae waza is the root of all newaza. It is vital to start with a sound knowledge of osae-waza. Learning how to turn an opponent into a hold and then keep him there is one of the key skills of ne waza judo.
The opponent generally frees himself as soon as the athlete stops forestalling and checking his next move, losing the pressure control.
It is important to underline some details which single out, in the light of the biomechanical analysis of the matter. The most important difference between Kesa (scarf hold) and Shiho (four-quarter hold) groups is that pressure exerted by Tori is, on the first group, applied by the lateral-costal side of the trunk, into the second one by the breast-bone side of the thorax.
This anatomical difference means a different amount of pressure applied on the Uke body, in fact remembering the formula:

$$\Delta P = \frac{\Delta F}{S} = \frac{\Delta mg}{S} \begin{cases} Kesa\ S_1 \\ Shiho\ S_2 \end{cases} if \rightarrow S_1 < S_2 \Rightarrow \frac{mg}{S_1} > \frac{mg}{S_2}$$

It is possible to state that the Kesa group exerted pressure is greater than that exerted by the Shiho group. This is true in the optimal biomechanical condition and more relaxed and with good hips control over Uke the Tori body will be, even more, the real condition will be like the optimal ones.
In the Shiho group, the lessening in pressure needs increasing help by the upper kinetic chains (arms) to lock Uke on the mat. The arms and hands are very important to gain effective control over the adversary. Grips on the Uke body aim to lock his body strongly to Tori body, providing to the lessening in pressure with the increase in a rigid connection between the two bodies, while the inferior kinetic chains (legs) normally tights aim to contrast the threatening to roll by Uke.
This last action is possible in two ways or increasing Tori's Inertial momentum (by open one's legs) or blocking the roll tentative with the knee.
The most important Uke reaction in the Shiho group is to roll. Then if Tori gains the Uke's head control, the optimal action will be to lock the Uke's cheek on the mat, then for obvious biomechanical properties, Uke can't roll in the nape of the neck direction, this means to lessen around to 50% the reaction capability of Uke.
.In the Sankaku group (Triangular hold), the pressure on the upper part of the thorax- shoulder blade-humerus- is applied by Tori's hips, and then lower kinetic chains (legs) lock the Uke's shoulders while the upper kinetic chains (arms) are moving with stabilizing function.
It must be remembered that pressure in the Kesa group is applied by the lateral –coastal side of the thorax.
In Shiho, group pressure is applied by the breast-bone side of the thorax. And finally, at the end of the Sankaku group, pressure is applied by the pelvis in connection with lower kinetic chains. And in the fighting, osaekomi pressure is connected to the hips zone put on Uke or to the head and neck put on Uke body. On this basis, it is possible to classify biomechanically speaking all the holds by pressure exerted and energy consumption connected.

Osaekomi Group	Pressure Exerted	Energy Wasted	Tori Stability	Biomechanical Value
Kesa	High	Low	High	Very good
Shiho	Medium/ Low	High	Medium	Good
Sankaku	Medium/Low	High	Medium	Good
Fighting osae	Very low	Very high	Very low	Poor

Tab.6.1.a Biomechanical classification of osae waza

The specific use of the kinetic chains, both upper and lower, for each group can be divided as

a. ***Primary Support*** or very strong tie to hold this function is directly connected to the exerted pressure greater is the pressure, lower is the kinetic chains primary support
b. ***Secondary Support*** or also stabilizing this function is pressure connected, but it is also related to relative bodies' position.

Primary Support		***Secondary Support***	
Kinetic Chain	***Hold Groups***	***Kinetic Chain***	***Hold Groups***
Arm	Kesa	Arm and Legs	Kesa
Arms	Shiho	Legs	Shiho
Legs	Sankaku	Arms	Sankaku
Arms and Legs	Fighting	Arms and Legs	Fighting

Tab.6.1.b Biomechanical connection between the kinetic chain and osae waza

It is necessary to understand the connected defensive methods that Uke could apply to break the hold. The main Uke defence is based on lifting Tori body by bridging, and when Tori's hips are lifted, Uke can roll and break the hold.
Other methods are connected to the Uke capability to apply shime (choking) or kansetsu waza (armlocks) or to hook Tori leg by his legs
The Uke biomechanical methods for freeing himself are:

a. Direct opposition to the pressure exerted by gravity component ***bridging method***
b. Indirect opposition to the pressure exerted by gravity component ***rolling***
c. Combined opposition to the pressure exerted by gravity component ***bridging +rolling***

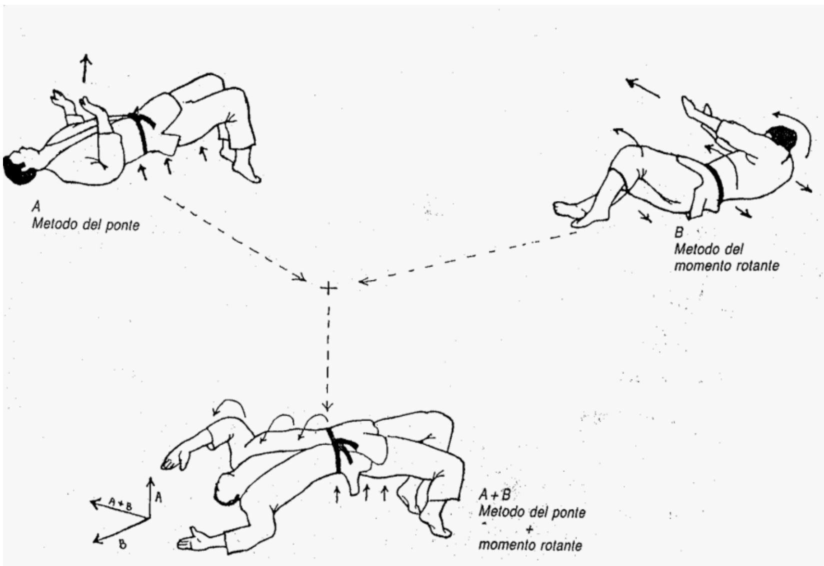


Fig.6.1.a Biomechanical method to break osae waza.

Fig.6.1.b.c.d.e.f.g.h.i.j, Example of Fighting and Classical Osae komi Waza (Zahonyi)

The Kodokan classification considers only Kesa and Shiho groups, but in his book (*Judo wa ko shite susume*), T. Oda describes before the fundamental holds (Osae Kata), the variation (Henka) and at last 65 methods to attack (Hairi Kata). His classification considers four groups KESAGATAME-KEI, SHIHOGATAME-KEI, UKIGATAME-KEI, and SANKAKUGATAME-KEI.
One of the complete classifications and motor learning systems was performed by Kawaishi. He showed in his book seventeen holds classified as laterals, longitudinal, transversals, and transitional, connected by a continuous motion evolution.

Kesa gatame	Mune gatame	Ura shiho gatame
Kata gatame	Tate shiho gatame	Kami sankaku gatame
Kami Shiho gatame	Kuzure kesa gatame	Kuzure yoko shiho gatame
Kuzure kami shiho gatame	Kata osae gatame	Tate sankaku gatame
Gyaku kesa gatame	Ura gatame	Uki gatame
Yoko Shiho gatame	Kashira gatame	

Tab.6.1.c Oda osae komi waza classification

Kolychkine classified the osae waza by his personal method of Primitive and analogous movements.

Primitive	***Kusure kami shiho gatame***	***Yoko shiho gatame***	***Kusure kesa gatame***
Analogous	*Gyaku kesa gatame* *Kata osae gatame* *Kami shiho gatame* *Ura shio gatame*	*Mune gatame* *Tate shiho gatame*	*Kesa gatame* *Kata gatame* *Makura gatame*

Tab.6.1.d Kolychkine Osae waza classification

In the old Japanese study, *an analytical study on the position of the centre of gravity in the osae-waza, art of holding in judo* was studied both the position of each COM and the position of COM of a couple of athletes, in the next figures, there are shown the results.

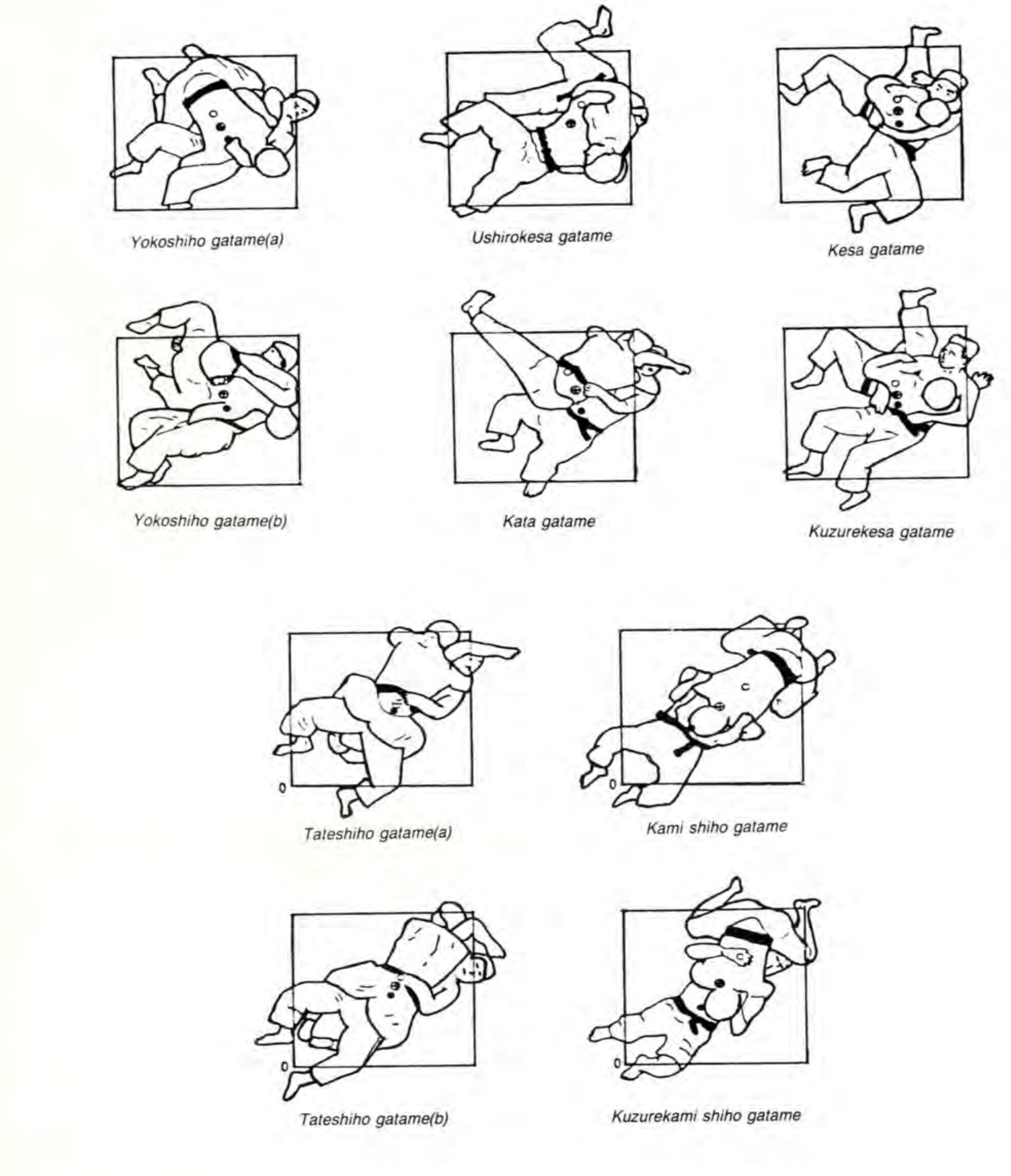


Fig.6.1.k. the relative position of COM in osae waza

In terms of energy consumption, old Japanese studies showed that Tori wastes more energy during the standing phase attack (RMR 18.5 vs 17.7), inversely during ne waza, the situation is completely reversed Uke wastes much more energy than Tori for example:
Yoko Shiho (RMR 18.4 vs 30.2) and Kuzure kami Shiho (RMR 21 vs 29.9).

6.2 Choking Physical Principle and Classification (Shime Waza)

Choking biomechanical approach

In the sport of Judo, all neck restraint variations are referred to under the global term *shimewaza.*
The biomechanical analysis shows that all the neck restraint is based on the ***Physical Lever Principle***, like throws of the lever group.
The main difference among them is that choking is based on the physical lever of the second type or inter-resistant lever because the neck (the resistance) is always in the middle between fulcrum and force application.

Fig.6.2 .a.b, Shime waza in real competition (Zahonyi)

Choking can be further grouped into two categories; respiratory and carotid (or vascular).

Respiratory choking			
Hasami jime Katate jime		Hadake jime Mae hadaka jime	
Vascular Choking			
Nami juji jime Gyaku juji jime Kata juji jime Ura juji jime	Kata ha jime Sode guruma jime Tsukkomi jime Tawara jime	Okuri eri jime Morote jime Sankaku Jime Gigoku jime	Katsugi jime

Tab.6.2.a Physiological division of choking

Respiratory Choking

The respiratory or 'armbar' choking is facilitated by applying direct mechanical pressure or compression over the structures in the anterior portion of the throat. Although this technique also can result in compression of the carotid arteries (leading ultimately to unconsciousness), the pressure created on the front of the throat also causes asphyxiation by compressing the tracheae and restricting or inhibiting the subject's ability to breathe.

Compression of the anterior structures of the throat can lead to serious injury to the cricoid cartilage, the thyroid cartilage, the hyoid bone, the larynx, and the trachea. When improperly applied with an upward pulling motion, respiratory neck holds have been implicated in vertebral fractures.

Vascular Choking

Vascular choking is a technique that applies lateral compression to the vascular structure of the subject's neck resulting in partial or complete occlusion of the carotid arteries as well as occlusion of the jugular veins. A properly applied VC will not compress or harm the structures located in the anterior portion of the throat, nor is it likely to cause harm to the cervical vertebrae; the subject's ability to breathe is not adversely affected during VC compression.

The subject is likely to experience pain due to the compression and stimulation of various nerves that are affected, such as the Hypoglossal nerve, the Brachial Plexus Origin and possibly the Suprascapular nerve.

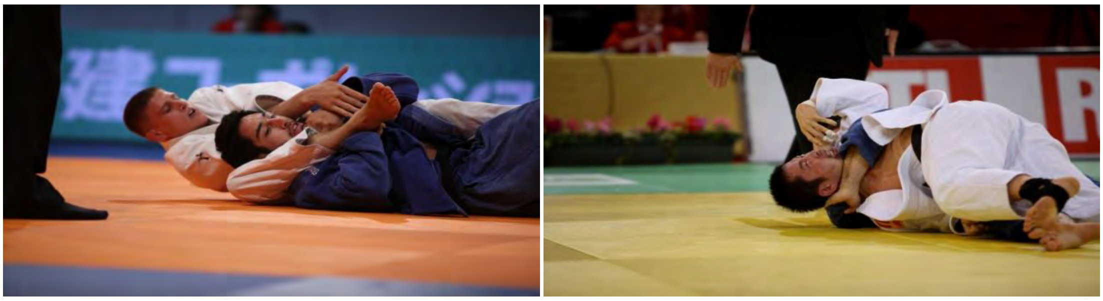


Fig.6.2.c.d two strong chokings in competition (Zahonyi)

Kawaishi classified the shimewaza in two groups starting from the bodies' relative position. More than a classification, the founder of French judo presented a motor learning progression based on the flowing continuity of movements from one position to the following.
The choking was grouped in two series the first series is based on six starting positions, the second one four. The internal duties of lower kinetic chains grow in importance.

First Kawaishi Group
1 kata juji jime 2 gyaku juji jime 3 yoko juji jime 4 oshiro jime 5 okuri eri jime 6 kata ha jime 7 hadaka jime 8 ebi garami 9 tomoe jime 10 eri jime 11 kensui jime 12 kata jime 13 do jime 14 hiza jime 15 tsukkomi jime 16 ebi jime 17 hasami jime 18ohten jime
Second Kawaishi Group
1 narabi juji jime 2 katate jime 3 sode guruma 4 hidari ashi jime 5 kagato jime 6 kami shiho jime 7 kami shiho ashi jime 8 kami shiho shami 9giaku okurieri 10 kaeshi jime 11 giaku gaeshi jime

Tab.6.2.b, Kawaishi shime waza classification

+
Kolychkine classified choking in a usual style based on the action side.

Forward action	Backward action	Sideward action
Gyaku juji jime *Kata juji jime* *Tsukomi jime*	*Ushiro jime* *Okuri eri jime* *Kata ha jime*	*Tomoe jime* *Sode guruma* *Othen jime*

Tab.6.2.c, Kolychkine Shimewaza Classification.

6.2.1 Physiological effects.

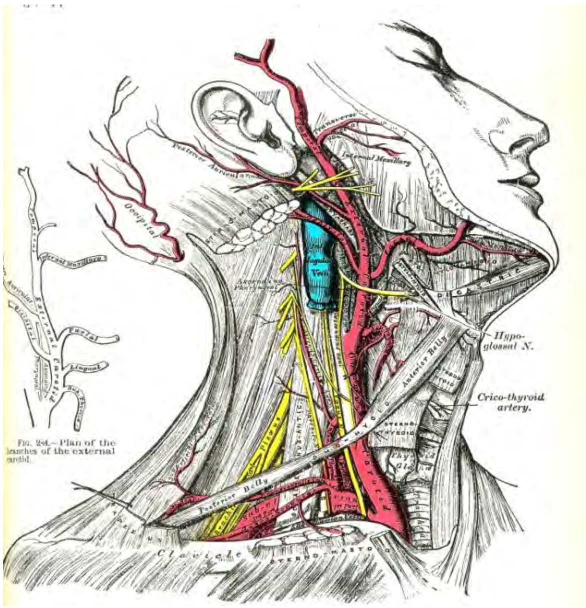


Fig.6.2.1a, Arteries and veins of the neck (by Gray's Anatomy)

Vascular Choking affects various structures of the head, neck and upper torso. When the athlete applies a vascular choking to the adversary, bony structures, cartilage, muscles, circulatory system and the nervous system are all affected to various degrees.
It is a combination of these factors together that makes the technique capable of rendering the subject unconscious, and then we analyze each component factor separately.
Bony Structures
The seven cervical vertebrae are present in the portion of the subjects' neck where the Vascular Choking is applied. When properly applied, the choking will not adversely affect these bony structures.
The adversary's sternum could also be affected as the athlete applies pressure downward and inward on the subject's chest with the leg of the encircling sankaku jime.
But normally, for each vascular choking like okuri eri jime and others, the sternum is not affected at all. The hyoid bone is a small 'horseshoe' shaped bone located deep in the throat under the tongue.
A properly applied vascular choking should not adversely affect the hyoid bone as there is no compression on the subject's airway.
The mandible is another bony structure affected by vascular choking as the lateral compression will apply pressure to both sides of the subject's mandible.
This results in discomfort to the subject as nerves located in this region are compressed against the bony process of the mandible.

Cartilage
The trachea, which contains the thyroid cartilage and cricoid cartilage, is located in the region of the neck where the vascular choking is applied.
The thyroid cartilage sits just above the cricoid cartilage and can be felt as a firm area just at the "Adam's apple".
The tracheal rings are more compressible than the thyroid and cricoid areas.
The trachea is the structure that allows for the passage of air to and from the lungs.
A properly applied vascular neck restraint will result in only minimal pressure on these structures; damage or injury is extremely rare.

Muscles
The sternocleidomastoid complex originates on the sternum, and the clavicle travels upwards along the side of the neck and inserts on the mastoid process of the skull.
The trapezius originates on the C-Spine and has attachments to the skull, scapula and clavicle. The application of vascular choking may result in temporary muscle soreness as a result of compression following a maximal compression application.
These muscular structures will not likely be injured as a result of a vascular choking application.

Circulatory
1. ***Arteries***: arteries carry oxygenated blood away from the heart. They are thick muscular-walled vessels and are the high-pressure aspect of the circulatory system.
The arteries that flow in or near the neck are the subclavian, carotid and vertebral arteries.
Arteries in the neck are not easily compressed without specific and direct pressure.
Only the carotid arteries are directly affected by vascular choking.
Arterial blood is supplied to the brain chiefly through the internal carotid and the vertebral arteries. The vertebral arteries are not easily compressed because of the bony vertebral structures that they pass through at the back of the neck.
The carotid arteries are occluded by the compression of the sides of the neck by the vascular choking application.
2. ***Veins***: veins carry deoxygenated blood back to the heart; they are the thin-walled, low-pressure aspect of the circulatory system and are easily occluded by external pressure.
The veins involved in the vascular choking application are the external and internal jugular veins. The venous return from the brain is chiefly accomplished through the internal jugular and external jugular. These veins are surrounded by muscle tissue are readily occluded by cervical pressure.
Nervous System
There are numerous nerves that travel along the sides of the neck.
The only affected nerve that *may* contribute to unconsciousness is the vagus nerve. The vagus nerve is one of many physiologic structures involved in controlling the heart rate and blood pressure. Artificial stimulation of the vagus nerve by external compression on the carotid bulb can result in a lowering of the heart rate.
Vascular choking is founded on the compression of the carotid arteries, compression of jugular veins and compression of the carotid bulb, which stimulates the vagus nerve.
The totality of these effects results in a decrease in blood supply to the brain, which in turn leads directly to altered levels of consciousness.
It must be understood that different subjects are affected by the technique in different ways, and some subjects may not be rendered unconscious at all (no technique is 100% effective).
The most extended studies on choking were performed in Japan about forty years ago. ***Physiological Studies on Choking in judo*** with the following goals:

1. Differences between vascular and respiratory choking.
2. effects during the time of choking
3. physiological mechanism of unconsciousness
4. dangers in choking

The answers to the previous points were obtained by electroencephalography, oxygen amount in the blood, electrocardiography, variations in fingers and forearm volumes, skin temperature, breathing movements, pupil reflexes, urinary reaction, cramps and convulsions.

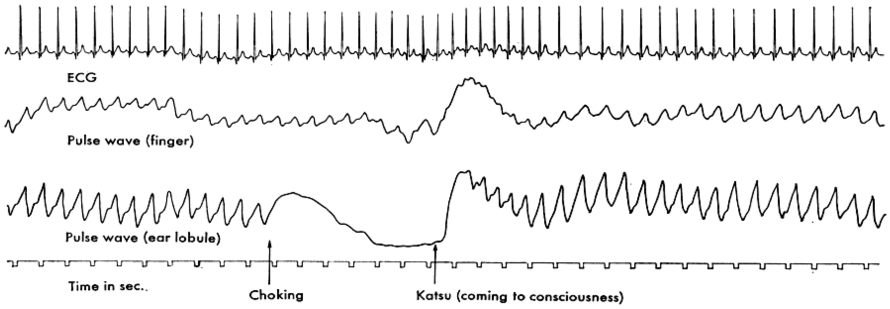


Fig. 3. Simultaneous recording of ECG and pulse wave during choking in Judo.

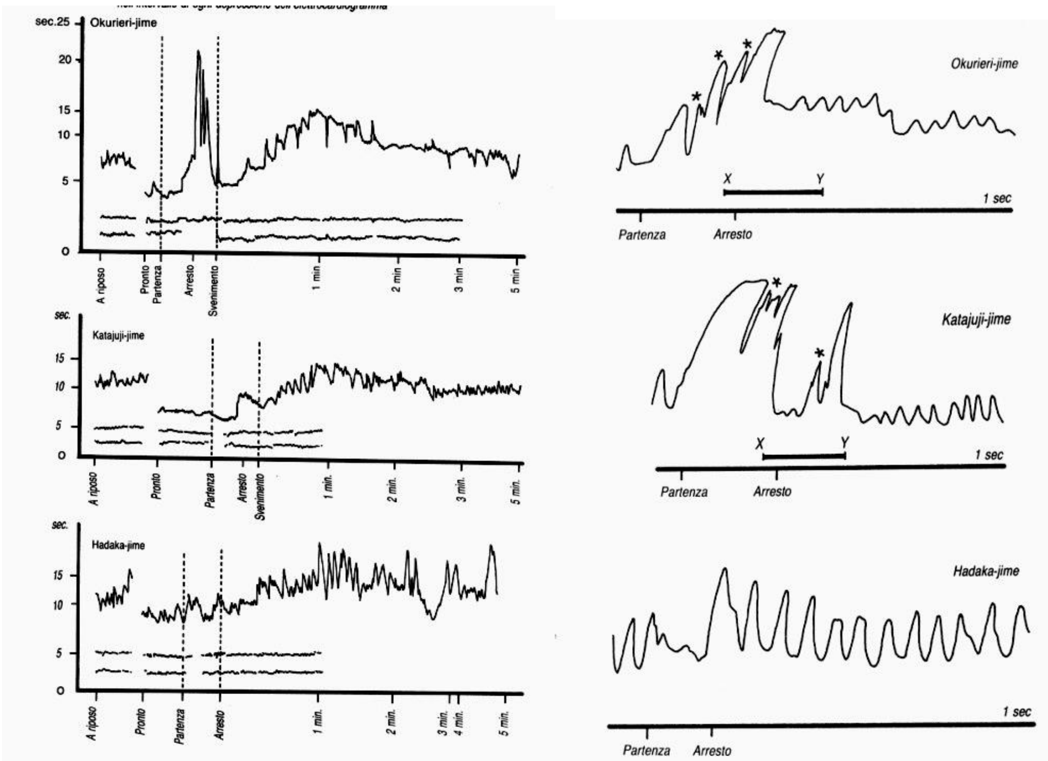


Fig.6.2.1.b.c.d, Some Results of the complete Japanese study on Choking (Physiological Studies on Choking in judo from the bulletin of Kodokan)

All the subjects didn't reach the unconscious during respiratory choking, but all they fell unconscious during vascular choking, based on the mechanical stop of blood to the brain.

Convulsions that arose during unconsciousness were very similar to epilepsy convulsions, and they are produced by the lack of blood to the brain and response of the vagus nerve.

6.3 Joint Locks Physical Principle and Classification (*Kansetsu Waza*)

Joints' locks

The physical principle that is basic for the ***Kansetsu Waza*** (dislocation techniques) there is again the principle of the physical lever, which result is to push. Both joint mechanics and motion muscles function out of the natural physiological boundaries.

The classical Japanese classification based on the joint name affected that is: ***Ude Waza*** (elbow techniques), ***Kubi Waza*** (neck techniques), ***Kote Waza*** (wrist techniques), ***Yubi Waza*** (fingers techniques), ***Koshi Waza*** (hips techniques), ***Hiza Waza*** (knee techniques), ***Ashikubi Waza*** (ankles techniques), ***Ashi Waza*** (feet techniques) ***Sekizuki Waza*** (Spinal column techniques)

In judo Sport, only Ude Waza are allowed in competition. Sometimes it is possible to see some ashikubi waza and ashi waza utilized to push down on the mat one competitor.

Kawaishi classified with the progressive position method only the ude waza allowed and without logical connection both ashi kansetsu waza and kubi kansetsu waza.

Ude kansetsu waza Kawaishi Method					
1 position	2 position	3 position	4 position	5 position	6 position
Udehishigi juji gatame Ude garami Ude hishigi Yokohiza gatame	Kami udehisigi juji gatame Yoko ude hishigi Kami hiza gatame	Ude hishigi henkawaza Giuaku juji Shimen garami Hiza gatame	Hara gatame Ashi gatame Ude garami henkawaza Ohten gatame	Kesa garami Kuzure kami shiho garami Giaku kesa garami Mune garami Mune giaku	Giaku tekubi Hizi makkomi Kuzure hizi makkomi Kannuki gatame Ude hishigi hiza gatame

Ashi Kansetsu Waza Kawaishi Method
Kata ashi hishigi
Rio ashi hishigi
Hiza hishigi
Tate Shiho hiza hishigi
Ashi makkomi
Kani garami
Ashi kannuki
Hiza tori garami

Kubi Kansetsu Waza Kawaishi Method
Kubi hishigi
Osae hishigi
Tate hishigi
Giaku hishigi
Tomoe hishigi
Kesa gatame kubi hishigi

Fig.6.3.a.b.c, Kawaishi classification of kansetsu waza

The anatomy of upper kinetic chains and the elbow joint mechanics allow us to single out two groups of Ude waza:

Ude Hishigi based on the elbow hyperextension mechanics

Ude Garami is based on the forearm supination/pronation motion that puts the elbow under stress.

If we consider the arm built by two main components, bone and muscles (everyone considered as safe, perfect systems), it is possible to apply the catastrophe theory to obtain a unified mathematical approach to all types of joint locks.

Catastrophe theory is a branch of bifurcation theory in the study of dynamical systems.

Bifurcation theory studies and classifies phenomena characterized by sudden shifts in behaviour (the joint break) arising from small changes in forces applied, analysing how the qualitative nature of equation solutions depends on the parameters that appear in the equation. This may lead to sudden and dramatic changes (break of elbow joint).

Mechanics of supination and General Mathematical theory of kantsetsu

The mechanics of supination/pronation movements is well showed in the next figure.
One important biomechanical notation during ude garami is if there is not first the effective movement of supination/pronation, the first lever is applied to the shoulder and a second time to the elbow.
This notation deriving by simple biomechanical and physiological properties of the upper kinetic chain is impossible to find in every judo book from 1940 till today, but this notation is present in the first judo book from Yokoyama and Oshima 1907 (note page 181 in the French translation by Le Prieur 1908).

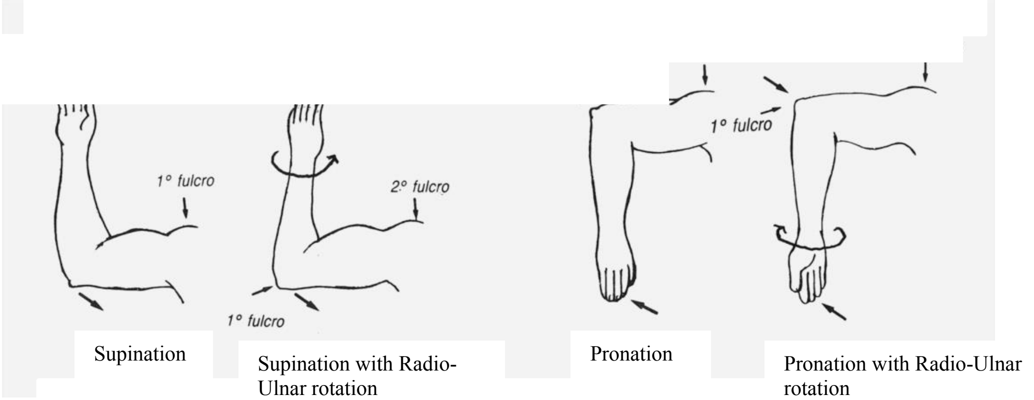


Fig.6.3a Right Biomechanical Application of supination (good with rotation, wrong without) from Biomeccanica del Judo 1988

The general mathematical formulation of joints lock passes through the following phases

the mathematical formulation of the potential developed in series is

$$V_p(x,y;F) = \frac{1}{2}(F_1 - F)x^2 + \frac{1}{2}(F_2 - F)y^2 - \frac{1}{4}x^4 - \frac{1}{4}y^4 + \frac{1}{2}cx^2y^2 + higher\ order$$

$$V_p = Potential\ \ depending\ by\ Force\ and\ Position$$

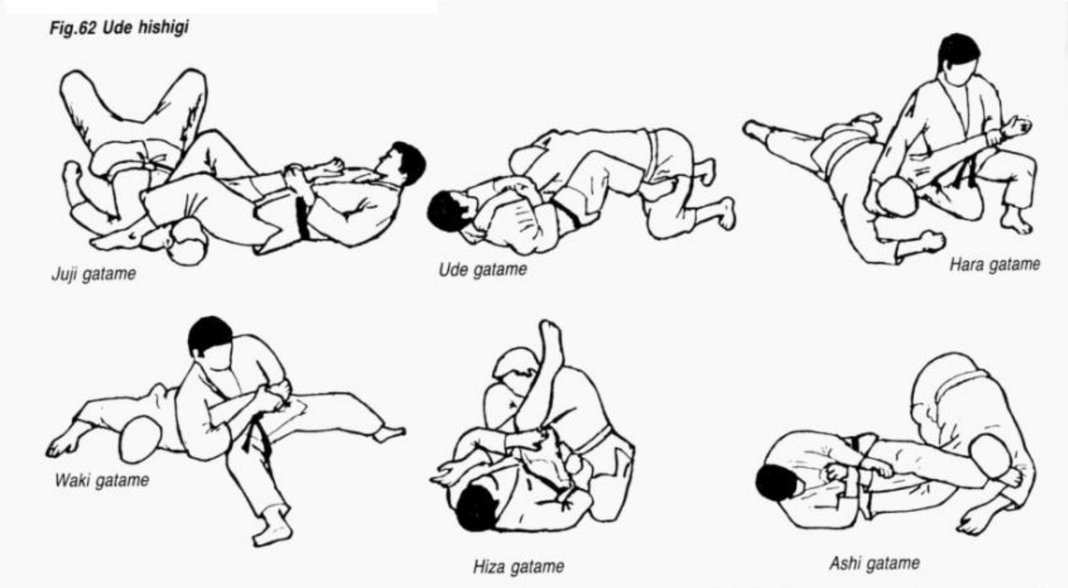
It is possible to determine its global stability properties qualitatively. For large values of r (elbow deflection) can arise the joint's break, and the breakpoint can be evaluated assuming the terms of degree larger than four are zero, and the term quadratic are negligible respect the quartic terms.

$$V_p \rightarrow for\ r\ large \rightarrow \frac{1}{4}x^4 + \frac{1}{4}y^4 - \frac{1}{2}cx^2y^2 =$$

$$= \frac{1}{4}(x^2 - y^2)^2 - x^2y^2 \Rightarrow V_p is\ unstable\ \ for\ x^2 = y^2$$

In this case, the instability (breakpoint) is of Morse Type point on a cusp surface.
Without considering all the mathematical arguments, the cusp branch presenting the possibility not only of extreme but worse, of unexpected imperfection sensitivity. This unexpected sensitivity arises through the strong coupling of the load failure modes of the two components subsystem (bone plus muscle). In this demonstration, the important point is that in terms of imperfection sensitivity, the fact that the combination of two "safe" systems (muscles and bones) can produce an "unsafe" (easy breaking) system should be considered.

Ude Kansetsu Waza Kodokan



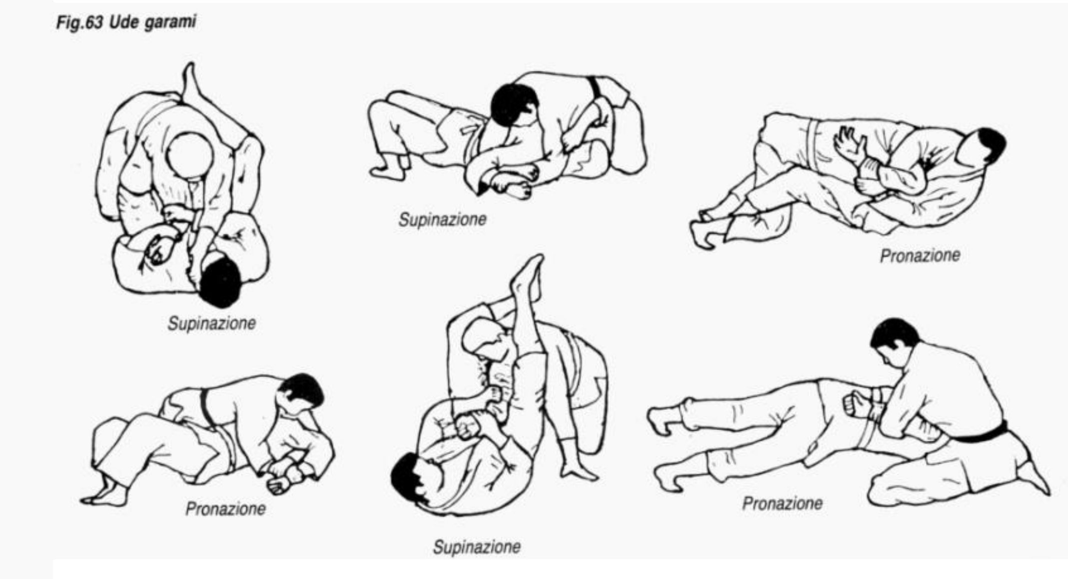


Fig.6.3.b.c, Joint Locks in competition. (Zahonyi)

6.3.1 Physiological effects.

Deep studies on mechanics and physiological effects of kansetsu waza in judo were performed in Japan, shown in the bulletin of Kodokan "*Studies on Kansetsu Waza*" in this study stated that the aim of the kansetsu is to attack the W*eak physiological point* of the elbow, were analyzed the following parameters:

1. respiration 2. heart rate 3. the volume of the blood circulation in the kinetic chains 4. flow of the blood circulation in the kinetic chains 5. the galvanic skin reactions.

The medical result, considering the autonomous nervous system, breathing, and heart rate, was: ***kansetsu must be considered as medical stress for the athletes***.

In the following figures, there are shown some Japanese study's results.

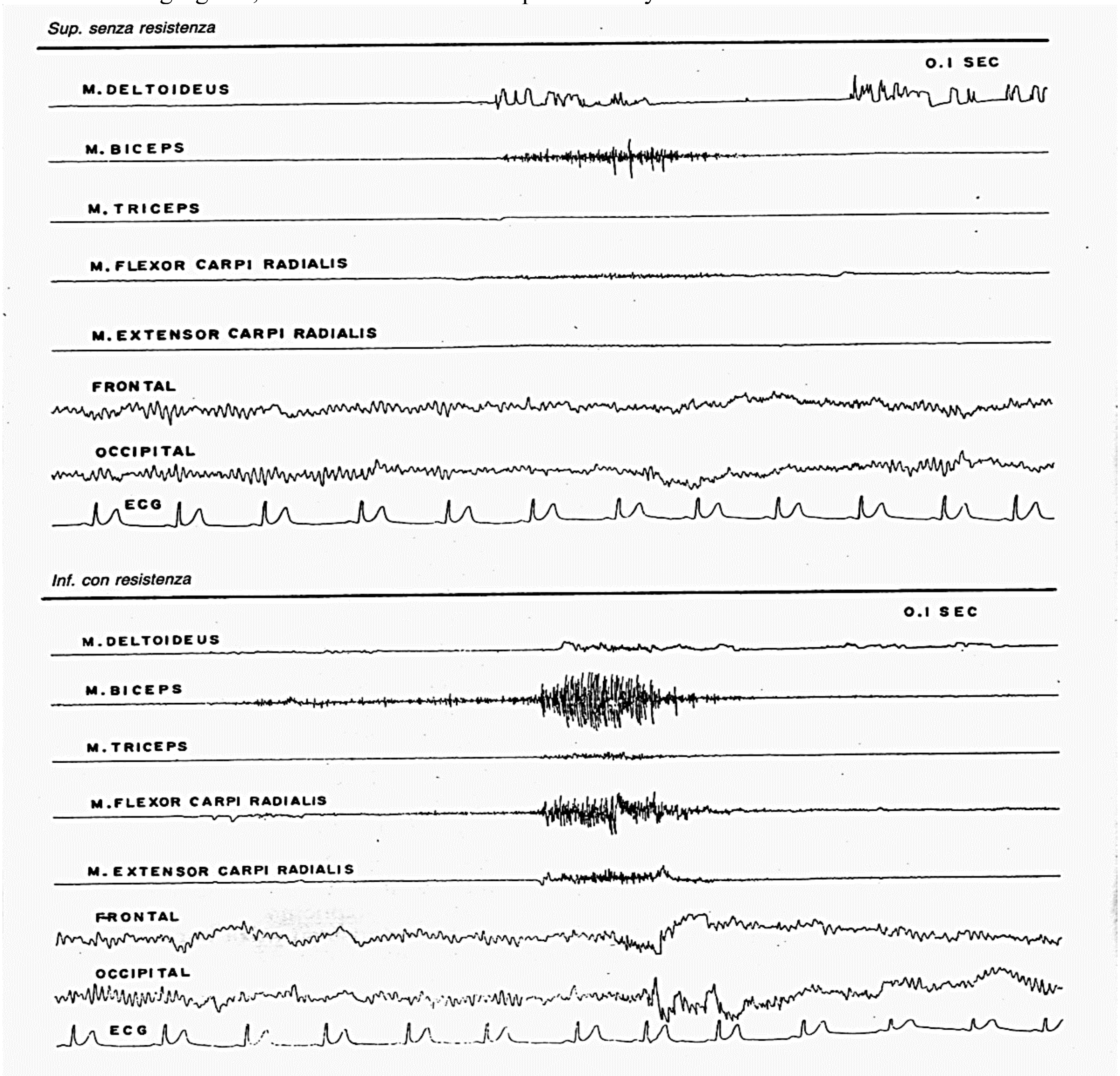


Fig.6.3.d. Results of a Japanese study on Kansetsu waza upper without resistance; lower with the opposition (Bulletin of Kodokan)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Chapter 7 Competition (*Shiai*)

7.1 Competition Classical Approach for Coaches and Athletes

Without ask for Giovan Battista Vico philosophical approach about the historical course and return in history, it is very strange for me after 20 years from my first edition of this book to speaks about competition with the actual changing rules.
When I started thirty years ago as a national referee, it was possible only to announce Wazari and Ippon, the other actions called Kinsa, and Wazari nichikai Waza were considered only strong and very strong attack (not officially evaluable), then I became European International referee with the changing rules (introduction of Koka and Yuko), the competition changed.
After the introduction of Ne Waza evaluation, we see another important evolution in the fighting style; simultaneously, in the red zone, a similar change happened, from the "no, out!" to the actual sorting for attack possibility.
Today after thirty years, the rules are changing again from 2009. No Koka will be awarded at all, and it is not possible to take the leg directly with the arm.
Writing this second edition, with these changing, historical recurrences can back to me, and Judo Sport can back a bit to his old Japanese way to fight.
Today with this third edition, rules usually changed after the London Olympic 2012 in 2013 with big changes that are evaluated in the 8.1 Paragraph. Other changes of minor impact were introduced in 2014 till to the Olympics in Rio 2016.
After the Olympics in Rio 2016, changes came in 2017.
By analyzing the actual competitions, it is possible to remark many interesting aspects, which will be exposed in this chapter.
How to define competition?
In a more abstract way, competition should be defined as a clash of interests based on the utility theory.
Athletes primary interest is to win by the right application of judo into the rules of competition.
In order to obtain this result, the coach must fit the Athlete's body to the physiological energy price of the fight, must assess relative motions both of the whole couple and of his own athlete in the couple (attack).
On the other hand, the athlete must know all wide judo techniques (from grips to throws), must practice understanding the time in the fight rightly, must know very well the competition referee rules, must feel that his "interest" in victory is deeper than that of the adversary.
In this chapter, we will see all these arguments in order to deeply understand competition and its biomechanics, both from the coach and the athlete side.

Competition: Classical Evaluation for Coaches.

A) Energy

As above mentioned, for the coach is very important to know the energy consumption during the fight. Many studies are performed in the world on this field from the indirect point of view. All activity performed during the fight and also the control processes of movements are contributing factors to the production, transformation, transport and use of the energy.
The energetic processes are from one side activated by fight intensity, and from the other side is the ground basis of a fight.
Sikorski in 1989 found a mean content of Lactic acid of 13.4-14.2 mmol/l.
The Lactate behaviour during the fight is affected by the intensity and economy of muscular contractions during the execution of technical-tactical actions.
It is important to remember that ***lactate is not connected to muscular fatigue*** (see 1.1.3) and that it is a valuable energy source within working muscles and non-working muscles, subject to training-induced improvements in its use as a fuel.
Its amount is also the function of the adversary activity during the fight, and then, in short, the more influent parameters for the amount of Lactate are:

1. Personal fight management.
2. The adversary performance level.
3. The Athlete's fitness.

The fights' energetic burden can be analyzed by Lactic Acid alterations, remembering that each fight should produce a different energetic burden on the same Athlete.
In synthesis (remembering the notations expressed in paragraph 1.1.3 and the linearity of approach underlined in these biochemical evaluations), the physiological price of competition is generally evaluated by lactic acid, for the anaerobic power, and by the VO_2 max for the aerobic power.
In the next tab, we can show the burdens results by different researches on judo fights:

Different energetic burden in different level competitions 1) Sikorski (1989), 2) Heinisch (1990); 3) Lehmann/Mueller-Dck (1994), Degoutte et al.(2007)					
	Polish [1] Championship	Coppa Matsumae	Training fights (3minutes,1990)[2]	Training fights (5 minutes, 1992, 1993)	Interregional Fight (2007)
Sample numbers	130		384	260	16
cid lactic Acid	13,5	14,2	7,7	9,1	12.3
Standard dev.	2,2	2,5			0.8

Tab 7.1.a – different energetic burdens in different level competitions.

The energetic burden of training fights at different technical level		
Fight level	Time Lenght	Mean Lactic Acid mmol/l)
International	5 minutes (effectives)	9,8
National	5 minutes (effective)	17,4

Tab.7.1.b- The energetic burden of training fights at different technical level

Aerobic fitness (VO_2max, ml·kg·min-1), grip strength (Newton) - judo Data mean (SD)				
	N	**VO_2 max**	**Grip Strength***	**Reference**
Males				
Canada Provincial	17	53.8 (5.6)	566 (89)	Little, 1991
Poland Club	15	50.1 (6.5)	na	Sikorski et al., 1989
Poland National -&	58	57.6 (4.6)	Na	Borkowski et al., 2001
Poland National- ¥	17	55.6 (3.2)	Na	Borkowski et al., 2001
Australia National	8	53.2 (5.7)	Na	Tumilty et al., 1986
Canada National	22	59.2 (5.2)	553 (65)	Thomas et al., 1989
Canada National	19	57.5 (9.5)	Na	Taylor and Brassard, 1981
Korea National	10	62.8 (5.9)	Na	Kim et al., 1996
USA National	18	55.6 (1.8)	na	Callister et al., 1991
Belgium National	24	54.3 (6.2)	na	Claessens et al., 1986
France National	18	55.0 (0.5)	Na	Degoutte et al., 2003
Tunisian National	na	55.4 (6.4) & 48.5 (11.9)$	Na	Hosni et al. 2007
Females				
Canada Provincial	8	43.7 (3.5)	312 (57)	Little, 1991
Poland National&	49	50.7 (5.5)	na	Borkowski et al., 2001
Poland National¥	18	49.9 (4.8)	na	Borkowski et al., 2001
USA National	9	52.0 (1.4)	Na	Callister et al., 1991
Korea National	10	50.5 (6.9)	Na	Kim et al., 1996
Tunisian National	na	45.9(6.4)& 44.8(5.9)$	Na	Hosni et al. 2007

Tab.7.1.c VO2max = maximal oxygen uptake; *data reflect the highest mean value of either the left/right or dominant hand; na = data not available; ‡on a cycle ergometer; #estimated from Astrand nomogram, & athletes representing Poland from 1994-1997; ¥ athletes representing Poland from 1998-1999; & Tunisian athletes 1998 $ Tunisian athletes 1996

B) Athletes' Motion Patterns in Competition (approach to the interaction)

The second area of classic interest in the competition for coaches is the observation and the study of motion patterns, see as a fundamental part of the interaction between athletes. In the next chapter, the argument will be deepened in light of a recent biomechanics study on match analysis. In this paragraph, there are quoted some classical studies performed on the subject.
A very interesting statistical study was conducted by George Weer, Coach of the USA Judo team, to investigate the types of Movement Patterns employed in Judo competition.
A total of 148 international matches were observed to investigate the possibility of determining the types of Movement Patterns used by top-level players. Videotaped footage of 1983, 1985, and 1989 World Championships, as well as the 1990 and 1991 All Japan Open Judo Championship, was used as the analysis material.
The observation makes able Weer classify five distinct Movement Patterns
Free Movement: used by players when coming into contact with their opponent.
Wide Step Lateral Movement: used by the players when they have both hands on the opponent but neither player has a Power Hand "set". It falls into the low range of rapid travel.
Study Movement by hesitant step: players appear to be testing the opponent's position taking two or three steps in quartering left or right diagonal directions towards the opponent's side.
The One Step Weight Shuffle: the player appears to feel for an attack seriously. The players shift weight rhythmically from one foot to the other, searching for a weakness in the opponent guard position.
The Spring-like Pattern also (Fox Trot): the player sets a pattern of quick steps that move the attacker away from the opponent and quickly back into the attacking position.
The most important conclusions obtained by Weer were the following:
The first four Movement Patterns appear to be a natural extension of the gripping situation.
The Movement Patterns had a distinct progression of use.
The movement began with light contact and large activity, which progressed to an economy of movement as the degree of Power being applied to control or attempt to control the opponent was increased.
The first four movement patterns were evident in all players and matches observed.
The degree to which the large, faster Movement Patterns was employed appeared to be inversely proportionate to the player's weight. That is to say, the higher the weight category, the less the players moved. The presence of the first four movement patterns in all players would suggest that these patterns are natural and do not need to be taught to players.
The facts:

a) ***The Spring-like was not evident in all players and***
b) ***The Spring-like was seen as part of an effective attack***

It suggests that Spring-like is a learned response.
The most effective attacks (with a few notable exceptions) progressed from a Weight Shuffle to a Spring-like. The Spring-like was also executed from Movement Patterns #2 and #3 but never from pattern #1.
Where the Movement Pattern, immediately preceding the Spring, was not a Weight Shuffle the attacker had great difficulty closing to the Throwing Space.
The most important discovery of this study was that there is a Movement Pattern that appears to be a requisite to successful throwing attacks.

C) Grips (for interaction)

Also, the grips have been thoroughly analyzed by George Weer in the same interesting and clever classical way. It is very interesting to note that his results are in agreement with some of the results of the quantitative biomechanical analysis of competition (see Appendix I)

It follows the quotation and the main results of his second study:

"The primary objective in the competition of Judo is to control the space between you and your opponent. The one tool that you have to control that space is your gripping skills. Space is important because it's the area you have to manoeuvre through to get into position for your attacks. It's also the area that your opponent has to travel through to attack you.

The term 'gripping skill' is very generic. To be able to analyze and evaluate gripping skills, we need to have a consistent taxonomy of gripping tactics, strategies and configurations.

Weer reviewed two hundred sixty-one (261) videotaped Judo matches from the 1996 Olympic Games. The objective of the research was to Catalogue grips' configurations; determine the frequency distribution of gripping configurations.

Intended use is benchmark gripping skills of elite Judo players; provide insight to gripping strategies; provide coaching guidelines for training players in gripping skills.

The analysis was done on the placement of the power hand.

Considering that the power hand is the side of the body with which you drive the defender's back toward the mat during your throw.

The power hand is usually the highest hand on the defender, and the attacker invariably stands with the power hand side turned into the defender's torso.

Throughout 261 matches, only four grip types were observed.

Same grips; both players took either a right or left power hand position.

Opposite grips; players adopted a right against left (or left vs right) power hand position.

Sleeve end grips; the dominant player gripped both of the opponent's sleeve ends.

Gripping without form, the dominant player did not allow the opponent to secure a power hand and did not commit their own power hand unless attacking.

The table below represents the distribution of gripping configurations observed.

	Same	Opposite	SleeveEnd	NoForm
Men's Divisions	8%	45%	4%	43%
Women'sDivisions	14%	50%	6%	30%
Combined Data	10%	48%	5%	37%

Tab.7.1.c- Analysis of the grips (by George Weer)

A review of the data indicates, at the international level, less than two out of ten matches are contested with both players using the same side power hand.

Over half the matches were contested in left against right-hand posture.

Gripping Strategies

Same Side Power Hand

Playing with the same power hand as the opponent requires moderate preparation. Athletes that play with the same power hand as their opponent set the power hand early and wait for an opportunity to attack.

'Same side' players rely on the fact that there's a minimum of space between themselves and the opponent. Minimum space means that the attacker will have to rely on a high level of

mobility to open the attacking space. Conversely, the defender only has to generate a minimum of defensive mobility to avert the attacker's preparation manoeuvres.
Restricted mobility requires greater effort to mount an attack, which is appealing to conservative players.

Opposite Side Power Hands

Playing with the opposite power hand as the opponent means a right against the left position. Gripping with a power hand opposite to the opponent provides a very strong defensive posture from minimal preparation.
Playing with opposite power hands limits mobility. Opposite power hand competitors do not actively seek attacking opportunities.

Sleeve End

Sleeve end grips provide a neutral gripping posture, i.e. both hands on the opponent ready to attack to either side. Sleeve end grips afford high mobility with moderate power. Gripping the sleeve ends requires moderate preparation while balancing offence and defence through moderate mobility.
The sleeve ends gripping strategy controls the opponent through a combination of grip control and movement. The grip is set with both hands early in the encounter. The sleeve-end player searches for opportunity through movement. Sleeve end grips can be very frustrating to the defender. The detriment to gripping the sleeve ends is that the direction of throws needs to be adjusted, and power development is limited.

No-Form

In the 'no-form style, the player employs the strategy to do not overtly commit to power hand placement.
The use of grips without form means not committing to a power hand until you're actually attacking. Playing without a commitment to a power hand requires a very high level of both offensive and defensive mobility.
There is one liability to gripping without form. Playing without a commitment to a discernable power hand takes great courage. It takes courage because all that movement requires a high level of aerobic stamina. Playing without form also requires a very high level of creativity. You have to be able to move and think and recognize the opportunity. Playing without form may not be for everyone, but it is for champions.
Another connection performed by Weer during this study was the strategic use of grips in the function of the type of contest: Preliminary, Repechage, semi-final and Final.
The following tables, divided for male and female athletes, represent the distribution of gripping strategies.
Distribution is reported by the percentage of matches contested using each gripping strategy.

Combined Men	Same	Opposite	Sleeve End	No Form
Preliminary Rounds	10%	49%	3%	38%
Repechage Rounds	10%	54%	7%	29%
Elite Rounds	2%	33%	2%	63%

Tab.7.1.d- Analysis of the Male gripping strategies (by George Weer)

Combined Women	Same	Opposite	Sleeve End	No Form
Preliminary Rounds	19%	55%	7%	19%
Repechage Rounds	18%	57%	7%	18%
Elite Rounds	7%	40%	4%	49%

Tab.7.1.e- Analysis of the Female gripping strategies (by George Weer)

Some final considerations of Weer are very interesting in coaching applications.
We quote them as useful remarks:
"- Different players from the same country utilized a variety of gripping strategies. The lack of a consistent approach to gripping suggests that the national coaching structures did not focus on, or even address, gripping skill development.
- We simply don't see the development of gripping strategies addressed in current books, magazine articles or videotapes.
A gripping strategy is the most important tool that a player develops. After all, your gripping strategy determines your ability to attack and, more importantly, how well you defend yourself.
It is a major Coaching error to leave something as important as the development of a gripping strategy to chance.
Players need to be trained to use movement as an integral component to grip from the very beginning. Coaches must learn to demonstrate and teach skills with an emphasis on movement over technical detail.
The development of a champion does not just happen. Successful Coaches will develop a systematic approach that includes everything from gripping strategy to newaza defensive skills."
Other works connecting grips and throws were performed by Carballo and coworkers (INEF de Galicia) with a bit too detailed approach that does very difficult a simple understanding. The main final results are summarized in the next table. They collected all throws with the tour and the technical direction that we translate in biomechanics term Couple of forces Body-Leg forward Uke (CBLf), Couple of forces Body-Leg backward Uke(CBLb), lever medium arm forward Uke (LMf), lever maximum arm forward Uke (LMMf), Couple of forces arm and leg backwards Uke (CALb), Couple of forces two arms backwards Uke (CAAb) Lever Maximum Arm Sutemi (LMAS).

Throws grips	LMf CBLf 22.7% 21.1%	CALb 13%	CAAb 13%	CBLb 7.3%	CALb 5.7%	LMAS 4.8%
Back-la	42%	50%		33%		33%
Back-le			37,5%		28%	
La -Sl	36% 42%	12%		55%		
La-	21%					
Sl-Le			18%			
Sl-Sl	21%					

Tab.7.1.f- Analysis of connection throws grips (by Carballo)

This approach makes very useful in a comparative way the guard position approach, simple, consistent and more biomechanically connected to the fight situation. (see 8.2)

Competition: Classical Athletes Approach

The need or better the main interest of coaches on competition aspects (called classical because the use of videotape is not fully developed) are treated previously.

Now it will be approached the main Athletes interest in the competition.

If the previous ones for coaching are energy consumption for conditioning needs or motion patterns and grips, both interactions are connected.

For the athletes, the attention is focalized on “How to overcome the adversaries” by tricks and skills.

Study of the starting phase (before grips)

The first part of the fight, carefully analyzed by elite athletes, starts from the condition of no grips; and ends with the condition of stabilized grips.

This fluid, open situation, well managed, is able to give:

A) A winning grip conditions.

Well, known is the remembering of the opening situation in the historic fight Geesink-Kaminaga at the 1964 Tokyo Olympic Games.

As Geesink himself remembered many years ago during a Stage in Italy: the Dutch Champion well known by the Japanese Champion started his fight hands up, the judogi sleeves went down, making more difficult the grips for his adversary, simultaneously Geesink gave out a cry and Kaminaga, bending the head, gave him an actual chance to acquire a dominant grip.

It is a common opinion, among high-level coaches and athletes, the importance, compared to your opponent, to make the first grip and secure a favourable position for the development of the fight and consequently for achieving the victory.

Since the judo match develops from the grips (kumi kata) on the judogi of the two competitors, the first attempt is to interfere with the adversary grips, normally by shortening his own sleeves, or by hindering with transverse harm the adversary grip, taking at first across grip with one harm, and then to stabilize his own grip.

Studies performed by Pierantozzi and coworkers on the video analysis of fights in high-level competitions (world championships) taking into account the judogi’s areas utilized show that the traditional grips lapel and sleeve (Ki on kumi kata) are generally privileged after the first phase of the fight.

In the next figures are shown the areas accounted for and the final results.

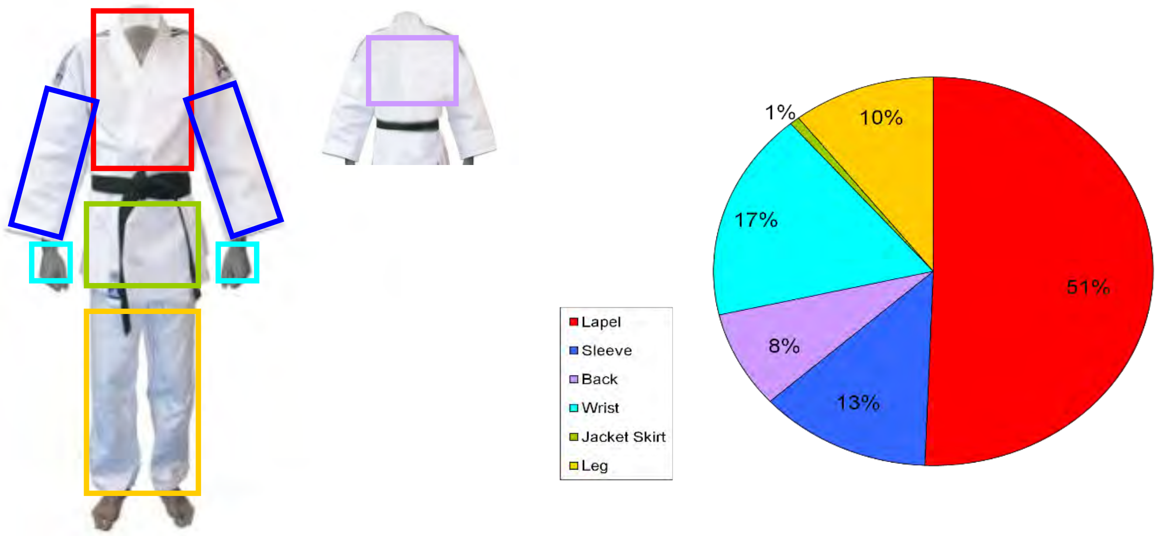


Fig.7.1.a- Analysis of the first point to grip strategies (by Emanuela Pierantozzi)

Again, Weer, in another research applied to *first contact and grip domination*, a study about the gripping habits and patterns of players taken from videotapes of three major competitions. The tapes were matches of the quarter-finalists of the 1987 All Japan Championship, medallist and championship matches of the 1985 World Championships, as well as elimination and medallist competition from the 1985 European Championship give us much information.
The most important result was that at a high level, the statistic gives us that 70.13% of elite players will grip first with the Locking Hand (hand to the sleeve).
After the first partial Kumi Kata with one only hand, the players are holding one another with opposing Power Hands (hand to the lapel) right versus left.
Each player is faced with two main problems:
1) In order to progress into an attacking situation, he must try to find a way to get the other hand in for a grip.
2) He also has to find a method of circumventing the opponent's defensive position of the "stiff arm" that has been allowed a grip.
Observation shows that the best grip fighters tend to prepare an opening for the Power Hand placement. In other words, the player will reach in with the non-Power hand, pull the lapel out for easier access, brush aside the opponent's hands or simply set a blind for the intended Power Hand placement and then take the Power Hand Grip.
However, the very top players take this one step further! The big boys don't just reach in and take a grip. What the champions do is to keep the Power Hand tucked in close to the side and moved the whole Power Side of the Body in under the grip.
In the following sequence, it is possible to see a fight for grips between Quintavalle and Boenisch at the Beijing Olympic 2008

Fig.7.1.b.c.d.e.f.g.h.i.j- Quintavalle and Boenisch gripping fight at the Beijing Olympic 2008 (Finch)

The Locking hand placement of the best players appears to be a continuation of one smooth movement in the gripping manoeuvre. The attacker "sets" his Power Hand and then moves his whole body toward the Locking Hand position. Upon securing the Locking Hand, a strong attack must be the inevitable final step of the sequence.

Some patterns of domination and outcome became clear:

1. If the Athletes do not fight for the grips, usually the competition will be awarded to the stronger player.
2. If the players fight for the grips, some standard situations can happen.
   - If the opponent attempts his Power Hand first, without any type of preparation, the player that prepared with Locking Hand followed by Power Hand was inevitably dominant.
   - At the highest levels, the players that attempted to secure a Power Hand without preparation were frequently reduced to taking any grip.

B) A chance for applying trick techniques.

Wiles techniques (Gleeson) are characterized by a short time of application.

In fact, if the astonishment is nullified, these techniques went ineffective. More often, these techniques are applied at the start or at the end of the fight.

The basic biomechanical principles of the trick techniques are timing, speed and attack by surprise.

Normally trick techniques are applied by grasping one or two legs throwing down the adversary.

In judo "slang", these techniques are called pick-ups, all of them are techniques founded on the fact that the attack is generally launched before the two adversaries take a grip, a difference of the other major throwing, which needs some form of gripping before the real attack can be made.

Connecting grips and throwing (Tokui Waza)

Generally, the outcome of a judo match largely depends on whether one athlete beats his opponent in competing to the first secure favourable gripping position prior to the opponent. Without exception, every player has his own most favourite gripping pattern and is confident of beating an opponent or leading the match if he can successfully apply this gripping pattern to the opponent.

However, if he is unable to suppress the other by any means in this competition, he will lose the advantage to control the match.

Thus, it is essential for judoka to master the gripping techniques that are essential in playing judo as a transfer system both of force and energy.

The grips are the key to effective throwing techniques, and all athletes have their preferred methods of gripping in order to bring off their favourite techniques (Tokui Waza).

Normally an effective grip feature has the particular that the two harms of an athlete are inside the harms of the other.

In such a situation, biomechanically speaking, the resistance of the adversary was less effective to contrast the adversary body contact.

Today most competitors develop a favourite technique (Tokui Waza) to the point that it can be applied against every opponent.

Very often, at a high level, Tokui Waza is relayed to some specific motion strategies connected to typical push /pull actions that force the opponent into a vulnerable position for the attack. Normally this is obtained by applying a Ko Waza as an opening for an O Waza, or vice versa. Most of the competitions are connected to the right application of one definite technique, but at a high level, one Tokui Waza, it is not sufficient. Every competitor tries to acquire other different Tokui Waza in order to increase their capability to the victory.

The strategy to build a new Tokui Waza with the connected tricks or typical actions is very time consuming, and most athletes have developed many different time-saving approaches to the solution of the problem.

The three main applications utilized are based on the flexibility, time-saving, and approach in changing Tokui Waza, like special grips that are able to be applied to different Throwing techniques, special Tsukuri Kuzushi actions that are able to be connected to different Throwing (Kake) Actions, special final position of the body that is able to apply different throwing techniques.
With these three main systems, Athletes are able to increase their technical baggage, switching most of the actions and tricks acquired to the new Tokui Waza, saving time and retaining most of the movements learnt.

C) Tricks: and New Techniques
The most intriguing part of the fight preparation is the research of new techniques and tricks. This part is very often developed, taking into account other fields or another type of wrestling. Normally also a simple variation of the throwing often can be considered as a new technique, but the variation is biomechanically speaking, may require a different direction of force and body placement.
Till today these new techniques use the name of the pioneering judoka in their nomenclature.
However, if we think for a moment, in judo, the Japanese nomenclature used for Tachi Waza is not the only standard across all competing countries but also provides a highly efficient description of any technique.
The need to give a Japanese specific name is connected to the descriptive form of this nomenclature for better teaching reasons.
For example, any leg-grabbing action (one of the highest-scoring actions in major tournaments today not allowed) will be termed simply 'Ashi-dori', but the specific variation used biomechanically speaking may require a different direction of force and hand placement.
And really, only with biomechanics, it is possible to build new and more effective techniques (see: par. 8.10). By looking at the two basic physical principles of the techniques, it is possible to state the more effective force direction in connection to the body structure defensive capability.
These are two basic biomechanical rules, which give us a better capability to contrive new judo skills and tricks in top competitions.
Normally tools to evolve techniques or introduce new techniques are based on:

a) The Psychology, for example, the most rational motion can be preview by the competitors and response preplanned, but the non-rational solution should be more difficult to preview.
   In the next figure, it is possible to see a completely new application of tricks, not rational but already very effective.

Fig.7.1.k.m- Two very unorthodox and effective throws (Finch)

b) The Biomechanics, for example, the right knowledge of the two basic physical principles to throw should be useful to apply the same principles in other direction of symmetry in the coupling system, utilizing the degree of freedom of coxo-femoral articulation, and in that way it can bear a new technique, as reversing the Tori motion in Uchi Mata in the opposite direction like Chabarelly (Mae Hiza Ura Nage) or better for the author (GyakuUchi Mata)

F*ig.7.1.n.o.p.q- Reversing movements- brought to new effective techniques (Finch,Zahonyi)*

D) Shortening attack time

Another very important goal of athletes is to shorten attack time; this obviously goes through two main directions:

The attack speed increase with some special conditioning exercises, but it is very difficult to increase adult speed both in simple and complex movement because it is a genetic property of the Athletes. Normally at maximum, it is possible only a very little increase in such ontogenetic quality, which is developed during 8 and 14 years of age.

But the time of the attack can be shortened not only by speed increase (practically impossible in adulthood) but also by biomechanics tools, remembering that velocity is Space covered in Time $v = \frac{ds}{dt}$ then it is possible to increase velocity shortening the space covered, in plain words, the solution can be obtained, by a sophisticated study of contact trajectories, that can be shortened with proper and well-timed movements, with the use of ***Hando No Kuzushi***, which is based on the biomechanical principles of action and reaction, normally the player uses the so-called, "proof" (action, motion or push/pull) to produce a reactionary breaking of balance. It is the clearer application of the Judo principle "Maximum efficacy with minimum effort", using this principle, the player applies the force to the opponent, and when he feels the typical movement response or resistance, he can take vantage reversing his movement into the right direction. By ***Hando No Kuzushi,*** every action or reaction of the adversary can be turned against him, shortening contact time.

E) Skill techniques evolution

With the continuous evolution of competitive style, for the right training of «top» athletes, we need a better understanding of judo skills and their trend in top competitions.

Obviously, the basic physical principles of standard judo techniques and judo skills (competitive throwing techniques) are the same, but the dynamical conditions are quite different (fast movements, more opposition, timing, change of speed, etc.).

The right way to learn the connection with standard techniques, and to understand the competitive evolution of judo skills, was signed for the first time by Dr Kano with the formulation of the principle of "Maximum effect with minimum effort".

This principle can be translated into two useful biomechanical remarks:

1) To improve techniques to win means to produce a maximum economy of movements.

2) To better techniques to win signifies to produce a maximum economy of strain.

The explication of remarks is that competition champions, consciously or unawares, tend to find the right methods of minimizing their total energy expenditure to win.

In some ways: either minimizing his own muscular strain with right changes in throwing patterns (e.g. pulling down the fulcrum), minimizing the defensive antagonist capability with right changes in attack directions (e.g. attack in the direction of the adversary side where the resistive muscular capability is weaker) or utilizing simple technical movements to throw the adversary (e.g. sweeping the leg with ashi harai).

These are two biomechanical rules, which give us a better understanding of the evolution of judo skills and tricks in top competitions.

F) Connection Tachi Waza –Ne Waza

This area is not full analyzed in the research world because of the potential infinitive relative positions and possibilities to solve this problem.

Here there are four specific methods to go from Tachi Waza into Ne Waza, starting from the more suitable to the less expedient:

1) To attack in Tachi Waza and to drive on Ne Waza without waste of time.
2) To drive on Ne Waza, the adversary by Ikkomi Technique.
3) To apply a Sutemi Waza and to continue in Ne Waza.
4) To be thrown with the idea to continue in Ne Waza.

Normally the easy connection Tachi Waza –Ne Waza should flow in a fluid connection among Osae Waza, Shime Waza and Kansetsu Waza.

In the next figures, we can see a classic connection Tai Otoshi –Ude Ishigi Giugi Gatame- applied by Adams on Jacobson, and a very dynamic connection Tachi Waza-Ne Waza by Flying Juji Gatame applied by Divisenko against Neureuther

Fig.7.1.r.s.t.u.v, Classical connection Tachi waza-Ne waza by Adams (Finch)

Fig 7.1.w.x.y.z. A dynamic Connection Tachi-Ne Waza -Flying Juji Gatame by Divisenko (Finch)

One basic way to approach the problem could be, ***considering each specific throw applied***:

1. By classifying the distance between Tori standing and Uke laying in the function of the relative position (e.g. from the head, the side, the feet)
2. By ordering the possibility of applying osae, shime and kansetsu, in terms of ease
3. By choosing the easiest solution in terms of movements to make
4. By finding the solution and adopting it as automatic as possible

7.2 Initiative as Psychological tool, Strategy and Tactics

The competitive dynamic is grounded on the study of forces and their connection with the execution speed of the specific motion (throwing techniques, Tsukuri, etc.) into the "Couple of Athletes" system, which often moves with his velocity on the mat (Tatami).
The parameter velocity plays a very important role both as relative attack speed and absolute shifting velocity of Couple System. In fact, at every shifting pace linked, in competition, to the Couple System, it is possible to apply a specific technique (cfr. Gleeson 5; Sacripanti 8.3).
It is interesting to remember that, during the fight, two very different facets are connected without a solution of continuity: The psychological facet and the technical facet.
The "Optimum" athlete's fighting skill (cfr. Biomeccanica del Judo) could be defined as a variable combination of previous facets, respect to the specific fighting situation.
Then it is possible to write the following formula:

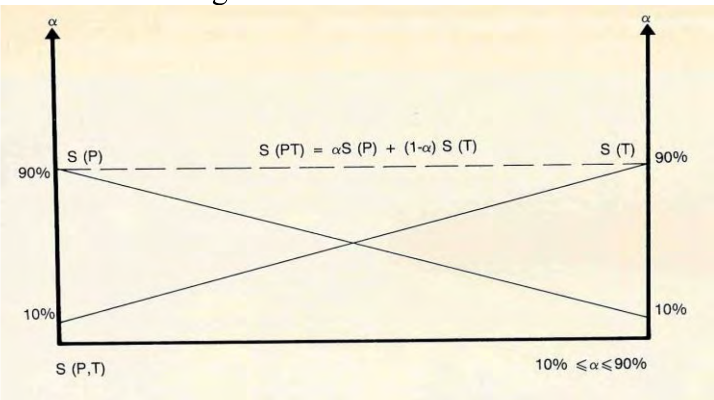


Fig.7.2.a Fighting skill as a function of psychology and technics

$$S(p,T) = \alpha S(p) + (1-\alpha) S(T)$$
$$with\ 10\% \leq \alpha \leq 90\%$$

S (p, T) = Fighting Skill; S (p) = inner or/and outer Psychological facet; S (T) = Technical facet.
If we analyze the psychological facet during the fight, it is necessary to review from the Technical – Psychological point of view, and a very important aspect previously analyzed from the Technical Biomechanical point of view (cfr. Biomeccanica del Judo) this is the main tool during the fight to grab the victory.
The Initiative: The definition of the initiative is the Psychological-Technical dominance of one component of the "Couple System" over the other component.
In the fighting dynamics, the Initiative is basic if we must develop active attack plans.
It is also clear that its preservation should be connected to execution speed, muscular strength, technical skill and psychological pressure.
The initiative is so basic during a fight that only the holder can carry out the attack and put the opponent on the defensive. There is scientific evidence of the previous statement?
Some studies support an outcome-based testosterone increase for winners and decreases for losers, However, the results are mixed across the entire literature (Gonzales-Bono, Salvador, Serrano, & Richarte, 1999; Mazur, Susman & Edelbrock, 1997; Schultheiss, Campbell, & McClelland, 1999; Suay & Salvador, 1999; Salvador, Simon, Suay, & Llorens, 1987). The lack of consistency suggests that factors other than outcome influence hormonal response to competition. For example, Serrano, Salvador, Gonzalez-Bono, Sanchis, and Suay (2000) found in a judo competition that testosterone levels were only positively associated with self-appraisal of performance and attributions of outcome to personal effort.

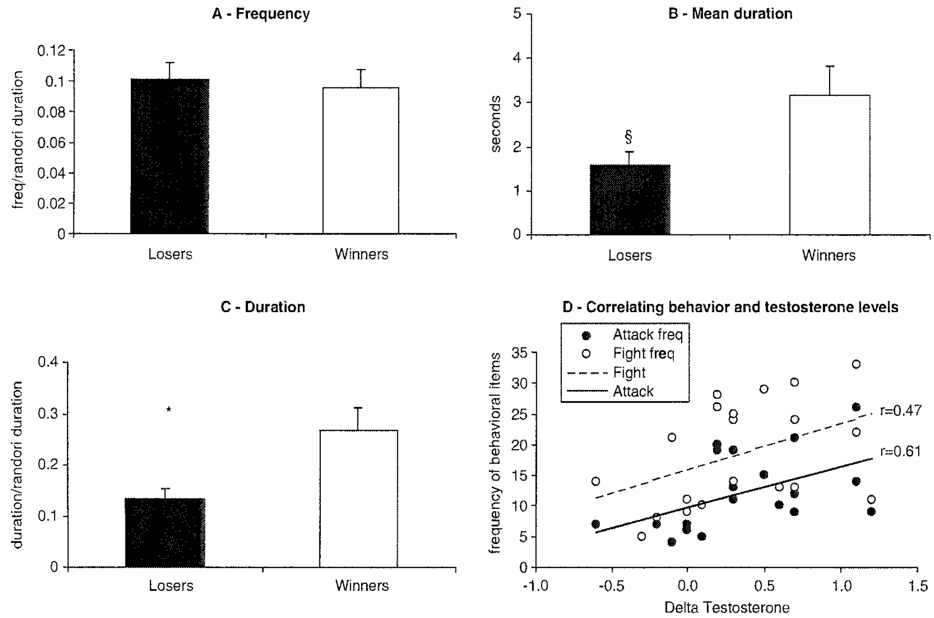


Fig.7.2.b.c.d.e, Behavior during Randori session. Comparison between winner and loser in frequency, duration and mean duration of the attack.Correlation between Testosterone level (pre/post) and frequency of attack and fight. From Parmigiani et al. In Judo, Randori (Free Fight) and Kata (Highly Ritualized Fight) Differentially Change Plasma Cortisol, Testosterone, and Interleukin Levels in Male Participants

Also, cortisol showed a significant relationship with negative mood.
All these studies show that the Initiative increasing is strictly connected to the motivation grounded on the technical skill and psychological pressure, which upset the opponent psycho-motor coordination and lessen his reactive capabilities.
Very often, Initiative assumes the compelling feature of continuous attacks that flow into a winning throwing. Sometimes it is possible to permit accordance in a psychological facet to earn again in the biomechanical initiative or vice versa.
A judo champion is a man who faces, solves and masters all the competition aspects.
The aspects of every competition can be grouped into three classes.

1. Pure psychological aspects.
2. Psycho-Technical aspects.
3. Pure technical aspects.

For example, some aspects are presented in the following indicative list:

A) Psychological factors

Public, Referees, Coach, Opponent, Anxiety, Negative Mood, Overestimation, Underestimation, Poor Concentration

B) Technical –Psychological factors

Combination techniques (chap 8.5), feints (chap 3.3), jamming grips (Kumi Kata) (chap 2.3; 3.4), right exploitation of fighting time, right exploitation of penalties, active obstructionism in competition, competition right pace variation, tricking techniques (chap 5.3), Initiative (chap3.3)

C) Technical factors

Rotational Unbalances (Chap 3.1), Kinetic energy exploitation (cfr. 3.3), Angular Momentum exploitation (cfr3.3), relative distance (cfr.3.4), grips (Kumi Kata) (cfr.3.4), shifting direction, attack direction (cfr.3.4), bodyweight balance, muscular conditioning, right exploitation of energy consumption during the fight.

Strategy and Tactics

Judo competition is a fight under referee regulations between two athletes who aim for the same goal: *to grasp the victory*.

Normally when the grips (kumi kata) are caught, the fight starts, with all possible attacks, defensive actions and counter blows which flow till to the final victory.

Generally, the actions developed are grounded, both on the competition regulations and on the fight specific situations.

These opportunities come from the athletes' personalities and technical capability.

A thousand competitions showed the experimental soundness of these concepts, while the biomechanical analysis shows us their scientific soundness.

Every fight has its specific way to victory, grounded on athletes' technical and psychical capabilities. A good athlete understands that basic notions like unbalance, combination techniques (Renzoku and Renraku Waza), or timeliness are variable concepts that depend on many parameters as his own actions, opponent actions, shifting speed of a couple of athlete's systems, grips, positioning, and so on. Based on the previous considerations, the governance of the fight must be grounded on Strategy.

Competition Strategy is interested in coordinating the external and internal forces, or the strains balanced with the relative motions, till to catch the victory.

The strategy gives general concepts to the athletes to rule the fight till the victory.

Tactics are based on the capability to rule and hold the transitory action.

Then we define **Strategy:** ***the plan or the flexible connection of more plans based on the coordination of physical efforts, harmonized with relative movement finalized to the fight victory*** instead we define **Tactics:** ***the capability to utilize the transitory phase.***

Tactics are connected to do technical actions naturally, as the natural perception of the actual situation like the Zen mystic status called **Satori** (cfr Introduction of the first edition). Tactics, in our advice, can be connected not only to specific attack motion on a transitory fight situation but also to Kaeshi Waza as a solution to a transitory situation like improvising attack applied by the competitors. In the next figures, we can see a beautiful left Seoi (with tactical Mae Mawari) of Koga on Ciupe, and the same trick (with tactical Mae Mawari) applied by Ciano during a fighting Tama Guruma.

Fig.7.2.f.g.h.i. -Tactic for throwing (Mae Mawari by Kokga) to overcome defence on Seoi (Finch)

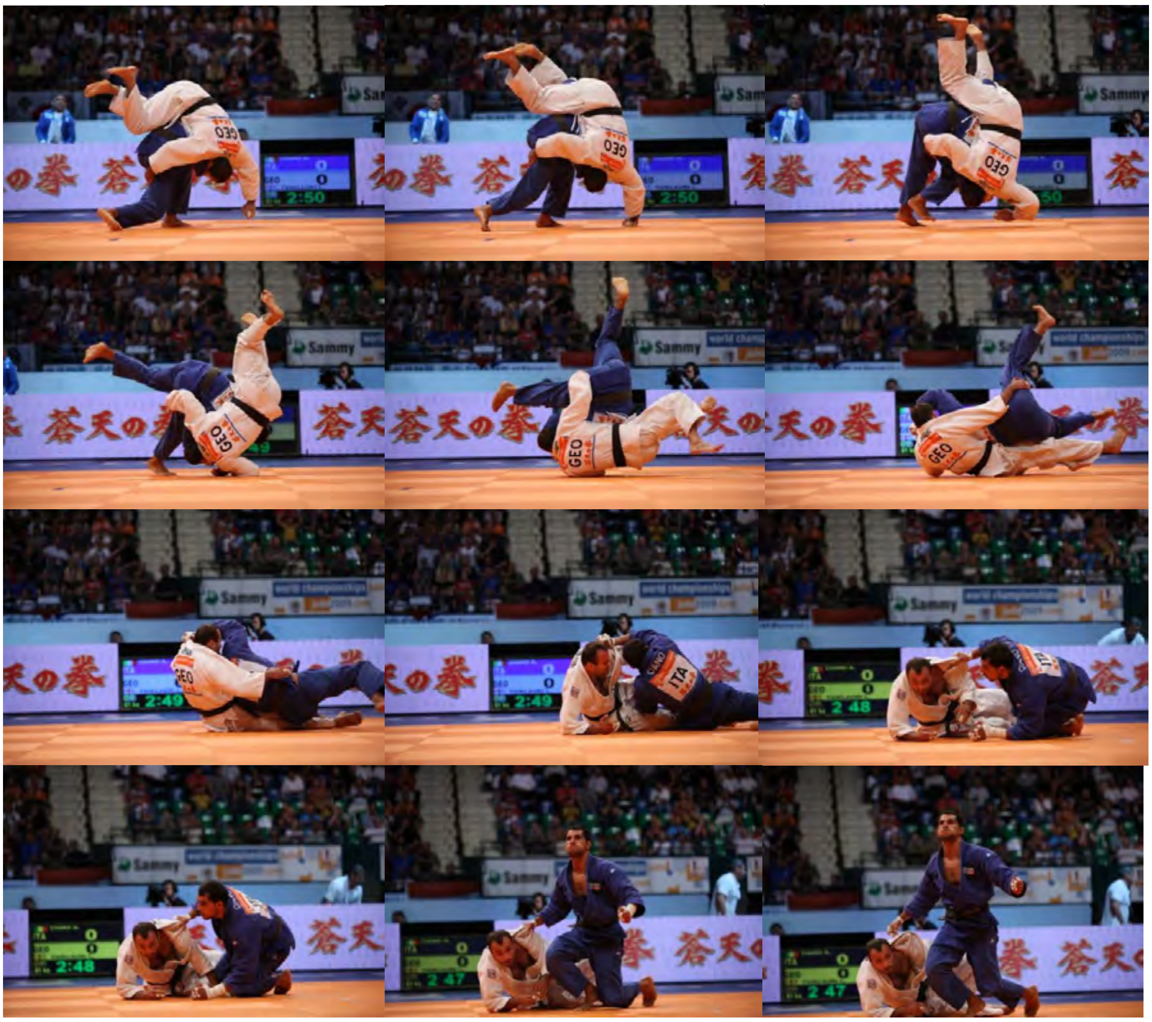


Fig.7.2. j.k.m.n.o.p.q.r.s.t.u.v.w- Tactic for throwing (Mae Mawari by Ciano) to overcome defence on Seoi (Zahonyi)

7.3 Scientific Studies on Competition: A Survey

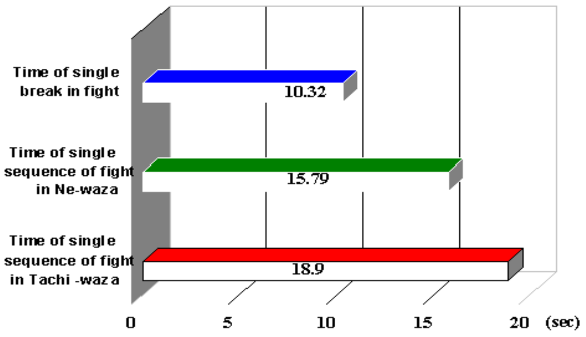
In these last twenty years, starting from the first edition of this book "Biomeccanica del Judo", a lot of scientific studies from Japan, Poland, Belgium, Brazil, United States, France, Spain, Italy and other countries, starting from the works of Matsumoto and Sikorski have been focalized on the competition. Unfortunately, their information validity has diminished due to changes in the refereeing rules. Some of these changes were introduced to increase the competition rhythm or to introduce prohibited techniques.
Many studies are connected to the physiological response of the human body, like energy consumption or hormonal changes in the Athletes, and so on, and we report some results of these studies in another paragraph (cfr 7.1; 9.1).
Many of the efforts are connected in the field of statistics applied to techniques utilized during the fight, with the goal to single out the evolution of competitive technical tools applied to victory, finding a connection to the technical preparation.
Others are connected to the study of fighting dynamics. In which the goal is to evaluate the technical supremacy of the victor by Kalina's methods. Very often, the supremacy is not only connected with the correct selection of fighting means but also with methods, which depend on the actual result of the contest
With the start of the female international competitions, to deepen the knowledge of competition mechanics, many people performed studies on comparative analysis of female vs males.
Also, the use of time in the competition was analyzed to connect attack and results as basic knowledge for building new and more fitted strategies.
In the following, we show a short summary of the methods and results obtained in these last twenty years.

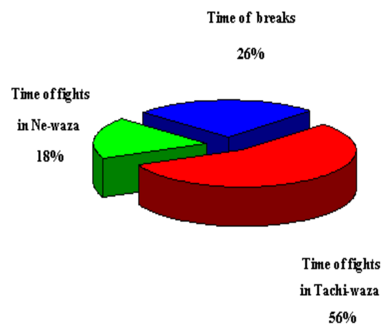
a) Statistical Studies on Competitions.
Judo, like other sports, needs to have data from real competitions for data on energy consumption to address athletes' conditioning rightly.
In situation sports, the statistical inputs are needed for other information, both: for the capability to build standard strategies. (See the first Italian edition : Biomeccanica del Judo) And for the capability to understand the judo technical evolution.
A lot of forbidden data, obviously, are in the archives of national federations, but there are also some data published, and we show what kind of information it is possible to single out from them.
Starting from Japan, one of the first and most interesting and really complete papers refers to Matsumoto, Takeuchi and Nakamura on the analysis of All Japa judo championships 1971, published in 1978, for example in this paper were studied the techniques most utilized its number, the results connected, the number for each athlete, the defensive actions divided for the weight class and against each technique, the grips and the dromograms (shifting path of competitors) connected to grips, the Ippon loci on the mat, the Arial utilization of the Tatami connected to the grips.
In 1997 Hirose and others made a comparison between Japanese games and the 1993 European championship, for the category 95 Kg.
The first result was that in Europe, many Ippon and Yusei gachi were awarded than in Japan, many Hantei Gachi.
About the technical information gathered: in Europe, most attacks were tried with incomplete grips, about throwing techniques, both Te Waza and Ashi Waza were found in the two countries, but in Europe Te Waza utilized were mostly Pick Ups, this also depends on the strategy of incomplete grips applied, instead of in Japan the most applied Te waza were Seoi Nage.
Also, about Ashi Waza, the researchers found interesting differences: among Ashi Waza in Japan were applied most O waza, on the contrary in Europe most Ko Waza.
This survey made clear the very big differences in the judo vision and fight approach between Europe and Japan.

The same author made a study on the dynamic development of judo fight under change of regulations by the International Judo Federation (IJF).
Some of the major findings were the increasing of ippon ratio both for men and women, and although there was a clear distinction between men and women until 2003, the sexual difference in competition performance became smaller when the difference in the time period was no longer used after 2003.

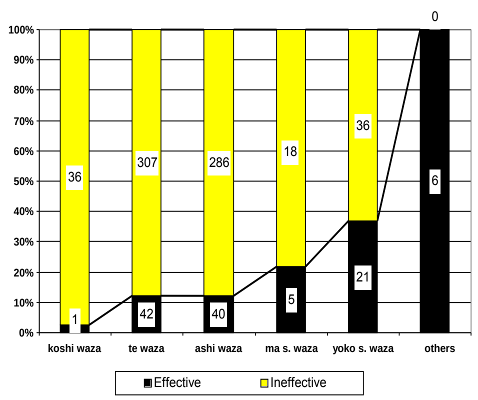
b) Male Athletes

Many data come from Poland, in which the Cracow Sports Academy has studied competition at a very high rank since 1980. Berkowitz was a leading researcher in the field of statistical studies on judo competition
Most of the next graphs and tabs are taken by Sterkowicz, Maciej works, and some of them are connected to other similar works.
The two graphs show the meantime utilized in Ne waza, Tachi waza and stop
The other graph is connected to the effectiveness of technics in Tachi waza





Graph 7.3.a.b, Time utilization in competition



Graph.7.3.c, Effectiveness of Techniques.Tachi Waza

Statistical data from competition could also give a lot of other indications, like:
The trend of the most applied judo Throwing, the side direction of the attacks, or the counters and the combinations most utilized, till to the strategic utilization of fight's time.

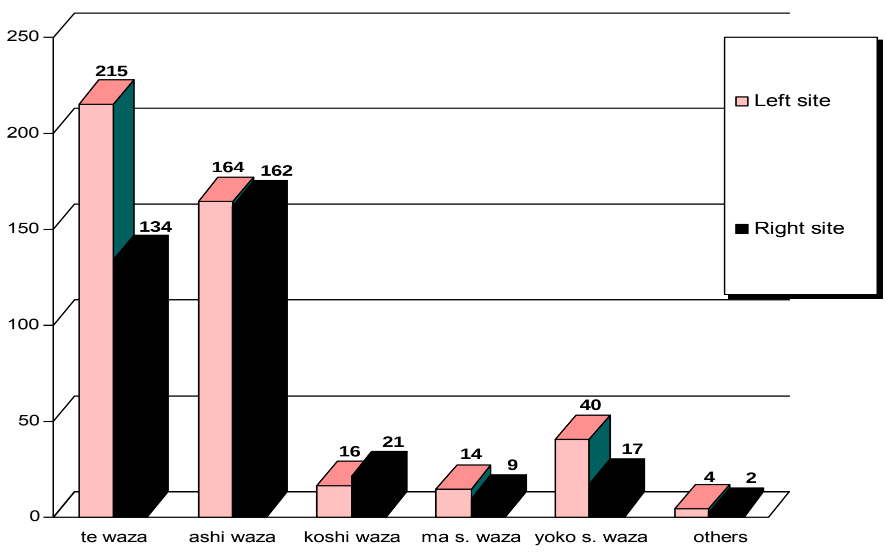
In the following tables taken by different works of Stercowictz and Stercowictz and Maslej are arranged all these data.

Name of throw		Number of all attempts	Number of left side attempts	Number of right-side attempts	% of the total number of attacks
1.	SEOI-NAGE	144	97	47	18
2.	UCHI- MATA	121	57	64	15
3.	TAI-OTOSHI	70	39	31	9
4.	KUCHIKI-TAOSHI	59	40	19	7
5.	O-UCHI-GARI	39	22	17	5
6.	KO-UCHI-GARI	35	16	19	4
7.	HARAI-GOSHI	29	13	16	4
8.	O-SOTO-GARI	28	12	16	4
9.	KO-UCHI-MAKIKOMI	26	16	10	3
10.	YOKO-OTOSHI	25	17	8	3
11.	SEOI-OTOSHI	21	10	11	3
12.	TANI-OTOSHI	20	12	8	3
13.	KO-SOTO-GARI	20	11	9	3
14.	KO-SOTO-GAKE	19	12	7	2
15.	KATA-GURUMA	19	10	9	2
16.	SUKUI-NAGE	18	10	8	2
17.	DE-ASHI-HARAI	18	10	8	2
18.	SASAE-TSURI-KOMI-ASHI	14	6	8	2
19.	UKI-WAZA	12	11	1	2
20.	MOROTE-GARI	11	5	6	1
21.	TOMOE-NAGE	10	6	4	1
22.	SUMI-GAESHI	8	3	5	1
23.	SOTO-MAKIKOMI	6	2	4	1
24.	O-GOSHI	6	3	3	1
25.	URA-NAGE	5	5	0	1
26.	SUMI-OTOSHI	4	2	2	1
27.	KIBISU-GAESHI	3	2	1	<1
28.	USHIRO-GOSHI	1	0	1	<1
29.	SODE-TSURI-KOMI-GOSHI	1	0	1	<1
30.	OTHER	6	4	2	1
	TOTAL:	798	453	345	100%

Table7.3.a Summary of the attempted TACHI-WAZA techniques (Sterkowictz)

Name of throw		Number of counterattacks		Average score received
		Total	Effective	
1.	TANI-OTOSHI	8	4	6.5
2.	KOSOTO-GARI	6	2	10
3.	UCHI-MATA	5	1	5
4.	SUKUI-NAGE	4	1	5
5.	SUMI-OTOSHI	4	4	5.8
6.	OSOTO-GARI	3	2	8.5
7.	KOSOTO-GAKE	2	-	-
8.	KUCHIKI-TAOSHI	1	-	-
9.	SUMI-GAESHI	1	1	5
10.	URA-NAGE	1	1	3
11.	HARAI-GOSHI	1	-	-
12.	SEOI-NAGE	1	-	-
13.	OTHER	4	4	5.3

Tab.7.3.b Summary of counterattacks attempted. (Sterkowictz)



Tab.7.3.c Direction of attack attempted (Sterkowictz)

Combination name	Number of combinations attempted		Average score received
	Total	**Effective**	
UCHI-MATA/KO-UCHI-GARI	11	2	7
O-UCHI-GARI/UCHI-MATA	3	-	-
KO-UCHI-GARI/KUCHIKI-TAOSHI	2	-	-
KUCHIKI-TAOSHI/TAI-OTOSHI	2	2	5
UCHI-MATA/KO-SOTO-GAKE	2	-	-
KO-SOTO-GARI/TAI-OTOSHI	2	-	-
TAI-OTOSHI/SEOI-NAGE	2	-	-
DEASHI-HARAI/UCHI-MATA	1	-	-
O-SOTO-GARI/TAI-OTOSHI	1	-	-
SUKUI-NAGE/OSAE-KOMI	1	1	10
SEOI-NAGE/KO-UCHI-GARI	1	1	10
DE-ASHI-HARAI/SEOI-NAGE	1	-	-
SEOI-NAGE/KUCHIKI-TAOSHI	1	-	-
UCHI-MATA/OSAE-KOMI	1	1	10
OUCHI-GARI/KO-UCHI-GARI	1	-	-
TANI-OTOSHI/OSAE-KOMI	1	1	5
KO-SOTO-GAKE/KUCHIKI-TAOSHI	1	1	5
SEOI-NAGE/KIBISU-GAESHI	1	1	3

Tab.7.3.d, Summary of combinations attempted (Sterkowictz)

Group of Techniques	1983 Polish National Championships (Sterkowicz I Kesek 1985) (n=512)	1996 Polish National Championships Sterkowicz (n=792)
TE-WAZA	56%	44%
ASHI-WAZA	28%	41%
KOSHI-WAZA	8%	5%
SUTEMI-WAZA	7%	10%

Tab.7.3.e, Comparison of the distribution of various techniques used in a judo competition in Poland in 1983 and 1996. From Sterkowicz

	ippon	**wazari**	**yuko**	**koka**	**Tot.**
Nage Waza	**172**	**149**	**246**	**127**	**696 -89.2%**
Ashi Waza	62	47	67	53	**230-29.5%**
Te Waza	54	43	83	37	**218-27.9%**
Yoko Sutemi	19	20	44	18	**101-12.9%**
Ma Sutemi	20	27	25	13	**85-10.9%**
Koshi Waza	17	12	27	6	**62-7.9%**
KatameWaza	**47**	**18**	**6**	**7**	**79-10.1%**
Osae Waza	30	18	5	7	**61-7.8%**
Shime Waza	4	0	0	0	**4-0.8%**
KansetsuWaza	13	0	1	0	**14-1.8%**

Tab.7.3.f, Example of Collective data on European Judo championship 2003

c) Female vs Male athletes

With the growing interest in female judo, most researchers analysed the different performances in a comparative way.

In the Rotterdam Symposium 2009, Monteiro and coworkers showed very interesting comparative results about the decreasing of strength between men and women on 63 judokas from many countries the result was that in man were no measurable decrease of strength in repetition, but in women, the verified decrease was till to the 15%

Stachowicz, in the same symposium, analyzed the difference in reaction time between males and females. The last showed a longer reaction time (0.426 s) than male (0.393s). The overall time could be improved by a special judo fitness test.

In the following tabs are shown the results of Sterkowicz about the technical quantitative and qualitative comparison male and female in Atlanta Olympic. In recent work, Prof Segedi from Croatia analyzes the Gran Prix in Rijeka 2013, comparing male and female technical results and fighting time divided into categories. His results are shown in the last two tables

Table 2. Fifteen most successful technical elements used during the Olympic Men and Women Judo Tournament — Atlanta '96 (figures and percentages)

Lp.	Techniques frequently used in womens' judo fights (Atlanta 1996)	n	%	Techniques frequently used in mens' judo fights (Atlanta 1996)	n	%
1.	Seoi-nage*	40	13,2	Seoi-nage*	60	12,3
2.	O-uchi-gari	33	11,0	Uchi-mata	39	8,0
3.	Uchi-mata	22	7,3	O-uchi-gari	38	7,8
4.	Harai-goshi	20	6,6	Ko-uchi-gari	27	5,6
5.	O-soto-gari	16	5,3	Ko-soto-gake	19	3,9
6.	Ko-soto-gake	15	5,0	Kata-guruma	19	3,9
7.	Ko-uchi-gari	13	4,3	O-soto-gari	18	3,7
8.	Kuchiki-taoshi	9	3,0	Ude-hishigi-juji-gatame	17	3,5
9.	Ude-hishigi-juji-gatame	9	3,0	Kuchiki-taoshi	17	3,5
10.	Kesa-gatame**	9	3,0	Tomoe-nage	15	3,1
11.	Yoko-shiho-gatame**	9	3,0	Sukui-nage	14	2,9
12.	Ko-soto-gari	7	2,3	Ko-soto-gari	14	2,9
13.	Tani-otoshi	7	2,3	Tani-otoshi	13	2,7
14.	Tate-shiho-gatame	6	2,0	Yoko-shiho-gatame**	13	2,7
15.	Tai-otoshi***	6	2,0	Tai-otoshi***	12	2,5
	Other	80	26,6	Other	151	31,0
	Total	301	100	Total	486	100

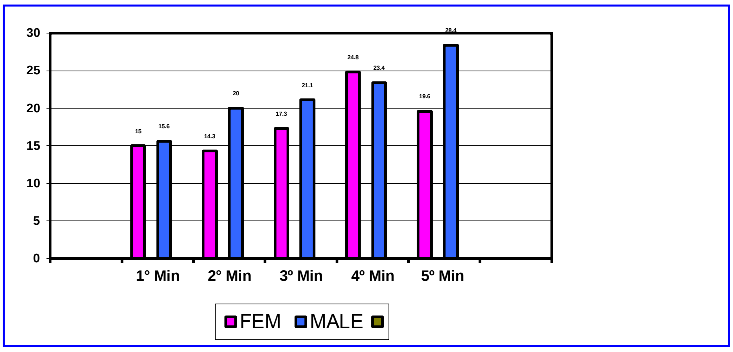
* Different variants (Eri, Ippon, Morote); ** Together with Kuzure; *** ex aequo with Sukui nage (n = 6)

Table. 4. Averaged quantitative and qualitative parameters characterising combat during the Atlanta Olympic Men and Women Judo Tournament

Group	Average time of the bout	Index $\frac{\Sigma actualtime}{\Sigma \max time} 100$	Number of scored action in one bout	Number of points from effective techniques in one fight ($\bar{x}$)	Number of points from penalties in one bout ($\bar{x}$)	Value of scored actions ($\bar{x}$)
Women	2 min 54 sec	72,5	2,86	11,21	2,93	5,18
Men	3 min 06 sec	62,0	3,95	14,27	6,2	5,15

Franchini from Brasil instead analyzed the techniques applied, grouping the Athletes for weights categories and for sex in order to have data for improving judo training.
Two hundred thirty-eight fights were analyzed in men, and 171 fights in women were part of the European championship.
Weight categories are grouping according to similarities of using certain groups of throws. For female categories, -48kg and -52kg and -57kg, the most dominant group of throws are hand throws. The second group comprises weight categories -63 kg up to +78 kg. Within this group, the leg throws are the most used ones.

In the men's part of the tournament, one can also distinguish two groups. In the first group, there are categories -60kg, -66kg and -73kg. The dominant group of throws in these categories is hand techniques. The leg techniques are the second most used ones. The second group includes categories 81kg, -90kg and +100kg, in which the leg techniques were the most used and the second most used techniques are the hand techniques. The conclusions that this clever researcher gives are very interesting and useful: ***“It is clearly shown that the judo is different for every category and that one must train it that way. The individual approach or at least making the homogenous groups enables bigger efficiency of the training and greater chance to accomplishing good international results”.***
The following diagram relative to the European Championship 2002: Monteiro and Chambel in comparison with other studies (Monteiro, 2001; Pulkinnen, 2001; Franchini, 2001; Sterkorwicz & Maslej, 1998; Castarlenas & Planas, 1997; Gorostiaga, 1988; Sikorski et al., 1987), show a decrease in the stop time and an increase in the proportion of the Ippon advantage.



Tab.7.3.g,-% Ippons in each minute of a contest in Female and Male Judoka (Monteiro &Chambel)

	TT	% Total Ippons	Nº Total GoldenScore	Medical Care Aver. of each	Belt/Judogi Aver. of each	Others ST (Aver.)
Female	**3´18´´**	**63.2**	**6**	**68.0´´**	**30´´**	**28.3´´**
Male	**3´30´´**	**70.7**	**6**	**71.7´´**	**34´´**	**38´32´´**

Tab.7.3.h, Female and Male in the contest: Total Time, % Ippons, Golden Score, Stop Medical Care, Stop Belt and Judogi and Others Stop

CATEGORY	END BEFORE REGULAR TIME	END IN REGULAR TIME	END IN GOLDEN SCORE	CATEGORY	END BEFORE REGULAR TIME	END IN REGULAR TIME	END IN GOLDEN SCORE
- 60 KG	10	5	0	- 48 KG	2	0	0
- 66 KG	11	11	1	- 52 KG	3	5	0
- 73 KG	7	8	2	- 57 KG	15	3	0
- 81 KG	19	4	1	- 63 KG	6	7	1
- 90 KG	10	7	0	- 70 KG	7	4	0
- 100 KG	10	4	0	- 78 KG	1	7	1
OVER 100 KG	12	3	0	OVER 78 KG	5	0	1
TOTAL (MALE)	79***	42*	4	TOTAL (FEMALE)	39**	26*	3

Tab.7.3.i, Comparative fighting time both for weight category and gender (Segedi 2014)

CATEGORY	SCORE IN NE WAZA	SCORE IN TACHI WAZA	CATEGORY	SCORE IN NE WAZA	SCORE IN TACHI WAZA
- 60 KG	3	10	- 48 KG	1	1
- 66 KG	3	13	- 52 KG	3	2
- 73 KG	1	11	- 57 KG	5	13
- 81 KG	5	19	- 63 KG	1	10
- 90 KG	5	11	- 70 KG	2	7
- 100 KG	6	5	- 78 KG	0	6
OVER 100 KG	4	7	OVER 78 KG	1	5
OVERALL	27	81*	OVERALL	13	45*

Tab.7.3.j, Comparative score in Ne waza and Tachi waza both for weight category and gender (Segedi 2014)

c) Female athletes

Kamjianovic and co-workers made the analysis of 359 fights of senior female competitors from the European championships in Düsseldorf (GER)-2003 and Bucharest (ROM)-2004.

The topic was a comparison analysis of situational efficiency among seven weight categories for female competitors.

The situational efficiency was calculated according to formula (Sikorski, 1985):

SITUATIONAL EFFICIENCY = Number of official attacks/number of all attacks x 100

The Situational indicators of judo fights are represented with seventeen variables which were registered in the official statistical protocol. Basic frequency and percentual value parameters were determined.

The results are shown in the following tabs

	48kg	**52 kg**	**57 kg**	**63 kg**	**-70 kg**	**-78 kg**	**+78kg**	**Total**
Nage Waza	**91** 91,0 %	**99** 86,0 %	**93** 88,6 %	**98** 91,6 %	**78** 82,1 %	**71** 89,9 %	**64** 84,2 %	**594** 87,7%
Katame Waza	**9** 9,0 %	**16** 14 %	**12** 11,4 %	**9** 8,4 %	**17** 17,9 %	**8** 10,1 %	**12** 15,8 %	**83** 12,3%
Total	**100** 14,8 %	**115** 17,0 %	**105** 15,5 %	**107** 15,8 %	**95** 14,0 %	**79** 11,7 %	**76** 11,2 %	**677** 100 %
χ^2= 6.84; Df = 6; p = 0.336; C=0,10								

Tab.7.3.k, Situation's efficiency of the groups' judo technique (Kamjianovic)

	48 kg	**52 kg**	**57 kg**	**63 kg**	**-70 kg**	**-78 kg**	**+78kg**	**Total**
TE	**27** 27%	**26** 22,6%	**37** 35,2%	**28** 26,2%	**26** 27,4%	**22** 27,8%	**11** 14,5%	**177** 26,1%
KOSHI	**8** 8%	**1** 0,9%	**8** 7,6%	**14** 13,1%	**8** 8,4%	**7** 8,9%	**5** 6,6%	**51** 7,5%
ASHI	**38** 38%	**39** 33,9%	**29** 27,6%	**41** 38,3%	**31** 32,6%	**23** 29,1%	**34** 44,7%	**235** 34,7%
MA	**6** 6%	**11** 9,6%	**4** 3,8%	**3** 2,8%	**1** 1,1%	**3** 3,8%	**1** 1,3%	**29** 4,3%
YOKO	**12** 12%	**22** 19,1%	**15** 14,3%	**12** 11,2%	**12** 12,6%	**16** 20,3%	**13** 17,1%	**102** 15,1%
OSAE	**5** 5%	**11** 9,6%	**8** 7,6%	**6** 5,6%	**13** 13,7%	**6** 7,6%	**11** 14,5%	**60** 8,9%
SHIME	**1** 1%	**0** 0%	**1** 1,0%	**1** 0,9%	**0** 0%	**0** 0%	**1** 1,3%	**4** 0,6%
KANSETSU	**3** 3%	**5** 4,3%	**3** 2,9%	**2** 1,9%	**4** 4,2%	**2** 2,5%	**0** 0%	**19** 2,8%
Total	**100** 14,8%	**115** 17,0%	**105** 15,5%	**107** 15,8%	**95** 14,0%	**79** 11,7%	**76** 11,2%	**677** 100%
χ^2= 58.3; df = 42; p= 0.048, C=0,28								

Tab.7.3.l, Situation's efficiency of the subgroups judo techniques (Kamjianovic)

	-48 kg	*-52 kg*	*-57 kg*	*-63 kg*
1.	O Uchi Gari 14%	O Uchi Gari 15,6%	Seoi Nage 11,4%	Sukui Nage 13,1%
2.	Uchi Mata 13%	Tani Otoshi 15,6%	Sukui Nage 9,5%	Uchi Mata 9,7%
3.	Sukui Nage 7%	Uchi Mata 9,6%	O Uchi Gari 9,5%	De Ashi Barai 7,5%
4.	Tani Otoshi 6%	Seoi Nage 7,8%	Tani Otoshi 6,7%	Harai Goshi 7,5%
5.	Kata Guruma 5%	Sukui Nage 5,2%	Uchi Mata 5,7%	Tai Otoshi 6,5%
6.	Ko Uchi Gari 4%	Sumi Gaeshi 5,2%	Kuchiki Taoshi 3,8%	O Uchi Gari 5,6%
7.	Seoi Nage 3%	Ude Gatame 3,5%	Soto Maki Komi 3,8%	Tani Otoshi 4,7%
8.	De Ashi Barai 2%	Kuchiki Taoshi 3,5%	Kata Guruma 3,8%	Ko Uchi Gari 4,7%
9.	Ko Soto Gari 2%	Ko Uchi Gari 2,6%	Yoko Shiho Gatame 1,9%	O Soto Gari 3,7%
10.	Tate Shiho Gatame 1%	Tomoe Nage 2,6%	Ko Soto Gari 1,9%	Koshi Guruma 3,7%
	-70 kg	*-78 kg*	*+78 kg*	
1.	Uchi Mata 9,5%	O Uchi Gari 15,2%	Uchi Mata 10,5%	
2.	O Uchi Gari 9,5%	Seoi Nage 13,9%	Sukui Nage 9,2%	
3.	Seoi Nage 7,4%	Tani Otoshi 7,6%	O Uchi Gari 9,2%	
4.	Kata Guruma 6,3%	O Soto Gari 6,3%	Tani Otoshi 6,6%	
5.	Mune Gatame 6,3%	Soto Maki Komi 5,1%	Kesa Gatame 5,3%	
6.	Tani Otoshi 5,3%	Uchi Mata 3,8%	Koshi Guruma 5,3%	
7.	Ko Uchi Gari 4,2%	Kesa Gatame 3,8%	O Soto Gari 3,9%	
8.	Juji Gatame 4,2%	Harai Goshi 3,8%	Ko Uchi Gari 3,9%	
9.	Harai Goshi 4,2%	Tai Otoshi 3,8%	Ko Soto Gake 3,9%	
10.	Kata Ashi Dori 4,2%	Mune Gatame 2,5%	Seoi Nage 2,6%	

Tab.7.3.m, -Quantitative indicators of successfulness of individual throwing techniques and controlling judo techniques used by female seniors (Kamjianovic)

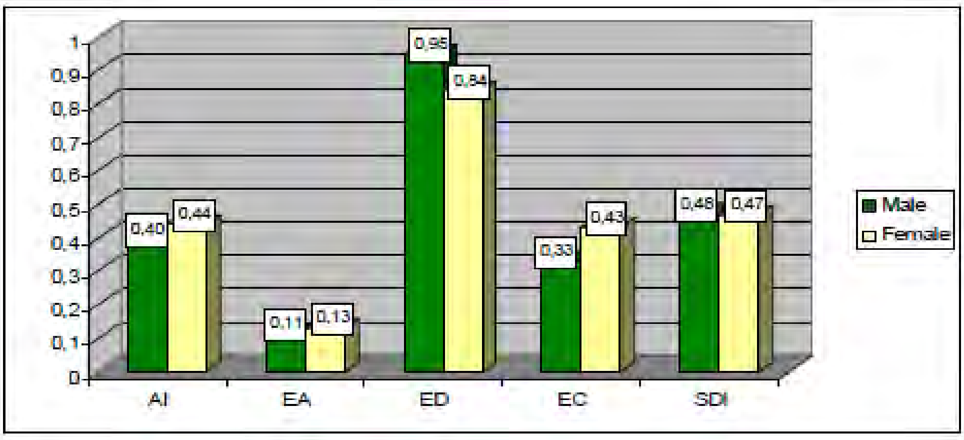
The technical trend is changing in connection to the referee rules changing, and the last study refers to European Championship 2008 in Zagreb (Rotterdam Symposium 2009) by Sertic and coworkers. The results show a high tendency to apply more hand techniques like Kata Guruma for men, and Seoi Nage for women, followed by Uchi Mata and O Uchi-Ko Uchi Gari, but also these trends will change because it is forbidden from 2013 to grasp the leg directly with the hands.

e) Studies on Dynamics of competition (Kalina Method)

Boguszewski and Boguszewska from the Academy of Physical Education in Warsaw, Poland, try to single out from the competition analysis another kind of information.
They made an analysis of fourteen gold medal contests, female and male tournament, in the European Judo Championship 2005 based on Kalina's method on struggle dynamics in judo [Kalina 2000].
Empirical data were obtained from multiple video recordings, all events noted for consecutive 10-seconds intervals.

Struggle dynamics was described by the following five variables and indices:
offensive/defensive activity index – AI,
index of effective offensive actions – EA,
index of effective counterattacks – EC,
index of effective defensive actions, without counterattacks – ED,
the global index of struggle dynamics – SDI, which is the mean value of those specific indices mentioned above, which were determined in the given contest.

The results were not very exciting; in fact, finalists of the European Championship exhibited very low activity. The average AI index for all contests shows that 59% time of contests, competitors didn't take any actions.
Also low was effectiveness of offensive actions EA = 0,12, higher was index of effective Counterattacks EC = 0,32. But the highest was the index of effective defensive actions – 0,92. The global index of struggle dynamics shows that most of the scores (58%) were achieved by penalty, not technical actions. In nine of the fourteen contests, a competitor who first scored – won. The highest struggle dynamics reflected by SDI were exhibited by male judoka, winners of gold medals from lights and middles weight categories.
The highest capability to undertake an action (offensive or defensive; AI) were exhibited by female judoka from the lightest weight category.



Tab.7.3.n , Kalina's Dynamics for European championship 2005 (Boguszewski and Boguszewska)

The not very good result of this particular analysis gives the authors the capability to conclude in such a way:

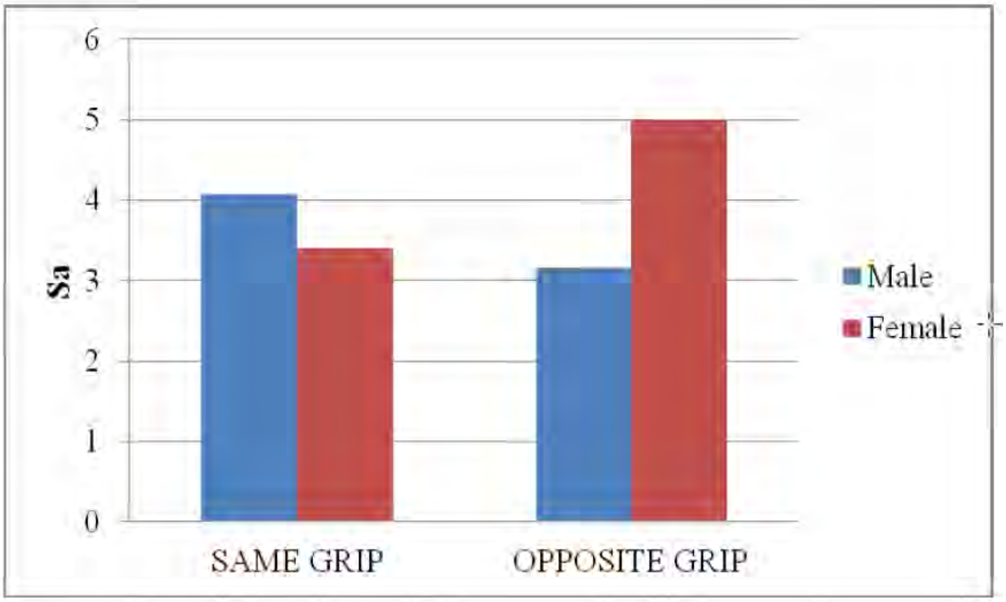
In judo contests on the highest-sports level, changes of leaders are rare. Most competitors who first scored keep the lead to the end of the match or win by "ippon" (before the time is over).
Changes in refereeing rules should be introduced to increase struggle dynamics. Technical and tactical training should be directed to achieve scores very quickly (by tactical action or by forcing the opponent to go against referee rules) and keep the lead.

f) Grips laterality and attack effectiveness

During the last time, the interests of researchers are not only focalized on throws in competition but also on the right skill applied to throw, like grips laterality and direction of throws that are most effective. For example, Courel Ibanez and coworkers from Spain (2014) analyzed systematically 242 contests from 12 World Ranking Tournaments. Results showed that attacking the same side of the kumi-kata increase the chance of scoring and winning the fight independently of sex and weight category. Perform same side attacks by Kenka-yotsu (adversaries using reverse grip, right versus left) was the most effective, especially for lightest weight judo fighters. Perform same-side attacks by ai-yotsu (both opponents using right or left grip at the same time increasing the likelihood of winning the combat.

The study of Kajmovic and Radjo from Bosnia and Herzegovina (2014) is based on the analysis of 280 grip configurations of males along with the equal number of throwing techniques and 166 grip configurations of females judoka along with the same amount of throwing techniques.

As a result, males dominate in regard to the same side grip, while females dominate in regard to the opposite side grip see next table



Tab.7.3.o, Efficiency of attacks versus grips configuration

The most efficient throwing technique for males considering side grip was Ippon seoi nage, while for the female was Harai goshi.

The technique which has the highest efficiency index both in males and females regarding the opposite side grip was Uchi mata

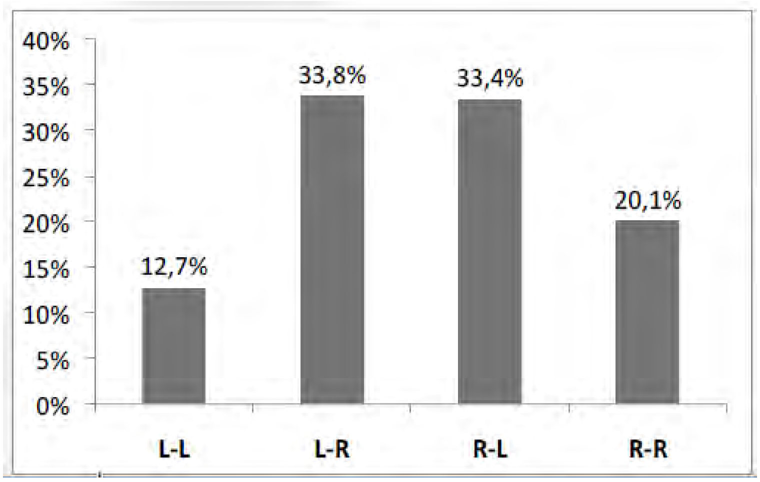
Dopico-Calvo and Coworkers from Galicia (Spain) ***EJU Poster Exhibition 2016*** studied very in deep the world championship 2013 with the relationship among:

a) sporting success in judo (i.e., scoring standing actions),

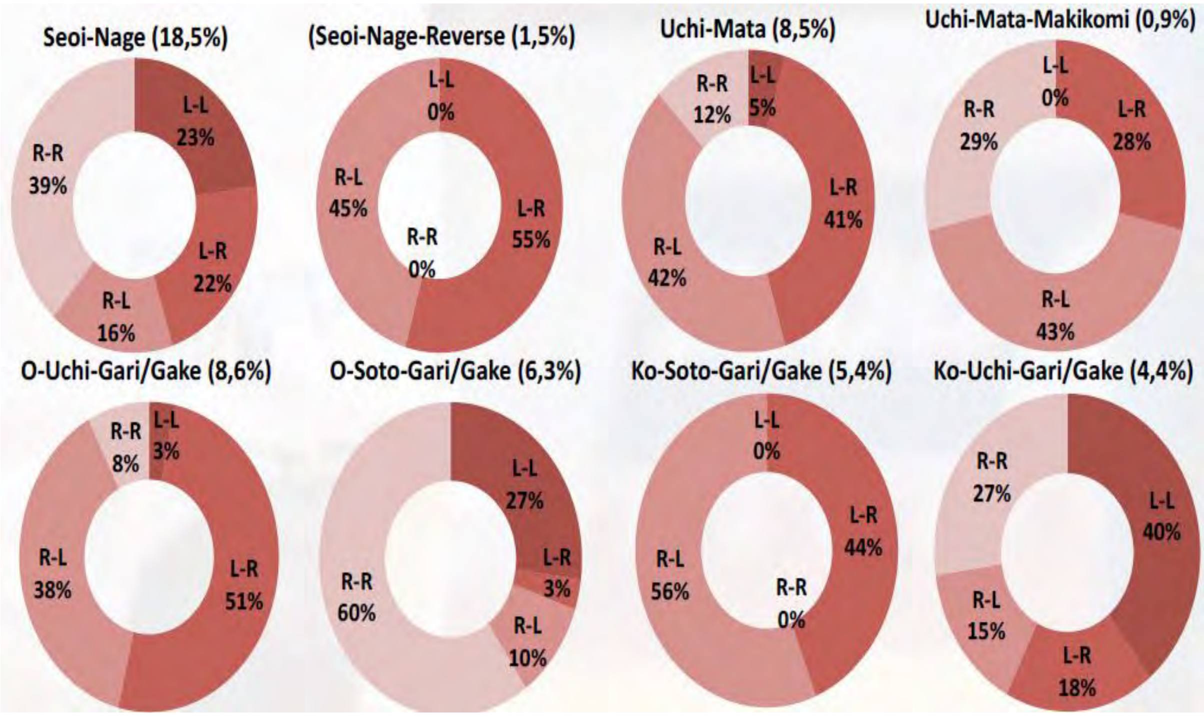
b) the lateral structure of confrontation or relative positions between judokas (i.e., scoring in symmetrical or asymmetrical position),

c) the lateral preference, or laterality, both for the execution of each performed action, or functional dominance (i.e., as for right- or left-dominant), as for the stand position of the opponent (i.e., right- or left-position).

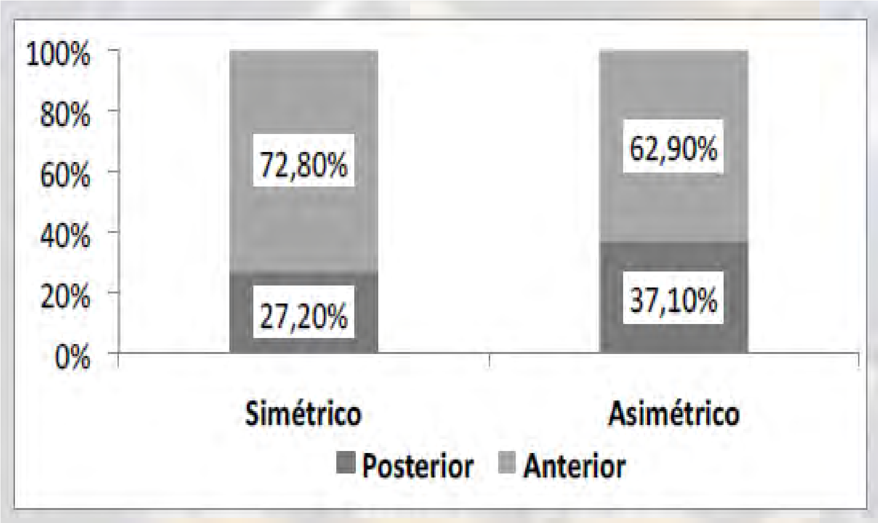
The results are shown in the next four tables.



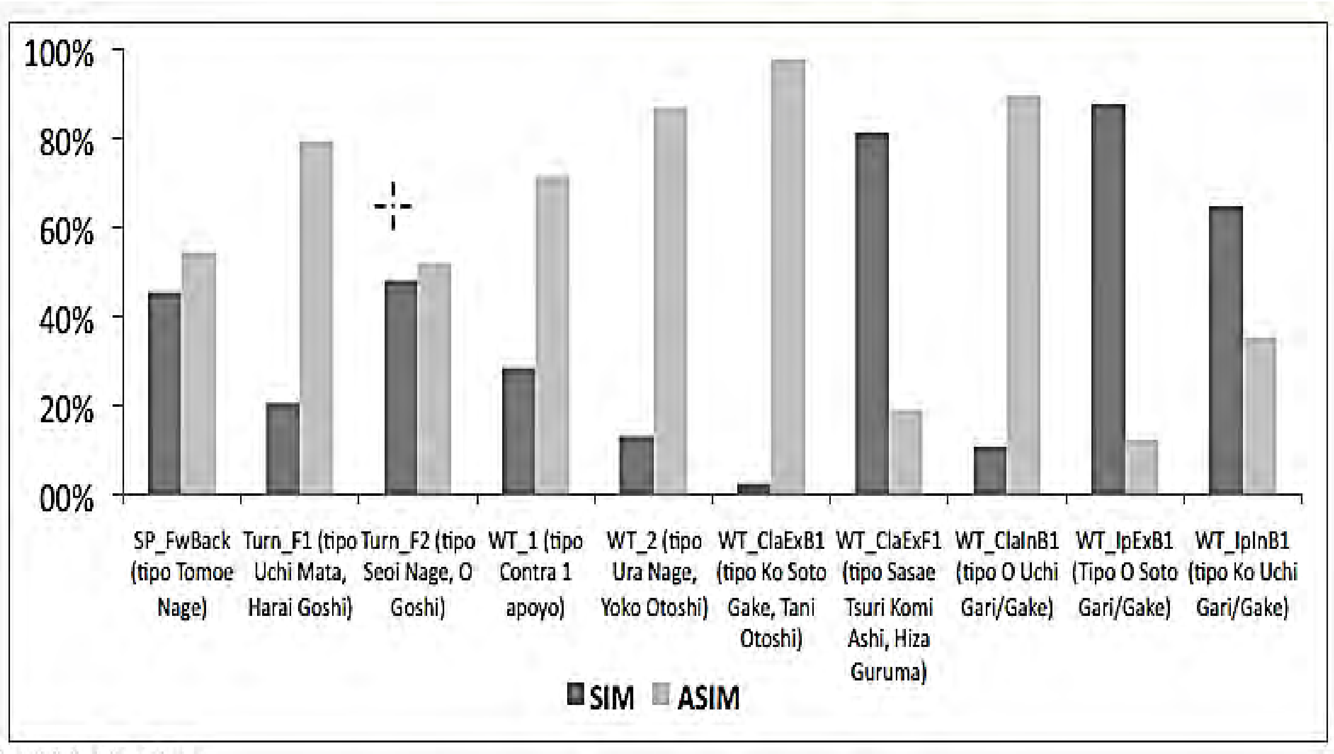
Tab 7.3.p. Scored actions in function of grips structure



Tab.7.3.q, Most successful techniques in function of grip structure



Tab.7.3.r Direction of Projection versus grips structure



Tab.7.3.s. Distribution of throwing groups (par4.3.1.1) versus grips structures

g) Technical-Tactical actions in competitions

Another hot topic in the researcher's literature is the translation of the whole competition in terms of normal scientific parameters. Many outstanding researchers like Calmet from France, Heinish from Germany, Sterkowicz from Poland, Sertic and Segedi from Croatia, Del Vecchio, Francini and Miarka from Brazil, Monteiro from Portugal, Carratala, Dopico, and Garcia Garcia from Spain, etc. have analyzed this area.

The main result is tentative to connect as many parameters as possible to describe the whole contest, like:

Competitions time quantization, Throwing, Quality, frequency, kumi kata, attack direction, effectiveness, Tachi waza ne waza transition, Ne waza evolution, Counter, Shifting evolution and others

In the following figures, there are presented a few of the results from some of the previous researchers in this area of study.

Autores	Competiciones	Actividad (s)	Pausa (s)
Castarlenas & Planas (1997)	1991 Mundial Sénior 1992 JJ.OO. Barcelona	18,0 ± 8,5	12,4 ± 4,1
Monteiro (1995)	1994 Europeo Júnior 1er. min de combate 2º. min de combate 3er. min de combate 4º. min de combate 5º. min de combate	 25,8 ± 7,8 27,0 ± 9,0 27,0 ± 9,7 22,4 ± 9,3 18,9 ± 10,4	 9,5 ± 3,2 10,4 ± 4,5 13,4 ± 7,6 13,2 ± 7,3 13,9 ± 9,0
Sikorski, Mickiewicz, Majle & Laksa (1987)	1986 Copa Matsumae 1985 Europeo Sénior	30,0	13,0
Sterkowicz & Maslej (1998)	1996 Polonia Sénior	25,1	10,3
Van Malderen, Zinzen, Watthy & Luyten (2006)	2004 Bélgica Sénior Femenino Masculino	 19,9 ± 7,3 18,8 ± 9,0	 7,5 ± 6,2 9,13 ± 5,1
García & Torres (2007)	2006 España sub´23 Femenino Masculino	 14,0 ± 2,0 23,0 ± 6,0	 12,0 ± 4,0 7,0 ± 2,0

Tab. 7.3.t Summary of a study on time use in competitions (from Miarca and coworkers)

Table 1. Statistical analyses of time-motion variables in total time (s).

Total Time	**International Championship**		**Olympic Games**		**Effects of the interaction between Level and Results**			
Combat Phase	**Winning**	**Losing**	**Winning**	**Losing**				
	mean(SD)	mean(SD)	mean(SD)	mean(SD)	F	df	p	η^2
Aproach	129.7 (13.3)	127.9 (13.3)	161.1(13.3)	176.5(13.3)	1.411	3	0.242	0.027
Gripping	79.4(7.3)	80.3(7.3)	99.8(7.3)	98.8(7.3)	3.280	3	0.076	0.076
Attack to Front	6.0(1.1)	2.3(1.1)	3.4(1.0)	3.6(1.1)	2.529	3	0.058	0.036
Attack to Right	9.9(1.5)	5.9(1.1)	6.5(1.1)	3.5(1.1)	1.477	3	0.222	0.021
Attack to Rear	9.3(1.5)	6.4(1.5)	9.3(1.5)	8.5(1.5)	0.439	3	0.726	0.006
Attack to Left	4.8(1.2)	3.7(1.2)	6.0(1.2)	5.9(1.2)	1.618	3	0.186	0.023
Defense	18.6(2.5)	16.3(2.5)	14.0(2.5)	17.1(2.5)	0.930	3	0.427	0.013
Groundwork	18.3(2.9)	23.4(2.9)	26.1(2.5)	33.9(2.9)***	6.623	3	$p<0.001$	0.089
Combat	266.3(22.8)	266.3(22.8)	326.5(22.8)	327.2(22.8)	2.381	3	0.071	0.034
Pause	50(6.0)	50(6.0)	57.2(6.0)	58.7(6.0)	1.283	3	0.281	0.019

***Significantly different from winning in International Championship ($p<0.001$).

Tab.7.3.u. Use of time in competitions (from Miarca and coworkers)

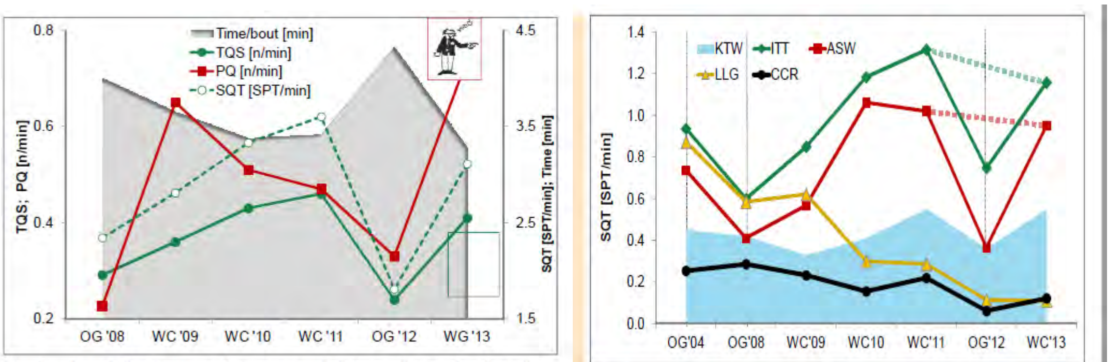


Fig. 1. Longitudinal course of average combat time, efficacy of technical-tactical actions and of frequency of penalties

Fig. 2 Course of efficacy of selected groups of throws

Graph.7.3.d.e . Technical Tactical Parameters evolution in time (from Heinisch &Busch)

Fig. 7.3.a Example of a group of throws (from Heinisch &Busch)

Table 3. Descriptive analyses of time-motion variables in frequency, by mean(SD) (s).

Total Time	**International Championship**		**Olympic Games**		**Effects of the interaction between Level and Results**	
Combat Phase	**Winning**	**Losing**	**Winning**	**Losing**		
	median (25%;75%)	median (25%;75%)	median (25%;75%)	median (25%;75%)	χ^2	p
Approach	18.0(13.0; 27.8)	19.0(11.0; 27.8)	25.5(11.0; 30.0)	24.0 (14.0; 30.8)	3.431	0.330
Gripping	16.5(10.0; 27.8)	18.0(10.3; 26.0)	24.5(14.0; 31.0)	20.0 (13.0; 28.8)	6.584	0.086
Attack to Front	1.0(0.0; 2.0)	0.0(0.0; 1.0)	0.5(0.0; 2.0)	0.0 (0.0; 1.8)	7.643	0.054
Attack to Right	1.0(0.0; 2.0)	1.0(0.0; 2.8)	2.0(0.0; 3.0)	0.5 (0.0; 2.0)	4.929	0.177
Attack to Rear	2.0(0.0; 4.0)	2.0(1.0; 3.0)	2.0(0.3; 3.0)	2.0 (0.0; 4.0)	0.405	0.939
Attack to Left	0.0(0.0; 2.0)	0.0(0.0; 2.0)	1.0(0.0; 2.8)	1.0 (0.0; 2.8)	6.945	0.074
Defense	5.0(2.0; 9.0)	5.0(2.0; 9.0)	6.0(1.3; 10.0)	7.0 (3.0; 11.0)	3.627	0.305
Groundwork	3.0(1.0; 6.0)	4.0(1.0; 8.0)	6.0(2.0; 10.0)	7.0 (3.3; 11.0)***	17.722	<0.001
Combat	9.5(6.3; 14.0)	9.5(6.0; 14.0)	12.0(7.0; 15.0)	12.0 (7.3; 16.0)	3.924	0.270
Pause	8.5(5.3; 13.0)	8.5(5.0; 13.0)	11.0(6.0; 14.0)	11.0 (6.3; 15.0)	3.924	0.270

*** Significantly different from winning in International Championship (p<0.001).

Table 3. Descriptive analysis of combat phase variables used for the clusters, separated by Winning and Losing athlete groups.

Group/Variable	Approach	Gripping	Attack	Groundwork	Pause
Frequency of actions [median (first, third quartile)]					
Winning Athletes	15(9, 23)	19(8, 31)	6(4, 10)	5(2, 6)	10(5, 15)
Losing Athletes	13(9, 24)	18(11, 29)	5(2, 8)	4(2, 7)	10(6, 14)
Total Time (s) (mean±SD)					
Winning Athletes	95.8±79.9	144.5±109.4	10.9±14.8	56.3±56.2	115.5±92.8
Losing Athletes	94.8±71.5	135.1±94.6	11.2±19.5	53.9±46.4	120.2±97.1
Time per each action (s) during combats ending in victory (mean±SD)					
Winning Athletes	6.2±4.0	6.8±3.4	1.4±1.5	14.7±17.3	11.9±06.8
Losing Athletes	6.3±3.0	6.7±3.1	2.0±4.0	13.1±12.0	32.8±11.2

Table 4. Descriptive analysis of technical-tactical indicators presented a
of total T-T frequency by the combat phases.

Variables	Left Antero-posterior Approach*	Right Antero-posterior Approach	No Form Approach	Attempted Gripping Approach
Winning Athletes	4.1%	11.3%	11.5%	12.5%
Losing Athletes	5.6%	9.8%	11.7%	14.2%
Variables	**Left Sleeve and Right Sleeve Gripping**	**Left Collar and Right Collar Gripping**	**Left Sleeve Gripping**	**Right Sleev Gripping***
Winning Athletes	3.5%	1.5%	1.2%	2.3%
Losing Athletes	4.5%	1.1%	1.6%	2.1%
Variables	**Right Collar and Right Sleeve Gripping**	**Left Collar and Left Sleeve Gripping**	**Right Back and Left Sleeve Gripping**	**Left Back a Right Sleev Gripping***
Winning Athletes	0.7%	0.2%	0.8%	1.5%
Losing Athletes	0.4%	0%	0.1%	1.2%
Variables	**Right Collar and Left Sleeve Gripping**	***Ashi-waza* Attack**	***Koshi-waza* Attack**	***Te-waza* Attack**
Winning Athletes	3.1%	6.5%	0.3%	3.5%
Losing Athletes	2.8%	5.9%	0.4%	2.7%

* significantly different between groups (p<0.05)

Desplazamiento	Francia	Japón	URSS	Otros	Media
Delante	37%	34%	39%	42%	38%
Atrás	29%	32%	26%	23%	27,5%
Derecha	14%	10%	17%	14%	13,8%
Izquierda	12%	15%	7%	12%	11,5%
Estático	8%	9%	11%	9%	9,3%

Tab. 7.3 .v.z. w.x. Examples of technical, tactical analysis from (Miarka and coworkers)

Table 2. Frequency of the highest scores achieved during the matches in men weight categories

CATEGORY	END WITH IPPON	END WITH WAZA ARI	END WITH YUKO	END WITH PENALTY
- 60 KG	10	2	1	2
- 66 KG	11	6	4	1
- 73 KG	7	1	4	5
- 81 KG	19	3	1	1
- 90 KG	10	4	2	1
- 100 KG	10	0	1	3
OVER 100 KG	12	0	0	3
OVERALL	79*	16	13	16

*significant difference between the frequency of Ippon and Waza ari, Yuko, Penalty

Table 4. Difference in frequency of scores achieved in ground (ne waza) and in standing (tachi waza) position

CATEGORY	SCORE IN NE WAZA	SCORE IN TACHI WAZA	CATEGORY	SCORE IN NE WAZA	SCORE IN TACHI WAZA
- 60 KG	3	10	- 48 KG	1	1
- 66 KG	3	13	- 52 KG	3	2
- 73 KG	1	11	- 57 KG	5	13
- 81 KG	5	19	- 63 KG	1	10
- 90 KG	5	11	- 70 KG	2	7
- 100 KG	6	5	- 78 KG	0	6
OVER 100 KG	4	7	OVER 78 KG	1	5
OVERALL	27	81*	OVERALL	13	45*

*significant difference between the frequency of ending match in ne waza and tachi waza position

Table 4. Difference in frequency of scores achieved in ground (ne waza) and in standing (tachi waza) position

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- 60 KG	3	10	- 48 KG	1	1
- 66 KG	3	13	- 52 KG	3	2
- 73 KG	1	11	- 57 KG	5	13
- 81 KG	5	19	- 63 KG	1	10
- 90 KG	5	11	- 70 KG	2	7
- 100 KG	6	5	- 78 KG	0	6
OVER 100 KG	4	7	OVER 78 KG	1	5
OVERALL	27	81*	OVERALL	13	45*

*significant difference between the frequency of ending match in ne waza and tachi waza position

Tab.7.3 aa.bb.cc Other analysis of Competition (from Sertic, Segedi and coworkers)

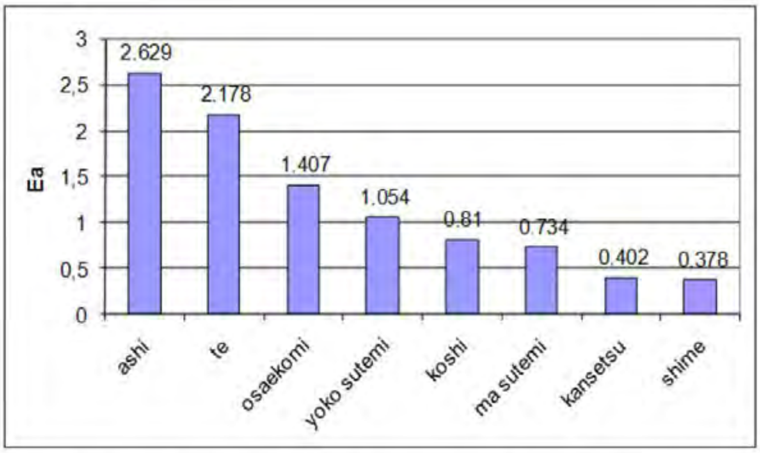


Fig. 4. The efficiency of attack (Ea) of groups of judo techniques during the World Championships in 2014–2015

Tab.7.3.dd Efficiency of attack (from Adam and Coworkers)

h) Throwing techniques effectiveness in competition

Throws Effectiveness In London Olympic 2012				
Throws	***Effectiveness Male %***		***Effectiveness Female %***	
Seoi (Ippon – Morote - Eri)	14.8	(329)	8.2	(222)
Uchi Mata	9.2	(138)	15	(143)
O Uchi Gari	15	(53)	24	(49)
Ko Uchi Gari	12	(57)	37	(35)
Tai Otoshi	25	(36)	23.8	(21)
Soto Makikomi	10	(10)	23.6	(17)
Tani Otoshi	46	(13)	50	(16)
Uchi Mata sukashi	90	(10)	100	(10)
Couple	***28.7***		***39***	
Lever	***24***		***26.4***	

Throws effectiveness in Rijeka 2015		
Throws	***Effectiveness Male %***	***Effectiveness of Female %***
Seoi (Ippon-Morote-Eri)	20.4	29
Uchi Mata	22.4	10
O uchi Gari	32	10
Ko Uchi Gari	36.4	50
Tai Otoshi	24.2	50
Soto Makikomi	27	21
Harai Goshi	37	25
Uchi Mata Sukashi	100	
Couple	***32,9***	***22,6***
Lever	***19***	***25,8***

Throws effectiveness in Rijeka 2015		
Throws	***Effectiveness Male %***	***Effectiveness of Female %***
Seoi (Ippon-Morote-Eri)	20.4	31
Uchi Mata	22.4	10
O uchi Gari	32	10
Ko Uchi Gari	36.4	50
Tai Otoshi	24.2	50
Soto Makikomi	27	21
Harai Goshi	37	25
Couple	***32,9***	***22,6***
Lever	***19***	***27,8***

Sertic and coworkers 2016 (modified)

i) Conclusion about competition scientific studies

Similar examples should be applied to all fighting sports.
Naturally, the historical data analysis about competition, times, techniques and kind of contests statistically evaluated could be a source of critical information, starting from judo competition tendential evolution, until to the accurate knowledge about preparation, technical skills and drawbacks of a specific athlete.
If we only think about the statistic as a kind of photograph of the past, they will give us the past situation and nothing else.
But if the measurable output of a system is viewed as data that include patterns and some error, a significant consideration in forecasting is to identify and fit the most appropriate model.
The critical task in forecasting is to separate the pattern from the error (random) component so that the former can be used for prediction.
The general procedure for estimating the pattern of a relationship is through fitting some functional form in such a way as to minimize the error component. One type of this estimation is the mean squared errors.
A significant consideration in the selection of forecasting method for judo is the type of patterns in the data. These patterns may represent characteristics that repeat themselves with time, or they may serve a turning point that is not periodic in nature.
In general, a data series can be described as consisting of two elements the pattern and the randomness.
The objective of forecasting is to distinguish between those two elements using the forecasting method that can most appropriately do so.
It is also possible for that pattern to be thought of as consisting of subpatterns, or components, each of which can be considered separately.
The components most frequently used in describing elements of the pattern are generally defined in scientific literature as Trend, seasonality and cycle.
Knowledge of the type of sub-patterns included in the data can be instrumental in selecting the most appropriate forecasting method.
As previously seen, the data can be fractioned for the team, weights, sex and more subtle fragmentations. Doing so, the use of data forecasting flows into scouting and spying the adversaries. (cfr Chapter 9)

7.4 Competition in the light of Classical and Advanced Biomechanics.

I) Basic Biomechanical parameters able to obtain the most effective performance

The analysis of "Couple of Athletes System" during Judo fight single out that, in the light of Biomechanics, the necessary parameters to perform effectively are only three.

a1) – *Shifting Velocity*
a2*) – Attack Speed against Reaction Capability*
a3) – *Bodies' Relative Positioning Management*

a1*) – Shifting Velocity.*

The "Couple of Athletes" shifting velocity on the Tatami is the speed of the system, seen as a whole. This is essential because, at every velocity class (low, average, and high), it will be possible to apply only some specific standing techniques (cfr 8.3; 9.3).
And then, it should be possible to manage a specific competition strategy.
If we think that every competitor has his own preferred pace of shifting velocity, depending on his own Tokui Waza, therefore, to compel him at another disliked shifting velocity, it will cause him big technical-psychological trouble.

a2*) – Attack Speed against Reaction Capability.*

The very useful attack speed, to be tactically effective, must be as high as possible.
This speed is a physical-technical athletes' capability, and it is a capability able to be trained.
It is essential to remember that increasing in attack speed; must not be to the detriment of precision of technical gesture which should be very flexible to fit the infinite and possible fight situations.
Then there is advisable before to increase the speed and after to better the precision, with the growth of his own technical maturity.
Judo, attack speed is undoubted, in most cases, shifting velocity independent.
But at the high shifting velocity of "Couple", fast attacking is connected to high "coordinative" skill. The increase of attack speed over his own personal maximum is very complex or impossible, but there is a very effective biomechanical tool to prevent the competitor reaction, the decrease of "*attack steps*" and attack "*logical path*": for example (three Steps Attack → two Steps Attack) in such way it is possible to prevent activation of competitor *Reaction Capability*. In the following figures it likely to see a clear example of

a3*) – Bodies' Relative Position Management.*

The capability to manage the bodies' relative position rightly is essential to the execution of a specific motor skill, like throwing in non-conventional relative position produced by competitor reaction (Hando No Kuzushi). In the next figures, it is possible to see a clear example of this right management of relative position performed by Huizinga against Morgan

Fig.7.4.a.b.c.d.e.f.g, Very skilled management of dynamic relative position in competition (Finch)

By analyzing the management of the relative position from the biomechanical point of view of the Couple of Athletes System, it is possible to detect two phases depending on the athletes' relative range.

1) Starting Phase

The starting phase in Judo fight judo is connected to the need of taking dominance grip (see chap) and to the possibility by both Athletes to apply fast trick techniques only Pick Ups.
It is the particular phase in which two standing competitors are far more than one harm distance, without contact points.
Into this phase, there are many possibilities of relative position, shifting, grips, attacks, or tricks for both competitors; and its management is complicated
In such a situation, the mechanics of interaction shows that among the three possible guards: low, medium and high, that are connected to the attack capability (high better for the attack, low better for defence), there is a well-determined attack, counter and defence surface, into which there is the need to know the potential technical actions to do or to receive.
Knowledge in this phase makes different elite athletes from the others.

2) – Stabilized phase

It is the situation that is born after grips stabilization, and it is the normal fighting judo situation that depends on the relative body positions, into which can be classified six subgroups (the guard position) belonging to two classes of shifting velocities (cfr chap 9.3). Remember, the first three-guard position connected to the slow speed approach is characterized by a bending forward position of uke that unbalanced increase his stability, slowing downshifting velocity. In the second three positions, the moving velocity is higher, and the slow down strategy is based on the right use of the application of the body's weight by grips.

II) Biomechanics of competition: some classical remarks.

In this paragraph, the first trial of global biomechanical analysis of competition will start.
The scientific methodology will help us to find the right way to do that.
At first, we need to define the physical condition of the Couple of Athletes System, for second the external forces acting on the motion of each component (shifting and locomotion), third the tools that transfer the internal forces each other (grips) and forth the whole balance situation, then for fifth the global motion and at the end as sixth the interaction (throwing).

III) Acting External forces on a couple of athlete system

The "Couple of Athletes System" is affected by only two eternal forces: Gravity and Friction, but Gravity is in first approximation nullified by the mat presence, and then it is possible to affirm that the motion of the Couple of Athletes System is affected by only one acting external force the friction that transfers the ground reaction force to the competitors' bodies.

a) ***Gravity Force***

This force is present:

1. in the standing fight: at the start of the fight when the athletes are far and are in unstable equilibrium, to contrast the starting phase of each throwing; to help the downhill phase and the unbalance of each competitor's body, but it is not present in the motion pattern of the whole system, when, with stabilized grips, the athletes are in stable equilibrium.
2. In the Ne Waza fight (holding and overthrows) is the essential force against competitors in disadvantage must fight.

b) ***Friction***

Friction is present between soles and mat and between athletes' grips.
Friction is essential to competition existence, in fact:

1. Without friction, Athletes can't move on the mat.
2. Without friction, it is impossible to throw the competitor
3. Without friction, it is impossible to transfer the impulse to the competitor

Then there is necessary to speak on this force that allows the fight.
Friction is a waste energy force, called also contact force, because it is born when there is contact between two bodies.
There is not a complete theory of friction, but for our needs, the Leonardo theory put in the formula by Newton is sufficient
The theory is based on the following experimental remark.
"***Friction produced by a weight oppose to the motion, in the same way, however, the contact surface could have different length and width."***
"If the weight doubles, also the fiction doubles."
In formula: $F = - \mu N$ or also $F= -\mu v$
This is the scientific explication of the grip's strategy application by most Japanese people.
It is necessary to remember that friction is connected to athlete weight but different from the pressure concept because, as seen, it is independent by contact surface.

Acting force in shifting and locomotion

Fiction is called dynamic when the foot slides on the mat (Tsugi Ashi) and static when the Athlete puts one's heel to the mat (Ayumi Ashi)
The friction coefficient (**μ**) lowers when speed increases, with a maximum at first detaching.
Consequently, in Tsugi Ashi, increasing the shifting velocity of Couple, friction decreases.
In Ayumi Ashi, because the heel is always still on the mat, at each step, the friction is most significant. About Ayumi Ashi, it is well known in biomechanics that the friction force

horizontal component is around 15% of the total athlete's weight when the body leans to the heel and 20% when the body leans on the tiptoe. (see fig)

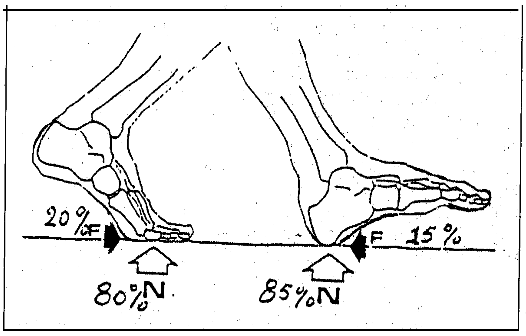


Fig7.4.h, % of weight division between the heel and tiptoe

This information makes clear the well known De Ashi Barai application in Judo. In fact, it is easier (less energy expensive) to sweep the foot when the heel is still touching the mat than the tiptoe is about to detach the mat.
Interesting results that confirm the previous arguments were obtained by Japanese researchers Sannohe and Coworkers in the paper "The Effects of *Tsugiashi* and *Ayumiashi* on Judo Throwing Techniques: about *Ogoshi*, *Uchimata*, and *Osotogari"* 2016.
These researchers analyzed in deep the effects of *Tsugiashi* and *Ayumiashi* on the rotating type of judo throwing techniques.
Three throwing techniques *Ogoshi, Uchimata*, and *Osotogari,* were applied for the research.
The results confirm that In
Tsukuri phase, the movement time of *Tsugiashi* was significantly shorter than the movement time of *Ayumiashi* in two steps.
The movement time of the *Kake* phase was significantly shorter when *Tsugiashi* was used in the *Tsukuri* phase than when *Ayumiashi* was used in the *Tsukuri* phase.
All the findings indicate that *Tsugiashi* is effective in making quick movements in the *Tsukuri* phase and in applying the *Tsukuri* movement to the *Kake* movement.
And as final information that the acquisition of *Tsugiashi* skill as well as *Ayumiashi* skill is essential to improve judo throwing skills.

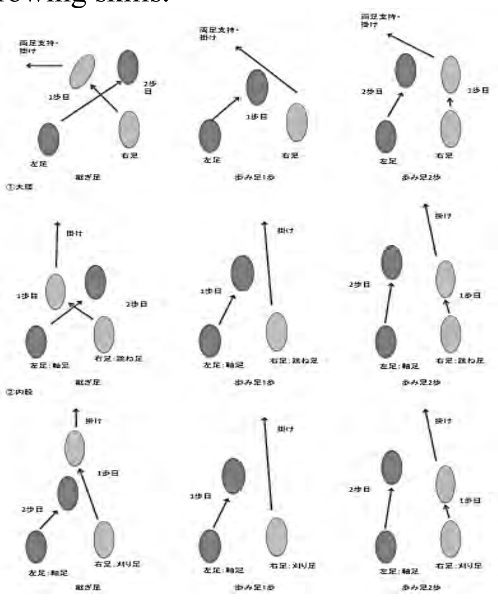


Fig.7.4.1.i Original illustration on feet movements in Sannhoe (2016)

IV) A couple of athlete System internal forces, motion analysis

The Study of the motion of the Couple of Athletes Systems on the mat during the competition could be solved by the application of statistical mechanics.
The analysis of the Couple system singles out that this system is in stable equilibrium if still, it is isolated when it goes the only force applied is (by friction) the ground reaction force, but this force for the third principle of Newtonian mechanics (action-reaction) will be produced by the push/pull forces given rise from the grips.
Then if we analyze the system inside, the force flows from the grips to the mat and becomes attacking effective, emanating from the mat to the points of application (grips) to the adversary body.
The Couple system achieves "random" shifting by changing couple velocity direction in push/pull forces produced by the Athletes to generate specific "situations" in order to apply winning techniques.
In this case, "random" means that statistically, there is not a preferred shifting direction.
The motion can be accomplished by friction between soles and mat on the base of the III° principle of Dynamics; the general equation describing the situation is the II° Newton's Law F =ma.
In the generalized force, F will appear both friction and push/pull contribution.
The friction component is proportional to the velocity $F_a = -\mu v$.
The changes in velocity and direction produced by push/pulls are created by resultant of force developed by the two Athletes themselves.
They are, with regard to the whole contest time, acting impulses in very short intervals of time.
Then the generalized force is $F = F_a + F'$, and the general equation of the motion has the well-known structure of Langevin's Equation:
Because time average of $\langle F' \rangle = 0$; the “Couple of Athletes System” does move of **Brownian Motion.** (See Appendix I)
In Judo competition, Athletes into the coupling system must control their dynamic posture efficiently because the interaction techniques (Throws) are mainly performed on constant displacements aiming at disturbing the balance of the opponent in order to make him fall.
Then, during fights, each judoist learns to use unstable dynamic situations to turn them to his advantage, using the stimulation of muscular, articular and cutaneous mechanoreceptors to adapt to the constant modifications of posture, support base, and partner contact.

V) Interaction (Throws) Connection on Shifting Velocity

On the basis of Biomechanical Classification of Throwing, it is possible to assert that:

A) – ***Techniques of a couple of forces should also be applied without unbalancing.***
B) – ***Techniques of Physical lever must be applied necessary with unbalance.***

The first statement involves that they are less fiction dependent.
In other words, the coupling group of techniques is less dependent on the shifting velocity of Couple, and they can be applied whatever shifting velocity the system should have.
The second statement involves very strict friction dependence.
In other words, this group of techniques should be applied, still or at low shifting velocity.
Not only, but a deeper analysis also shows us that for using such kind of techniques, whatever shifting velocity the couple will have, the athletes need to stop for an instant the adversary is unbalancing him and throwing him.
One other useful tool for both systems should be to detach the feet's adversary from the mat and then to depend from the relative positions to apply or, a kind of Mae mawari Ukemi throwing the adversary, or a kind of Yoko Ukemi to throw the adversary, as it is possible to see clearly in the next sequence of Uchi Mata by Inoue.

Fig7.3.1.l, Mae Mawari Ukemi as a useful tool to help throws (Finch)

In such types of technical actions, unbalance obviously is not necessary.
In the speed attack difference, inside the Couple system plays a significant role
The crashing down action, which very often is applied in competition, produces a friction increase for the undergoing competitor, with a lowering shifting capability.
In contrast, lifting lowers the competitor weight, also reduces friction and makes throwing easier. Biomechanical analysis of competition must also study the rotational approach to Throwing.
This approach is advantageous and energy saving because the muscular structure of the human body is less effective in defence by sided throwing or rotation unbalances.
And the rotational uses of competitor push mean not to contrast but to turn aside from his drive with better exploitation of energy, also lowering the relative range between athletes' bodies.
The rotational development of throwing needs also the use of rotational unbalance. In such a way, we have the best utilization of the adversary's energy.

VI) Athletes' Interaction

Athletes' Interaction into the Couple of Athletes System shall be analyzed by differential methodology (sharing the whole system action, in three sub-actions in time)

A. Relative positioning (starting and stabilized phases)
B. Collision and Throwing
C. Biomechanical Means to apply standing techniques
D. The technical evolution of throwing

A) – *Relative positioning (starting and stabilized phases)*

1) Starting Phase

The starting phase of the competition is a particular phase in which a Couple of Athletes system shall be "open", in such a situation, it should be possible to apply only throwing the group of a couple of forces, essentially belonging to the subgroups (harms and harm-leg) pickups

2) Stabilized Phase

After holding the grips, the Couple of Athletes System shall be "close"; there is the normal fighting situation, in such phase, it is clear that the number of the *optimal relative positioning* Tori v/s Uke could be infinite. There are the final positions of the Tori body in relation to the Uke body able to throw the competitor (final phase Kuzushi-Tsukuri, before Kake).
Obviously, it is not possible to analyze all these final positions, but a more in-depth study based on a differential methodology (sharing the whole system action, in subsystems in time) shows that they are built by some movements during the kuzushi tsukuri phases that are similar each time for each throwing technique. These few preparatory movements, among the others, are called ***Action Invariants*** (cfr 8.3, 9.3++), and they should be analyzed carefully.
Essentially it is possible to group such trajectories to get closest to the adversary in three geometrical classes: rotations (nearly 180 ° forward and backward Uke), semi rotations (between 10° to 90° on the right or on the left side of Uke), and straight-line (nearly 45° from the front till to 22.5 on the right and till to 22.5 of Uke).

B) – ***Collision and Throws***

The kake phase starts with an inelastic collision with friction between two athletes' bodies, and then it is possible to analyze Throwing by variation analysis.
The throwing problem was solved, **in a static situation**, singling out the results of the use of forces in space; **in a dynamic case**, analyzing the throwing paths, trajectories, and connected symmetries (cfr Chapter 5).
This study was able to single out the two fundamental physical mechanisms which carry out all throwing.

A) Techniques where Tori makes use of a couple of forces for throwing Uke.

B) Techniques where Tori makes use of a physical lever for throwing Uke.

The throwing problem was solved at zero shifting velocity, but on the basis of the Galilean principle of relativity, it is possible to extrapolate such results also to the real competitions.
in the following figures, it is possible to see two clear applications of the basic throwing principles

Fig7.3.1.k, Clear application of the two Biomechanical principles (Finch)

C) - ***Standing techniques, as Biomechanical System***

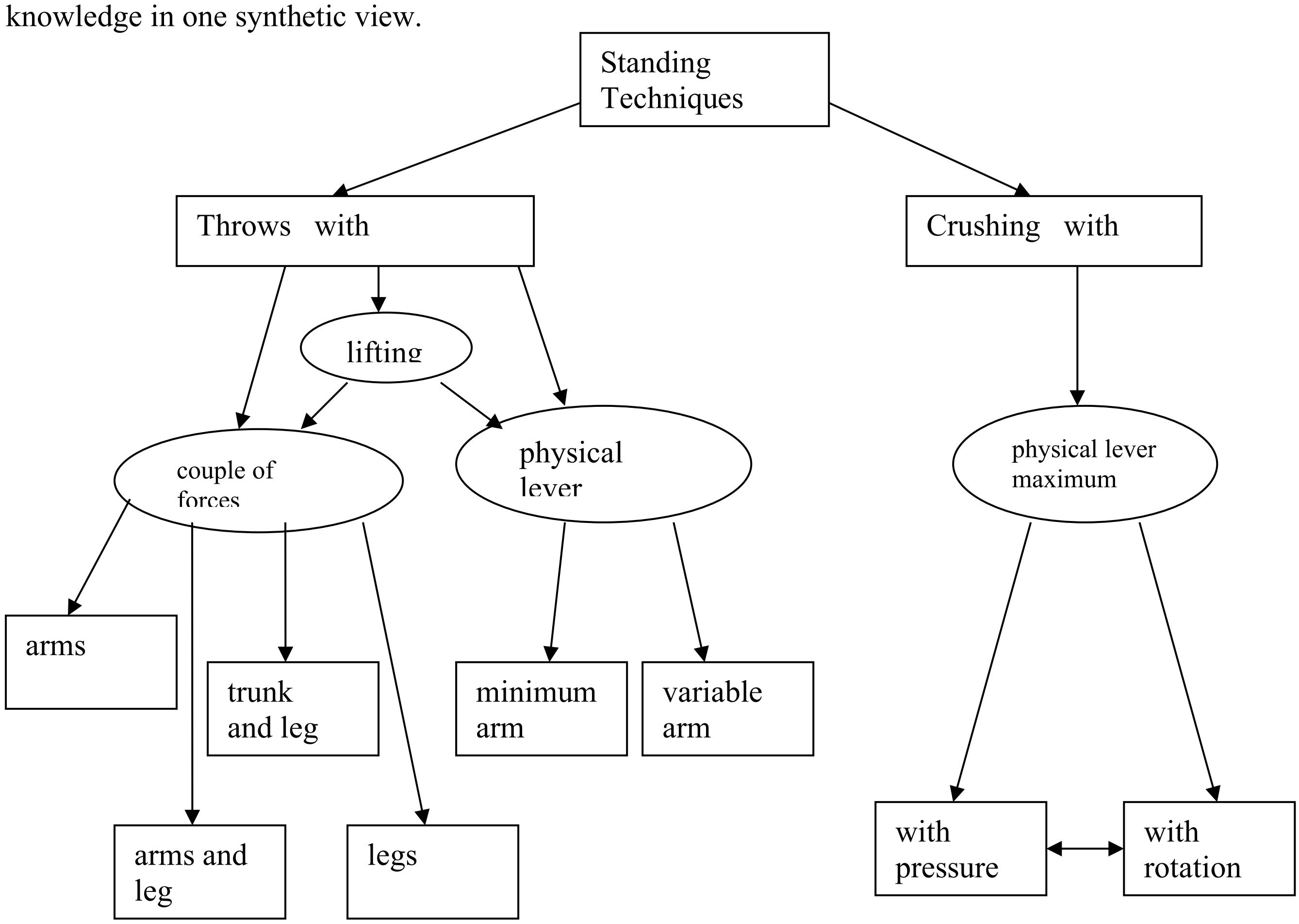
If we analyze the throws (Tachi Waza) in Judo in a systemic way, it is possible to find some exciting properties of the movements that are at the basis of this system.

We already speak about Action Invariants (see Stabilized Phase), but very interesting that there are also the flight paths travelled by the thrown Uke. Such trajectories are the "geodetics" of the specific symmetries found (see 5.2); this means that they are the shortest lines connecting two points among all the possible trajectories connecting the same two points.

These trajectories are also the more convenient, energetically speaking for Tori. Then if we consider the resultant applied and the mechanical properties of the joints used:

1. The three degrees of freedom of the coxo-femoral joint
2. The three degrees of freedom of the lumbar part of the spine
3. The two degrees of freedom of the constrained kinetic chain shaped by hip and legs

It is possible to single out the means utilized to throw Uke, and it is possible to group all this knowledge in one synthetic view.



Graph 7.3.1 a, Physical tools to throws or landing adversaries in Judo

Fig.7.4 all, Miscellaneous Example of application of couple forces system and lever system (Zahonyi, Finch)

D) – ***Expected Technical Evolution***
Athletes' Interaction analysis, from the biomechanical point of view, let us understand the hidden physical rules on which competitions are grounded. The forecasting of the throwing evolution in time should be based only on physical quantities (it is impossible to foresee, for example, the development based on changing referee rules) because they are controllable. The main parameters in forecasting are two, Energy and Power. For a better understanding, we can consider Energy as overall energy consumption and Power as muscular power applied.

a) Energy

Kano reminds us of the principle to obtain in competition the maximum effect with the minimum energy expenditure.
On the basis of minimization of energy, it is possible to show what biomechanical classes of techniques shall be used more and more in the foreseen competitions.
In general, couple techniques shall be preferred to lever techniques.
Among lever, techniques shall be preferred more and more the group of the maximum arm.
The lever techniques will change in a variation where new movements shall be applied, able to evolve the lever principle in a couple of forces principle.
For example: to apply a sweep on Tai Otoshi, with the extension movement of the barring leg, Or to apply a standing up movement from Suwari Seoi (the couple is push up and gravity down), or to evolve Ashi Guruma into a sweeping leg technique (as a strange variation of Harai Goshi) and so on. On this basis, the shifting velocity shall increase, with consequent more dynamic competitions. The couple techniques shall be more energy-saving if Tori is able to improve even more the "rotation arm". This means, for example, to apply Uchi Mata sweep to the leg (till to malleolus see Inoue first sequence 5.2) and not to the thigh. For this group of techniques, friction independent, the timing is a second way to decrease energy. Then both the increase of rotation arm and the timing shall increase the attack speed and the shifting velocity, with a consequent increase in competitive dynamics.

b) Power

The second parameter is the muscular power increase. In contrast with the previous one, the increase of this parameter shall decrease the shifting velocity consequently, with more body contact and complete closure of a couple of athletes (heads in contact) by strong grips, with also short-range distances.
In such a way, it is possible to apply lever techniques like Tama Guruma and every possible variation from that, like the one with back throwing direction.
It is also possible to apply reverse couple techniques like Khabarelli (Backward Kliket) or Mae Hiza Ura Nage, or (that are grounded on a very strong power application.
This kind of technique needs to detach competitors' feet from the mat, working against the gravity force with a high increase in energy expenditure.
A small shifting velocity obviously, it is possible to apply also a very effective couple of forces techniques, but the application of muscular power makes that the athletes don't take further interest in timing, with an increase in energy expenditure that also means to do a great number of movements applying the same techniques. Another very important remark is the decrease of shifting velocity and the increase of muscular power lets necessary to apply at the end of the attack throw movements similar to makikomi or Ukemi movements. It means that the use of his own's body weight fallings helps Tori to throw Uke.
The following example shows the difference between Timing Ko Soto Gake very fast and with fewer movements, Nakamura against Lauren, and Strong Ko Soto Gake, very powerful with a lot of parasitic movements Metrev against Had but also very effective.

Fig.7.4.aa.bb.cc, Timing Japanese Application (Finch)

Fig.7.4.dd.ee.ff.gg.hh.ii.Powerful Russian Application (Finch)

VII) Functional Tactic

It is important to deal with a subject that is often overlooked in analyzing the competition: “***functional tactic”***.
In fact, little has been written on the subject, and it is often treated empirically or even disregarded also in the field of high-level coaching.
A good analysis is possible to find in the very interesting book of Prof. Garcia Garcia “Rendimiento en Judo” Onxsport Publishing 2012.
“Functional tactic” refers to the need by the high-level athlete of having to control the intensity of work with which they face each stage of the competition, trying to match the moments of increased activity with the needs of the competition tactics, based on a previously trained functional support.
Teach this to an athlete. It is an essential task of the coach, which must work closely with the fitness coach.
It depends both on the physical condition of the own athlete, from that of the opponent, as by the result marked on the light table.
The good management of the ***functional tactic*** is essential when, for example, the athlete is at a technical disadvantage, but there is plenty of time on the race board.
In this field of functional tactics, it is very difficult to drive the competition against the adversary functional predominance, but it is easy to try to drive the contest with a pace sustainable for his own physiology.
Some interesting gross indication on the pace preferred by the adversary could be inferred by the scouting of throws preferred.
The functional tactic is one of the most important aspects connected to time management during high-level competitions.

7.5 Competition from a Female point of view

I)*Somatotype and Morphological features*

The term somatotype is used in the system of classification of human physical types developed by U.S. psychologists. In Sheldon's system, a human can be classified as to body build in terms of three extreme body types: endomorphic, or round, fat type; mesomorphic, or muscular type; and ectomorphic, or slim, linear type. A somatotype number of three digits is determined for an individual classified by the system, with the first digit referring to endomorphy, the second to mesomorphy, and the third to ectomorphy; each digit is on a scale of 1 to 7. Hence, the extreme endomorph has the somatotype 711, the extreme mesomorph 171, and the extreme ectomorph 117.

Human body shape is a complex phenomenon with sophisticated detail and function. The general shape or figure of a person is defined mainly by the moulding of skeletal structures, as well as the distribution of muscles and fat.

The evaluation of morphological differences among female judoka of different grades would make it possible to estimate the influence of motor activity in judo on athletes' performances, leading to a more refined selection process in this sport.

A recent Russian study by Elipkhanov and Nemtsev aimed to compare the morphological characteristics of female judoka of different ranks was performed on twenty-three athletes of higher grades and thirty-two judoka of lower ranks.

When compared with less skilled judoka, highly skilled judoka (chosen among Masters of Sport of Russia and Masters of Sport of Russia, International Class) have significantly thinner triceps, forearm, chest, medial calf and front thigh skin folds, as well as a lower total body fat percentage. The high skilled judokas also have shorter lower limbs, longer hands, and more developed forearm muscles (greater values for maximum forearm circumference and lower values for forearm skinfold measurements). Their neck, arms and thorax have larger circumferences and as a final result among this comparison Judoka with less body fat, more thoracic muscle mass, and shorter arms and legs were more successful among female judo players analyzed.

II) Female strength in grips

It is well known that muscular strength between men and women is different; normally, women have the 80%-85% of men's muscular strength in the legs and around the 60-70% in harms and grips.

It is common knowledge that with strength training, women's muscular force of harm could increase at a near level of same weight men 85-90%.

This information is not validated by scientific studies.

About grip strength and gender difference among men and untrained and well-trained women, an interesting German study also involving well trained female Judo athletes, performed by D.Leyk and co-workers in 2006, give us interesting results about real grip strength in women.

In the following figures, there are some results from this study.

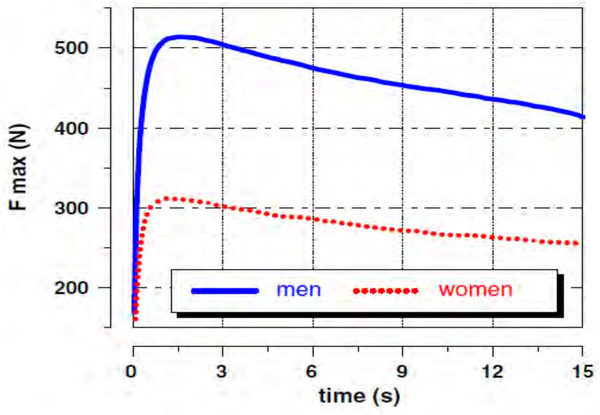


Fig 7.5.a Evolution in time of grip force in man and women

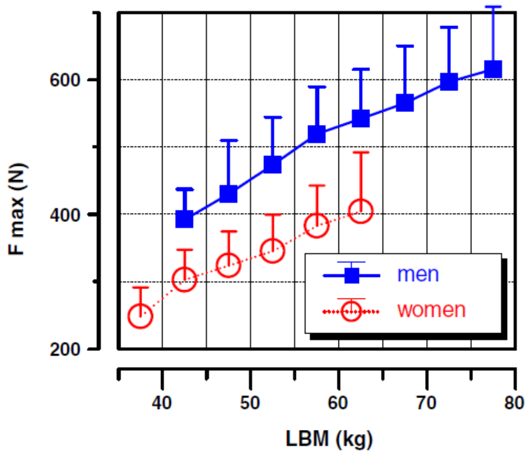


Fig 7.5.b Maximum handgrip Force of different Lean Body mass

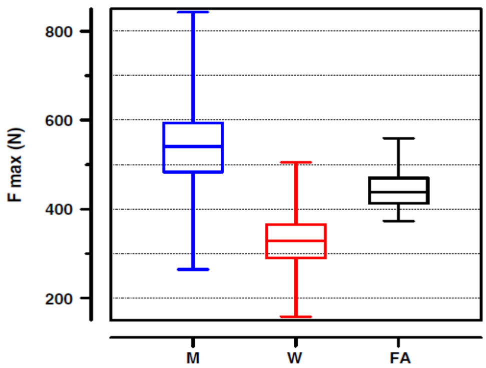


Fig. 7.5.c. Maximum hand grip force among non-trained men, women and female elite Judo athletes

Then female elite athletes, also after training, have a lower handgrip strength than the untrained male group. This situation leads to a different approach to competition; a Thesis performed by Paulo Henrique Junqueira Hudson in 2007 on the world championship of the same year shows the following results:

G. Técnicas com ippons	Masculino	Feminino
Ashi-waza	24,1	11,8
Koshi-waza	3,4	0
Te-waza*	**55,2**	**17,6**
Sutemi-waza	13,8	11,8
Katame-waza**	**3,4**	**58,8**

Notas: * Diferença estatisticamente significativa masculino *vs* feminino (χ^2 = 8,895; p = 0,003)
** Diferença estatisticamente significativa masculino *vs* feminino (χ^2 = 7,364; p = 0,007)

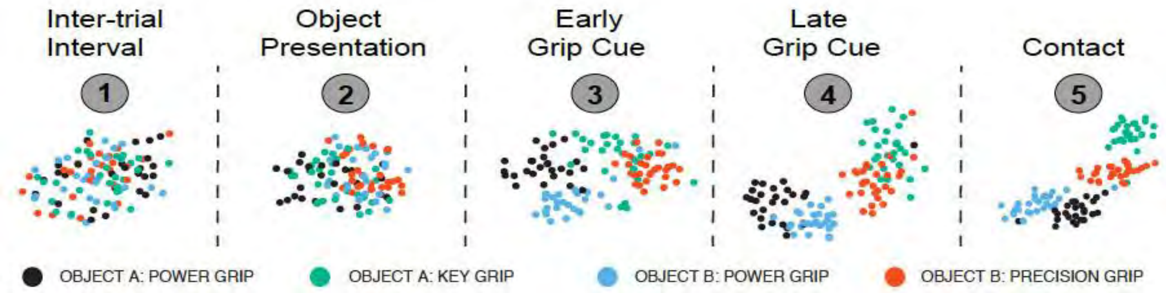
Tab. 7.5.a Example of difference in techniques application between Male and Female (%)

These results are instantly connected to the previous ones' women apply the same percentage of (Ashi) legs techniques and (Sutemi) Sacrifices, but very few (Te) hand techniques and in the competition are more consistent and effective in (Ne Waza) groundwork.
Another big difference in women constitution is their greater joints' laxity and flexibility. This is the reason that it is possible to see, high body's turn both during throwing actions and in Ne Waza, or long resistance with extreme angles in the Kansetsu Waza application.
Also, in attack rhythm, there is a difference Sterkowicz note in the Olympic games of 1996 that " *Other characteristics feature of female athletes was the lower intensity of action during the attack and especially the frequency of penalties than in men who were better able to use the time of the fight."*

III) Grips and neuroscience

In a new study at Brown University, neuroscientists have a firmer grasp on the way the brain formulates commands for the hand to grip an object. The advance could lead to improvements in future brain-computer interfaces that provide people with severe paralysis a means to control robotic arms and hands using their thoughts.
The key finding of this research is that neurons in the area of the brain responsible for planning grasping motions retain information about the object to be gripped as they make their movement plan. The collective neural activity, therefore, looks different when executing the same grip on one object versus another. This may help the brain design unique patterns when similar actions are performed in different environments.
Typically, what's studied is the relationship between a single object and a grip associated with it.
In the last time, scientists start to investigate how the brain can formulate different grips on the same object or the same grip on different objects.
They found the interesting results that the brain has many ways to formulate a gripping command, and those seem to be influenced by what it's gripping.
"You can have the same movement resulting from very different activity patterns within the context of different objects."

Probing for patterns
The research team made its findings by recording and analyzing the neural activity in the ventral premotor cortex of three trained animal cavies (rhesus macaques) as they participated in a series of grip tasks. Over about a five-second span, the researchers would present one of two different objects. Then they'd show a red or yellow light to signal which of two different grips to use for each, and then flash a green light to signal that the grip should begin. After analysis, the researchers were able to observe how the patterns of neural activity were changing at each stage of each task.



Plotting patterns.
Plots that relate the neural patterns from each experimental instance show how the plans for gripping either of two objects in different ways clusters distinctly and identifiable, from the start of gripping effort (left) to contact.
The patterns can be distinguished based on differences in their activity and can cluster together based on their similarities without the researchers imposing their own view of events going on in the task. What the analysis showed is that neurons in the ventral premotor cortex follow patterns of different objects and actions. They began to show distinct, identifiable patterns of activity as soon as the object was presented, but the animal knew how it was supposed to grasp that object. By the time grips were actually made, the patterns had become so distinct that all four object-grip combinations could be distinctly identified with about 95 per cent accuracy. Looking at neural activity patterns in and of themselves and at relationships between them, it is possible to quantify their relative similarity and group them without any knowledge of what the kinematics are. In this experiment, the neural activity patterns can be subdivided into groups that correspond to the basic grips and objects."

Meaning
The results of the study demonstrate not only that objects have a significant effect on the evolution of the gripping plan. But also that the brain can produce a variety of activity patterns. They arrive at an appropriate grip plan that suggests the brain is flexible enough to handle a wide variety of object contexts and can do so with a local network of neurons. On the basis of these results, training to grip corresponds to finding the optimum pattern by the brain and also different patterns and plans to solve different defensive activities if a judoka let so the solution of grip fighting can change from the conscious area to the automatic brain solution with time gain.
On the basis of the previous information, we can agree about women's judo throwing with Roy Inman statement " *... for years they have suffered by being forced to do techniques which are incompatible with their physical and mental characteristics, and the fact that they have survived in judo long enough to develop their own style is a tribute both to themselves and to the flexibility and absorbing interest of judo itself."* Another interesting note again from the same author is " *it becomes...clear that women had to compensate for this lack of power by aiming for greater precision, which meant a greater awareness of when to attack; and they*

also had to acquire the level of fitness which would allow them to spend much of the contest on the move."

IV) Throws preferred

Today it is different, and female judo is a well-defined Olympic sport with its own characteristics.

Both in terms of grips and in terms of throws, but one situation is already the same as seen by Roy Inman: strong and static judo is inappropriate for women "Movement was the key."

Generally speaking, women's grips application is more standard than men in percentage (Classic Ki Hon Kumi Kata left or right), but the increase of Russian gripping is also present from Nation to Nation. More often, the application of throws is Innovative or Classic. Very few Chaotic Forms are seen in women competition, but the percentage of Innovative variations is higher due to the body's flexibility of athletes.

Connection Tachi Waza – Ne Waza, for Koshi Waza, is very often linked to the application of the Makikomi tool like the variation of throwing, as is shown in one of the following figures.

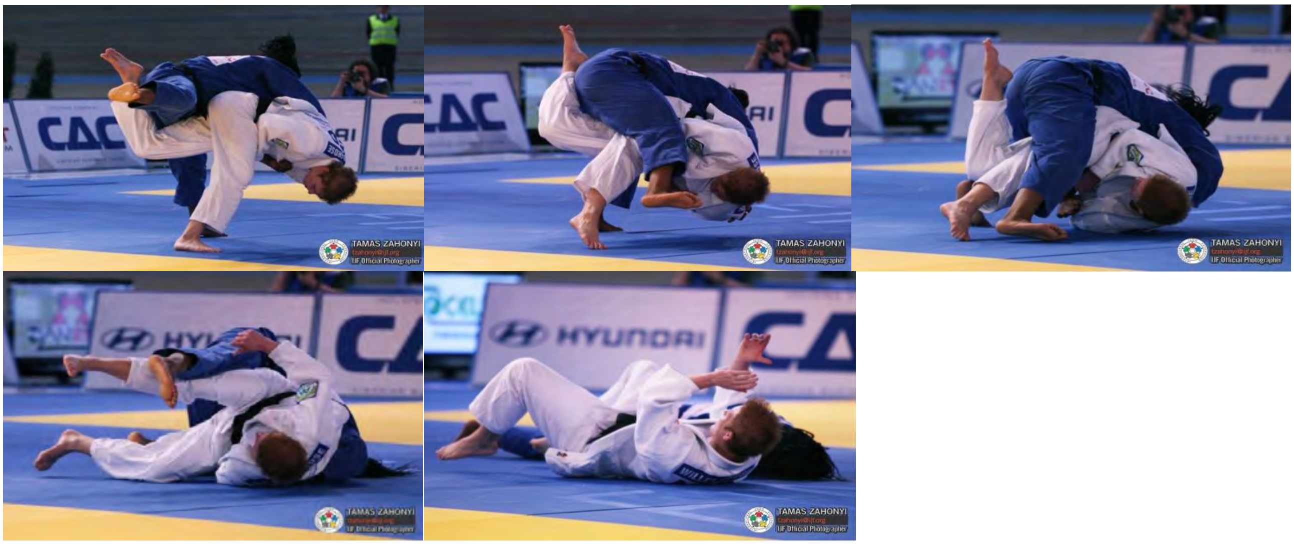


Fig 7.5.d.e.f.g.h. High trunk flexibility in Innovative Uchi Mata

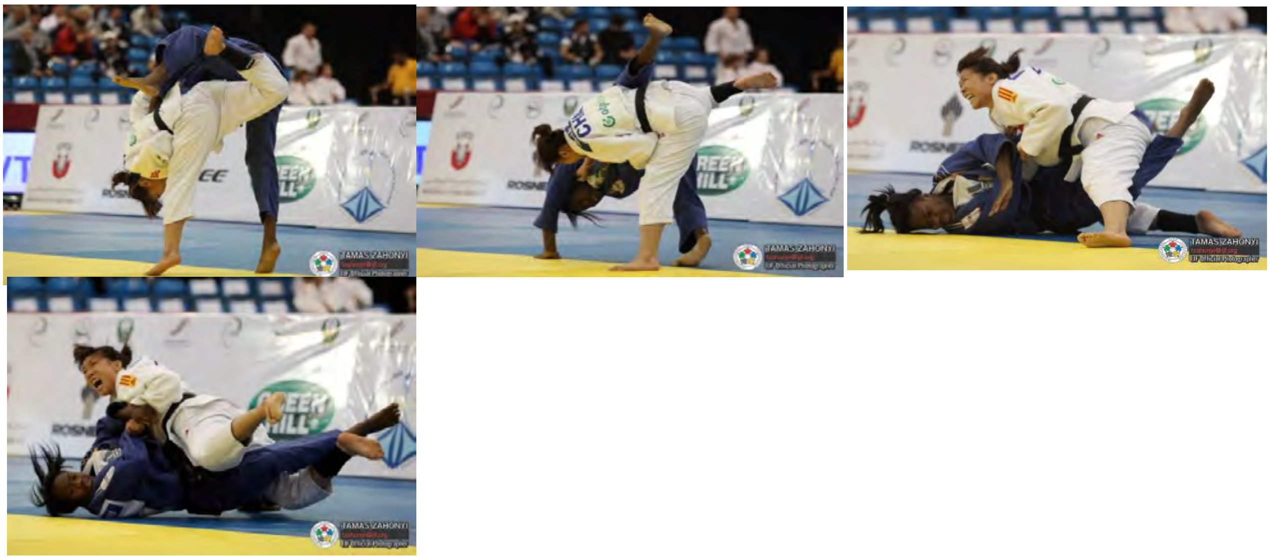


Fig 7.5.i.j.k.m. High hip flexibility in Innovative Uchi Mata

Fig 7.5.n.o.p.q.r. Innovative Makikomi

Normally, in women competitions, grip fight is less strength-based, attack velocity is not as explosive as in men competition, and generally, the pace of contest is slower, and it is possible to note that almost all female judo contests are smoothed confronted to male judo.
It is interesting to note that the poor presence of the Chaotic Form of techniques in women games is directly connected to the natural and relative lack of strength both in the hands and legs of a female athlete's body structure.
Then women's judo remains more connected to Kodokan Judo as for grips preference, as for the form of throwing techniques applied (Classic or Innovative).
Now can be asked a common idea in West countries: Sports Judo is a male or female?
In the previous ranking based on gold medals, the ranking is
1,) RUS; 2) FRA; 3) NED; 4) GER.
However, considering the grand total, the result is **1) RUS; 2) FRA; 3) GER; 4) UKR.**
But what is the importance of the role of women judo in EJU and IJF?
If we are looking for the top four, highlighting the women role only, changes are introduced in EJU and bigger in the IJF previous rankings.

Women TOP FOUR EJU NATIONS FOR EJU COMPETITIONS		
NATION	GOLD	GRAN TOTAL
FRA	**61**	**199**
RUS	**45**	**193**
NED	**38**	**74**
GER	**32**	**85**

Women TOP FOUR IJF NATIONS FOR ALL COMPETITIONS		
NATION	GOLD	GRAN TOTAL
JAP	**102**	**245**
FRA	**40**	**144**
CHN	**36**	**88**
KOR	**16**	**75**

If we see the male contribution to Sports Judo, all previous ranking is speedy and totally changed, both in EJU and IJF, showing the big weight of women in the final ranking.
As it is possible to see in the next two tables

Men TOP FOUR EJU NATIONS FOR EJU COMPETITIONS		
NATION	GOLD	GRAN TOTAL
RUS	**92**	**261**
GEO	**50**	**189**
FRA	**30**	**128**
AZE	**24**	**85**

Men TOP FOUR IJF NATIONS FOR ALL COMPETITIONS		
NATION	GOLD	GRAN TOTAL
JAP	**57**	**167**
RUS	**43**	**154**
KOR	**43**	**106**
FRA	**19**	**66**

Then Sports Judo seems not a male prerogative, and women play in it a very important role both in EJU and IJF.
The participation of women in Sport is a cultural problem in many countries, but we must also remember that if the basic physical principles of throwing are the same for men and women athletes; Female Judo is totally different on the basis of physical and anthropometric differences, strength differences both in leg and more in arms and hands, or psychological differences and so on.
All this means a different way to think about training, to approach technical preparation, or to choose the right class of applicable throwing techniques.
From the previous considerations, generally speaking about useful and effective throwing techniques, the question is obviously connected to athletes' body strength and morphology, then to their weight and preferred pace of competition, and finally to the physical skill and capability both of athletes and opponents.
But How the last change (2013) in refereeing rules affect the female Judo style?
Less than males, because women apply a more classic style, the only change is the increase of Ashi waza variation or, in biomechanical terms, the increased use of Couple throwing techniques.
The following figures, there are shown some actual classical applications of judo during the last few

Fig. 7.5.s.t.u Three elegant applications of Couple tool in women high-level competitions

Fig 7.5.v Classical O Soto Gari *Fig.7.5.z Innovative Tai Otoshi*

Fig 7.5.x.w.y. Innovative Ko Uchi Makikomi with non-forbidden grips

Fig.7.5.aa.bb.cc.dd. One hand Sode Tsurikomi Goshi attack

In a general way, women judo athletes prefer Ashi Waza, Sutemi Waza and some Koshi waza in Makikomi evolution. All applied both in Classic and Innovative form.
In Biomechanical terms, they prefer specifically Couple Techniques most of trunk leg group, Physical Lever Techniques with minimum arm applied with Makikomi final closure, and Maximum Arm Techniques (Sutemi) most applied with body weight and legs, few with a big contribution of arms.
Few Chaotic Forms are seen because, normally, they need to be applied by the use of strong arms contribution.
For their flexibility, they utilize a lot of Ne Waza with a preference for Osae Waza.
Till now, at the EJU level, three of the Four Top Nations give the just importance at Women Judo. In the last few times, some new income came from Kossovo, Ukraina and Israel.
At the world level only: Japan, France, China and Korea seem to have understood this lesson in the right way.

V) Tips for training (Sogabe)
The main result of this paragraph refers to an article written by Dr Akitoshi Sogabe, PhD, who curtsey translated the Japanese version for the author.
It is worthy of attention to the development of clear thinking about the training approach of Dr Sogabe (trainer of the Japanese female judo team at London Olympic) that can be summarized as **Define, Build and Apply** consistently.
We can assess that method by the titles of the following paragraphs of his article:

1. **Analyzing and Assessing in Detail the Characteristics of Judo as a Competitive Sport**
2. **Creating Training Goals to Build Stamina**
3. **Introduction of a Training Program that Distinguishes between the 'Trunk' and the 'Center Axis'**

The Actual Coaching of Training
1. **Inconsistencies Between Theory and Practical Coaching.**
2. **Differences in Group Consciousness Between the Sexes.**

Define
The main goal in organizing a training program is to evaluate in the right way the energy consumption and the characteristics of this consumption during the competition time. As Dr Sogabe reminds us: ” *Judo is a competitive sport divided into sexes and classes. Therefore, the ultimate physical abilities to be attained are not the same for all of Judo*”.To have the right parameters to evaluate the physical burden that athletes have to overcome in competition, this last will be carefully analyzed.
For example, Dr Sogabe in his article: “ *After an analysis of the Kodokan Cup All Japan Judo Competition by Weight Class, which selects the certified athletes of Japan, we found the following average times per women's weight class: 6 min 25 secs for the 48kg class; 6 min 2 secs for the 52kg class; 5 min 31 secs for the 57kg class; 7 min 41 secs for the 63kg class; 4 min 33 secs for the 70kg class; 4 min 32 secs for the 78kg class; 3 min 57 secs for the 78kg and over class* (Sogabe *et al.*, 2011). *Moreover, considering the time it takes to achieve the top prize (6 matches until the final bout), simply calculating the average time for each weight class yields: 38 min 30 secs for the 48kg weight class, 36 min 12 secs for the 52 kg class, 33 min 06 secs for the 57kg class; 46 min 6 secs for the 63kg class; 27 min 18 secs for the 70kg class; and 23 min 42 secs for the 78kg and over class*.

*On top of this, we must also consider the number of seconds and number of times the instruction for '**mate**' was given by the referee to temporarily suspend the match, as well as the progression of the match to **newaza**, which requires the use of all muscles in the body*."

Build

Normally it is well known that Judo is a high-intensity physical activity where the pulse can reach 190 beats per minute (Nakamura, 1977), and peak performance must be sustained intermittently for close to 40 minutes each day. The definition of the energy burden let the coach organize the right training program utilizing knowledge from physiology, judo, fitness and motor science.

As Dr Sogabe suggests to us in his paper: " *Thinking of Judo in terms of its metabolic characteristics, it is a mix of aerobic exercise and an anaerobic exercise. Therefore, we introduced a 400-meter run that relies on an 82.0% rate of the anaerobiotic energy supply mechanism, combining both the ATP-CP system and the glycolysis system, as well as an 800-meter run that relies on a 49.4% rate. The energy to perform this exercise is supplied from muscle glycogen and hepatic glycogen. Thus, in situations demanding high strength performance, the conserving of glycogen, a raw ingredient to strong performance, will allow strength performance for longer periods of time, and is believed to be an important adaptation for Judo*." "*… to uncover the relationship between the 400m and 800m running abilities and maximum oxygen uptake and pulse rate, we had the athletes do a 20-meter shuttle run test and traditional speed drills (drills conducted as quickly as possible in a given amount of seconds), had them wear a pulse rate meter (POLAR RS800CX), and then measured their maximum pulse rate and the degree their pulse lowered 1 minute after the shuttle run.*

To collect these data was created a 'Cardiopulmonary System Conditioning Evaluation Sheet' and provided the athletes with feedback" see next figure

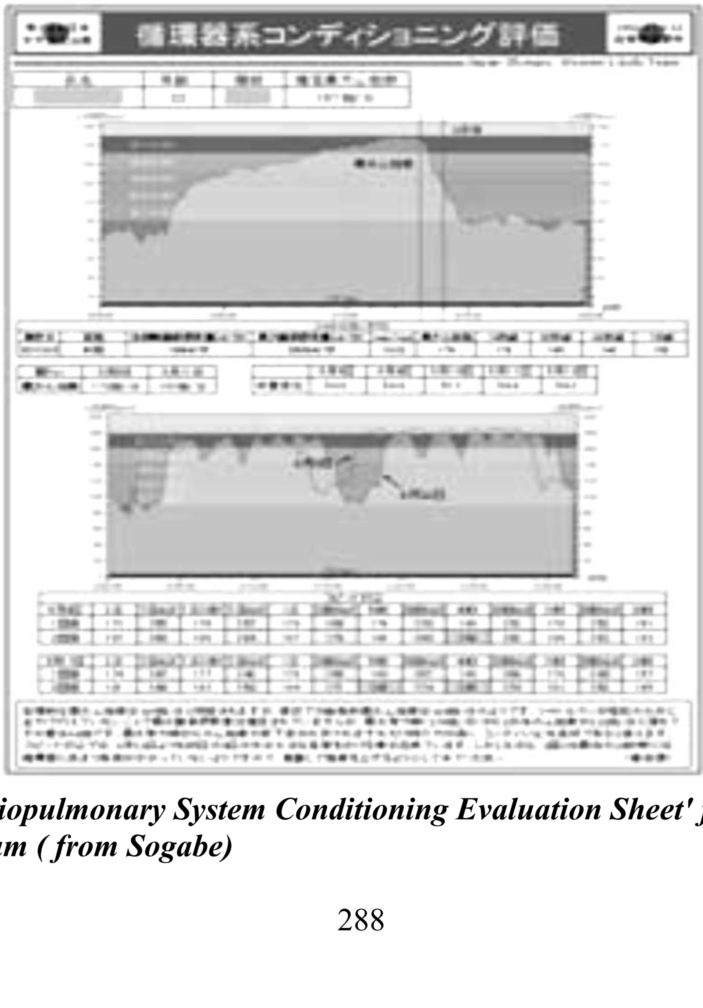


Fig. 7.5.ee. 'Cardiopulmonary System Conditioning Evaluation Sheet' from Women Japanese Judo team (from Sogabe)

Apply Consistently
We remember the concept of ***Breaking Symmetry*** in competition (paragraph 4. l). It is interesting to see how Japanese people in different words aim at the same goal, again from the article of Dr Sogabe: *" When applying a technique in Judo and one loses their balance and can no longer stand, or one's trunk bends when facing off with an opponent, it is often said that one's 'trunk is weak' or one has 'lost the centre axis'. However, there must be a clear distinction made between these two. There are circumstances where one's trunk is weak, and they cannot maintain their 'centre axis'; however, there are also circumstances where some other element may be the cause. Thus, if we ascertain if the cause of 'losing the centre axis' is actually the muscle strength of the trunk, the intended effects may not always be yielded through training. Therefore, prior to strengthening the trunk, we used a manual muscle testing device to evaluate isometric muscle strength, to provide a comprehensive evaluation of isotonic, stabilization and conditioning, and also to evaluate specific parts—not just the abdomen and back—such as the upper arms, the peripheral muscle groups of the hip joint, the quadriceps femoris muscle, and the hamstring".*
These measurements were organized into a Judo Trunk Strength Evaluation sheet and returned to the athletes with an explanation, and programs were created individually to overcome weaknesses.


柔道体幹筋力評価

評価した筋肉の役割

Fig. 7.5.ff. Trunk Strength Evaluation sheet for the female team (from Sogabe)

"Another aspect we needed to consider is that muscles are dynamic stabilizers, not static stabilizers like ligaments. Since all skeletal muscles are controlled by signals from the brain, if the brain does not send any signals for a moment in response to the necessary circumstances, stabilization cannot be achieved through strong contraction no matter how much muscle strength there is.

Quite the opposite—if too much conscious attention is constantly put on the muscles to stabilize one's centre axis, focus on the match may then be distracted, and one will no longer be able to adapt to the opponent. Therefore, we feel that it is important to not focus on stabilizing the body during a match, but to pay attention to the match and the execution of waza, and to put one's self in a state where the muscles will appropriately respond as needed".

Fig.7.5.gg.hh. Japanese Women Team training (from Sogabe)

The last notation of Dr Sogabe article is about the real practical application and not only the theoretical one., but interesting is also the notation underlined that speaks in real terms of the practical nature of problems that a coach can face during the top athletes training.
Again, Dr Sogabe is thinking:
"There are many theories of training to attain a certain ability, and there are numerous methods for this as well. By looking at the physiological theories submitted to scientific journals, training is tested with laboratory-like protocol, such as "strong physical activity of xx%/VO2max is carried out for xx mins, and xx set are performed after xx min of rest, showing an improvement in xx strength and an increase in xx in the blood..." "If these kinds of protocols were actually followed when coaching, we would receive that kind of response". "However, the person being trained is not a rat where the strength level can be forcefully controlled, nor a volunteer subject who is cooperating in an experiment; they are top athletes who are strongly adamant in their own thinking. Training then is a less technical practice to improve technical abilities for competitive sports and more like work that steadily accompanies simplicity and mental fortitude. Due to this, in comparison to technical practice, athletes have a tendency to form their own mental limits to lessen exhaustion as much as possible in training. If athletes are not coached to remove these limits, they will not be able to benefit from the theory discovered by so many researchers. Therefore, when coaching athletes in training, it may be fine to use various methods, but, even with simple training where the abilities to be ultimately attained are identified when a program is created, it is important to carry the training through to the very end. To accomplish this, the coach must come to terms with the fact that they will come to be hated by athletes".
Also, the final conclusions are full of interesting notation, made by a man who is a contemporary researcher and coach in a practical way.
There is also some connection with Roy Inman's practical consideration, such as the following; *"I rapidly discovered that women are more easily "coachable" than men, if you give them a program, most follow it religiously*".
Another interesting introduction from Roy was music during the warming-up and uchi komi sections, and also in the long squad session during the weekend.

In sum, women, in comparison to men, have a firm sense of self but also tend not to like sticking out within a group. Due to this, in group training, female athletes will be observed not performing at their maximum potential due to a fear of placing a burden on the team by them pushing their own limits or showing consideration to veteran athletes by pretending to be winded.
In this kind of environment, no amount of training will improve the team's effectiveness. Thus, training must begin by creating an environment where the athlete, no matter their position, can train without any worry about how they fit into the group.
Obviously, the final analysis of Dr Sogambe reassumes some interesting findings that every female coach can share:
“ There are not much of a connection between the differences between the sexes when it comes to basic training programs in competitive sports.
Whatever the case may be, the most important thing is to have a full understanding of the characteristics of that competitive sport. If these are not given a clear form, no program to improve competitive potential can be made. However, the coaching method to apply a program differs between men and women. One must fully understand the aforementioned characteristic differences between the sexes and use this understanding to provide coaching that takes into consideration how to improve training effectiveness.
The theory is for the desk, and coaching is for the floor and an exchange between two humans. The coaching of training is an extremely physically demanding job.
However, the happiest moment for us is when the athletes overcome difficult training to achieve victory. From here on out, I will be putting the noses of my athletes to the grindstone in anticipation of seeing smiles on their faces later on”.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GROUPE EDF

Chapter 8 High-Level Coaching I.

Complementary technical-tactical tools

This chapter will be developed the first part of the high-level Coaching connected to the way of victory in high-level competitions.
The aesthetic beauty of an Ippon in a competition similar to a throw exhibition not only a technician but also the public is able to appreciate,
But, in high-level competition, an outcome like this can only happen if there is a very big difference in judo skill between athletes or if one competitor makes a very big mistake.
Normally in a situation like competition, Ippon is not easy to obtain or for the defensive capabilities of adversaries, or for the dynamic of the situation in which forces cannot be applied in the totally right direction, or because the perfect tsukuri position connected to the throw performed is very difficult to achieve.
To overcome all these real difficulties, athletes or coaches(?) by experience or study developed a number of complementary tools.
To show these tools utilized in connection with the biomechanical class of throw (Couple or Lever) will make easy their use and help coaches and athletes to broaden the potential effectiveness of their throws or to find new tools to obtain Ippon.
Some tools could be considered of general application like the use of body weight, for example. Normally in Sutemi, body weight is the primary force to obtain throwing action, but as a complementary tool, his function is to finalize, in the right way, a non-perfect throwing action. This chapter will start with some of the effects that change in referees' rules introduced in judo competitions.
Then the analysis goes through the first contact, breaking symmetry use direct attack and combination, with some reflections on Seoi and Uchi Mata Family, to explain the really easy mechanism of how to build new (not Kodokan) throws.

Fig 8.a. Dynamic birth of a new throws

8.1 Referees' rules and their impact on competition

During these years, from the first English edition of my book 2010, many changes have been introduced into the Referee Rules from the International Judo Federation. The main change was in 2013 in which, for example, breaking the opponent's grasp using both hands, failure to engage the opponent promptly at the outset of the match, and delaying the progression of the competition through evading the opponent's attempts at gripping action all became prohibited under a 2013 rule revision. Violations of these rules result in a shido penalty.
These changes were introduced to enhance the dynamics of contests, and the following statistics show the results over more or less 9000 competitions.

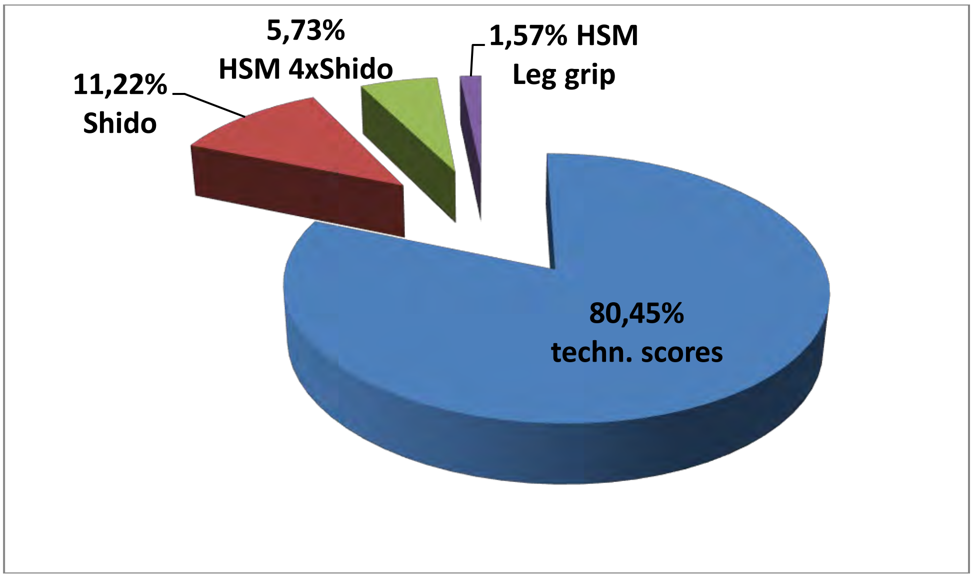


Fig 8.1.a Statistics of results after the introduction of new rules 2013 (9000) competitions

The most important change was to ban grips directly below the belt. This means that classical or innovative throws like Morote Gari, Kibisu Gaeshi, Kata and Tama Guruma, old Ko uchi Makikomi, Tawara Gaeshi, Te Guruma, etc. were banned from competition as a classical application. From the other side, all blocking with one or two hands under the belt were penalized by Hansoku Make (disqualification). Also, special grips like Bear Hug were banned without grips but allowed when Tori took almost his own grip.

Fig.8.1.b. Bear Hug Banned

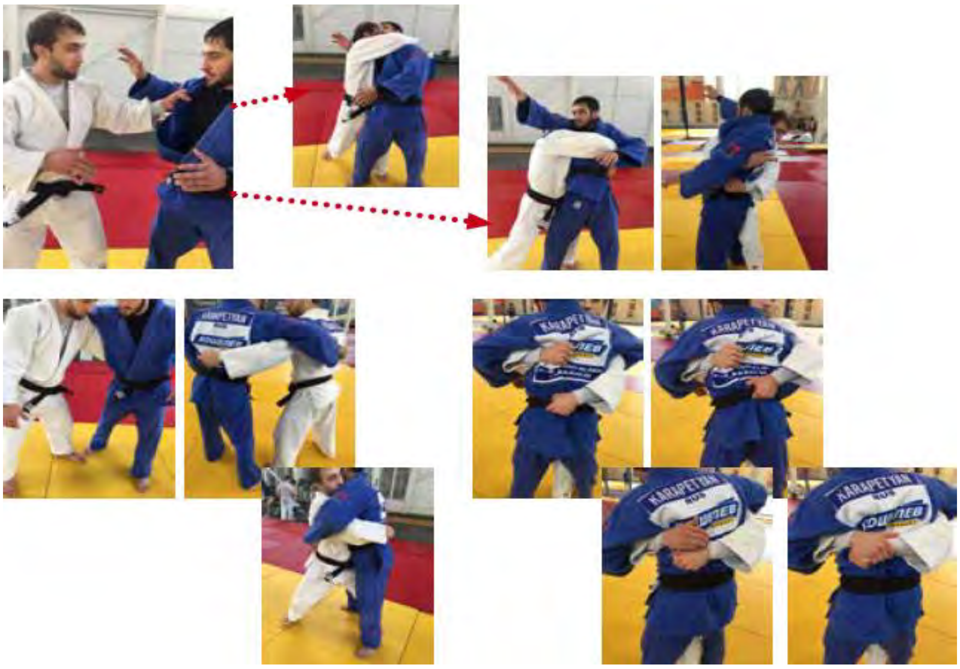


Fig.8.1.c Bear Hug Variations Allowed

All these new rules heavily changed the competitions, and one of the first to study the impact of the new rules 2013 in the competition were the Japanese Ito and coworkers that analyzed Grand Slam between 2012-2013. The results showed a significant increase in the attack efficiency index of combination and counter-attacks preceded by three applications of *kumi-te*.

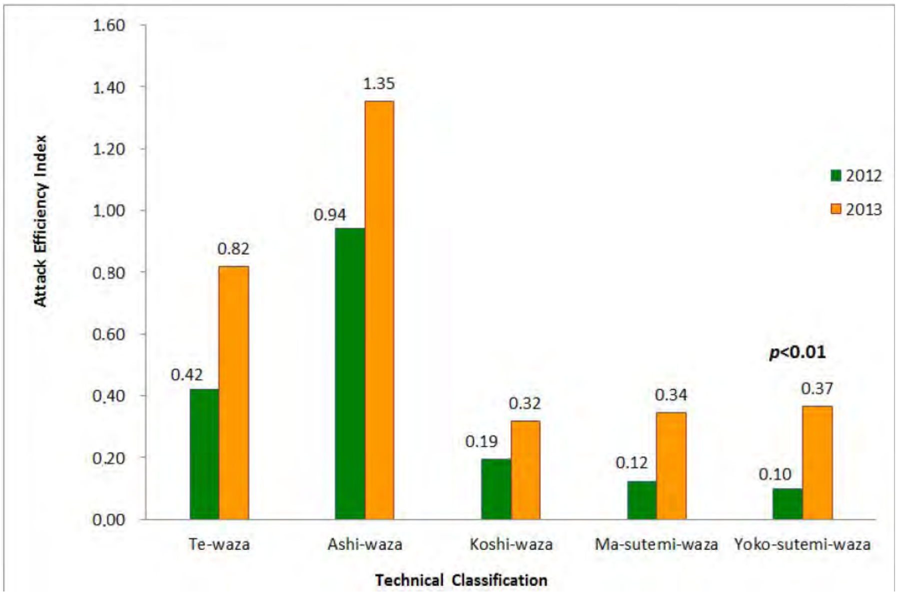


Fig.8.1.d. Attack Efficiency Index by technical classification (3 Kumite)

All changes in refereeing rules made by IJF aimed at more dynamic and active performance based on scores in competitions. Introduction of only one referee within the competition area and the inclusion of a video review (VR) in cases where there would be some doubt concerning the result of an action. Today a match can be won only by technical superiority. Unlike previous refereeing rules, there is no equality between a single penalty and scores

now, but hansoku-make given directly or as a result of three consecutive penalties ends a judo match (International Judo Federation [IJF], 2020 version).
In contrast, previously, an athlete was awarded hansoku-make as a result of four consecutive shido (IJF refereeing rules, 2016 version). IJF has aimed a more "positive" judo that attracts the spectator and bases on scores instead of penalties with the latest rule changes in 2017 with which some changes were made related to scores (more rigorous criteria for awarding an ippon score, exclusion of the yuko score, decòaration of the only ippon and wazari scores). Penalties (the disqualification with three penalties and not four as before and the exclusion of winning via penalties in the regular period). Match duration (the decrease in the duration of men' matches to 4 min) and world ranking points (IJF, 2017 version). All these changes in rules improved dynamics in the competitions. In the next table, it is possible to see the influence of VR on referee's actions during the Gran Slam (Paris and Dusseldorf 2020)

Referee's actions	***Male Frequency n (%)***	***Female Frequency n (%)***	***Total Frequency n (%)***
Score assigned	66 (77.6)	24 (64.8)	90 (73.7)
Penalties assigned	11 (12.9)	10 (27.0)	21 (17.2)
Removed scores	4 (4.7)	1 (2.7)	5 (4.1)
Declassification	3 (3.5)	2 (5.4)	5 (4.1)
Removed penalties	1 (1.7)	0 (0.0)	1 (0.8)

Table 8.1a. Absolute and relative frequency of referee's actions according to the type of action requested by video review. (Paris -Dusseldorf 2020 GS)

In these two competitions, VR was often used at the beginning of the match, mainly in the female group, mostly concerning scoring attribution, which directly affected the match result in more than 80% of the cases.
Also, forbidden Actions are important with the three shido disqualification rules. In the next table, we can see the percentage difference between a winner and no winner of 1 and 2 shido and 3 shido events.

		Winners		**Non-winners**		
Forbidden actions	**Total %**	**1 shido %**	**2 shido%**	**1 shido%**	**2 shido%**	**3 shido%**
Non-combat.	**40.5**	**37.2**	**38.7**	**40.3**	**45.1**	**44.3**
Avoid Grips	**18.8**	**24,3**	**13.6**	**21.8**	**12.4**	**6.2**
False attack	**16.4**	**14,4**	**24.5**	**13.6**	**17.4**	**25.6**
Defensive posture	**6.8**	**7.4**	**5.8**	**6.4**	**7.2**	**5.9**
Outside Cont-area	**6.3**	**5.4**	**6.3**	**6.9**	**6.2**	**7-5**
Others	**11.2**	**11,2**	**11.1**	**11**	**11.7**	**10.5**

Tab.8.1.b Percentage of forbidden actions for winner and bo winner From (Ceylan, et al. 2021)

Refer to the IJF Sport Organisation Rules for the most recent rules. You can find the SOR here https://www.ijf.org/ijf/documents/5

8.2 First Contact Tactics and Rotational Approach

A deeper meaning of grip

A well-known sentence gives us the most classical information about grips: *without a grip in Judo, you will not be able to throw anything. This is easily demonstrated. Try and throw someone with no grip at all (not touching), then with one hand on your opponent, then with two hands, with gripping all becomes easier to throw.*
This very sound "Common Sense" give us the right direction to the truth.... but the not conventional "Biomechanical Sense" shows us a different "deeper" path to truth.
In fact, to do that, it is essential to deep into the biomechanical tools applied in the throwing techniques movement (Couple and Lever).

Couple Group
Analyzing the Techniques of "Couple of Forces" Group, the *General Action Invariant* (basic shortening movements of distance into a couple of athletes system), are directly connected to Tsukuri, Kake Phases and the astonishing information is that, in this case, Kuzushi (unbalance) is not a necessary condition, and theoretical speaking it is possible to perform these techniques without unbalancing and also theoretically without grips.
In fact, unbalance could be not present in some agonistic applications of couple techniques.

Fig.8.2.a.b General Action Invariant flowing in Kake phase without Kuzushi (competitive Okuri Ashi Harai);

This means that in such a group, there are necessary only Tsukuri-Kake phases, in fact, the presence of Kuzushi helps and eases obviously the throws, but it is not absolutely necessary. Because biomechanically speaking: Uke is in unstable equilibrium, and the rotation around his centre of mass with the fall down is helped by the external gravity force.
Other valid information singled out is that these simpler techniques, biomechanically speaking, can be applied in competition whatever shifting velocity a couple of athletes' systems could have. Couple techniques could be grouped in function to their three shortening distance movement called: *General Action Invariant* :

I. *First GAI straight movements forward or backwards*
II. *Second GAI 180° degrees of rotation clockwise or counterclockwise*
III. *Third GAI 90° degrees of rotation clockwise or counterclockwise*

Under these conditions, it's easy, considering the Tori three body's symmetry planes in which lie a couple of forces, to find the inverse movement or throw.
For example:

A) Sagittal Symmetry Plane Application of
1st *General Action Invariants*: O Soto Gari, reverse direction Mae Ushiro Uchi Mata,
2nd *General Action Invariants:* Harai Goshi inverse application Ushiro Hiza Ura Nage,
3nd *General Action Invariants:* Uchi Mata, inverse (Back) Ushiro Uchi Mata
B) Transverse Symmetry Plane Application of:
3nd *General Action Invariants:* O Uchi Gari, Ko Uchi Gari (There are not inverse but opposite from the other side.
C) Frontal Symmetry Plane Application of:
1st *General Action Invariants:* Okuri Ashi Harai; opposite Okuri Ashi Harai from the left
3nd *General Action Invariants:* Ko Soto Gari opposite Ko Soto Gari left-side

Kuzushi is not necessary for this group; it is possible to throw someone in a still position or slow-moving as a teaching situation, by De Ashi Barai or by Uchi Mata (for example) without grips and then without unbalance. (True, but out of common sense!) .
Because grips are responsible, among other functions, of the application on the Uke's body of the unbalancing forces, this notation underlines that theoretically speaking, Couple Throws are the main eligible throwing techniques for a *Limit Judo Without grips*

Lever Group
On the other side, Lever throws are heavily dependent on kuzushi, and this means that they depend strictly on grips and their unbalancing action.
In other words, Lever group techniques are not eligible for a *Limit Judo Without grips.*
In general, considering the degrees of freedom connected to the superior kinetic chains, related to body movement, it is easily understood that all the potential movement in the *Specific Action Invariants,* for the superior chain, in the Kuzushi actions are connected to the three degrees of freedoms of the Achromium Joint (shoulder).
From the other side, the most important part of the inferior actions is in charge of two Joints hip and knee, less part to the system foot/ankle (the first for setting better his ones' body in relation to Uke's body, and the second ones to applying the only fulcrum in the lever).
Biomechanical analysis assures us that the Kake phase, for the techniques of the physical lever, is the result of the interconnected work performed by both kinetic chains in different time steps.

1) At first, the superior chain starts to unbalance and open space for the body into adversary grips,
2) then the *General Action Invariant* is applied
3) They are followed harmonically by the connected work of both *Inferior* and *Superior Action Invariants* through the abdominals and trunk muscles.

These techniques need more skill in harmonic chains related movements than couple techniques; in fact, often, they are ineffective because of a lack of harmony into one of the previous

movements are able to stop the throwing result**.**
In terms of biomechanics, for example, the same *General Action Invariant* (full rotation) as shortening distance movement (considering only the inferior chains) splits by three different *Inferior chain actions* from up to down, into three well-known techniques Seoi nage standing, Seoi Otoshi and Suwari Seoi.

All Kuzushi-Tsukuri movements flow into the Kake phase of physical lever application with the variable arm, from the most energy-wasting one to the lesser ones

Fig 8.2.c.d.e. Inferior Chain Action Invariant (Seoi); Inferior Chain Action Invariant (Seoi Otoshi) (Finch); Inferior Chain Action Invariant (Suwari Seoi)

The presence of interconnected movements makes this technique biomechanically speaking more complex, furthermore on the basis of the physical principle involved for their useful application, whatever shifting velocity a couple of athletes has in competition, and these techniques need to be applied a stopping time (very short).
For these techniques, if Kuzushi is essential, grips are essential (Common sense).
But if we speak in terms of Biomechanics, it is interesting, remembering the Galilean relativity, to think that grips are for these techniques a "necessary" approach to interaction. This means that contact, connecting the two bodies in one whole unit, is essential to apply to throw forces, but the connection could be accomplished not only by two but also by one side only. In other terms, the first thing that grips do is to connect two athletes in a Couple System changing their equilibrium situation.
If somebody grips the opponent and the opponents do not grip him, they are connected in one System of Couple of Athletes.
The connection is assured by contact point, not only by our hands but also by the opponent's hands alone. Then from this point of view:
if grip is accomplished by the opponent's one hand, the two bodies are "in such way" connected, and for the athlete connected without taking grip, it is possible, utilizing the opponent's connection strengthened by his hands on the gripping arm (*if the grip is not strengthened opponent could open hand and solve connection*) to apply to throw techniques using his own body's weight (internal Tai Sabaki lowering the centre of mass) as unbalancing and throwing force in the direction of the gripping arm.

Therefore, grips are tools with many roles; we list the most important among the many roles that grips can undertake in high-level competitions:

1) *Connecting role*: at first, they connect the two athletes in one system: The Couple of Athletes System.
2) *Driving role*: they, by the push/pull activity, let drive the opponent in a potential favourable position.
3) *Stimulating role*: they by opportune push/pull actions to try to produce good opportunities by previewed reactions
4) *Shortening role*: they by right actions shorten the distance between Athletes letting useful tsukuri positioning
5) *Alerting role*: they can be used to receive from the adversary body's movements alert about his attack action

6) *Advising role*: they can also receive information from the adversary's body about his movements
7) *Mastering role*: they master the distance into the Couple of Athletes system
8) *Slowing down role*: they are able with the bodyweight (Japanese tool) or with the curled body's position (Russian Tool) to slow down the opponents' speed movement
9) *Creating role*: they can create Innovative or Chaotic forms of throws transferring forces in nontraditional or non-rational directions by arms (*Superior Specific Action Invariant*)
10) *Avoiding role*: to avoid the adversary's attack technique utilizing his impetus to throw him (ex. Uchi Mata Sukashi)
11) *Destroying role:* to destroy the opponent tentative to build up an attack technique
12) *Active role*: to transfer to the competitor's body an impulse to realize throwing techniques by arms (Superior Specific Action Invariant).
13) *Passive role*: to stop the impetus and the movement of the competitor during his throwing technique.

But the lesser analyzed role is the connecting role, and on this aspect, it is possible to study and develop the capability to apply "*judo without grips*."
Remembering that the human body standing is in a position of unstable equilibrium, the action of unbalance is**:**

1. It makes a motion impossible, when applied (the unbalanced body freezes up his motion capabilities),
2. When it is applied in classical Kano didactic way (the unbalance force direction more or less 45° up), athletes' bodies also become rigid, making easier the throwing action,
3. When it is applied in real competition, the classical unbalance concept changes into *"Breaking Symmetry"* action that ends with a collision between athletes' bodies "Butsukari" (ぶつかり)in Japanese.
4. When applied in a rotational way, both classical unbalance and "Breaking Symmetry" action is very difficult to avoid.

From the previous line on unbalancing and Breaking Symmetry, it is possible to infer that the more effective way to apply Lever techniques in Limit "no grip" situation in real competition is the rotational application.

"Judo without grips."
Basic theoretical approach

In judo, there are four situations that can be identified not only as interval time during the competition evolution but also as an attack space separating the opponents and subsequently by kind of grips that fighters can apply.

I. Athletes separate in no grip situations.
II. One-handed grip.
III. Classic two-handed grips.
IV. Curled up grips.

The first situation today, with the last refereeing rules, is the area specialized in grips fight. Grip fighting is a wide field of deep study among the National Federation, but in high-level competitions, it is also, more often, the most boring part. For this reason, referee rules consider shido (small infraction) if grip fighting is too long.
Dr Kano underlined the concept of "Ju" in the use of the opponent's force, and in the text, it is shown a subtler way to overcome this boring phase with the application in a more general meaning of the "Sen No Sen" concept.

This special way is often applied to this specific situation as a very effective and useful tool by some Korean champions and today also applied by European Athletes like French or Dutch competitors.
The wide area of application of judo without grips is obviously the transition period between no grips and stabilized grips, in other words, every time after matte application.
The basic theoretical approach is grounded on the meaning of connection and the physics of two bodies.

- when one athlete grips the other with one arm
- when both athletes are gripped together

If we consider Interaction (throwing action), then we must analyze an articulated system of two bodies moving into the three symmetry planes Sagittal, Transversal, Frontal.
As principal, the best way to make sure to score is the throwing action applied with internal rotation with respect to the adversary's arm gripping; in such a way, blocking the gripping arm, Tori assures himself that Uke can't use this arm to stop the throwing action, (normally for Tori these movements are an example: for Uke's right tsurite arm, clockwise and for Uke's left tsurite arm counterclockwise).

Biomechanical Reassessment
Finding a nontraditional way to do judo, we try to find biomechanics "original" way to apply physics in high transitory non-standard situations.
The connection is a very simple concept. To "connect" in the judo sense means to link two athletes' bodies by their grips, but if we think that only one arm that links with a grip the two bodies is a real bridge between them, this means to connect.
In such a case, if the gripped athlete prevents the adversary's grip detachment from blocking the arm that grips him, he can throw the adversary without taking a usual judo stabilizedì grip.
The unbalance force will be transmitted to the adversary by his bridging arm.
That's *"judo without grips"* or Sen No Sen on grips, was applied mainly by Korean Athletes years ago, today in many different variations but with the same principle, it is common knowledge of many skilled athletes in the world, thanks to match analysis.
In effect, during the transitional phase of *the first contact,* that can happen time and time again during a competition, that sen no sen on grips are applied.
It is not necessary to grips with a known kumi kata (classic or not) the adversary, but it is sufficient to establish contact (in a broad sense) with the adversary body if that happens. One of the two athletes is able to apply a lever throwing technique.
On the other side always during *the first contact* time, if the athletes are specialized in Couple throws, they need only to shorten the distance to apply the couple on the adversary body.
The biomechanical analysis assures that the body right or left rotation to apply Lever techniques is the common denominator for these throws linked to a quasi-plastic collision and a downward leap.
Sometimes also the fast and fully rotational application of these techniques is allowed utilizing as contact wrapping their arms around the adversary's body.
For the Couple techniques easier, the skill action is only straight shortening distance and Couple application

Practical application in high-level competition
All the tactics previous described are always applied in high-level competitions as a sen no sen on adversaries' grips.
In effect, the subtler way to apply Sen No Sen, in such a situation, is to throw *without grip,* using the opponent's grip that let him stay connected.

A very clever expert of this approach was Won Hee Lee from Korea, who applied this method many times.
Lee, timing, makes the right space with internal Tai Sabaki (General Action Invariant based on Hando No Kuzushi), stabilizes his contact, using the well known: two hands against one arm grip to strengthen the connection, and throws the opponents in harmony with the two hands contact as shown in the next Sequences.
It does not matter of techniques. Everybody can apply his preferred technique in a specific situation (compulsory is the Lever Group belongings).
The internal Tai Sabaki more often follows the opponents pull, and with it, the athlete shortens the distance and set his body for throwing action. If the athlete performs external Tai Sabaki, he avoids opponents' action (wasting some time) and can apply some couple group throws like Innovative Uchi Mata. Avoiding and Sen No Sen form strategies also depends on the weight and personal speed and skill of athletes.
An opportune and ad hoc training of these situations would be useful to apply carefully in real competition.

Tactical application of Lever throws at first contact

Fig 8.2. f.g.h.White grips straight left hand, Lee Attacks two against one hand jumping with left Tai Otoshi

Fig 8.2.i.j.k White grips right from the top. Lee attacks two against one hand right Suwari Seoi

Fig.8.2. l.m.n. Blue cross grips Lee's left side, and Lee attacks two against one hand right Tai Otoshi

Fig.8.2.o.p.q.r.s. Tactical application of O Soto Makikomi at First contact, blocking the one Tsurite arm contact

Fig.8.2.t.u.v.w.z.x. Oblique Suwari Seoi tactic applied at First Contact, gripping the left Tsurite adversary's arm.

Fig 8.2.α.β.γ.δ.ε.ζ.η.θ.ι.κ. Hiza Guruma Rotational application at first contact

Application of Couple Group Tactic at first contact

Fig 8.2.aa.bb.cc.dd.ee.ff.gg.. Shortening forward distance and Couple application in the Frontal Plane at First Contact Tsubame Gaeshi

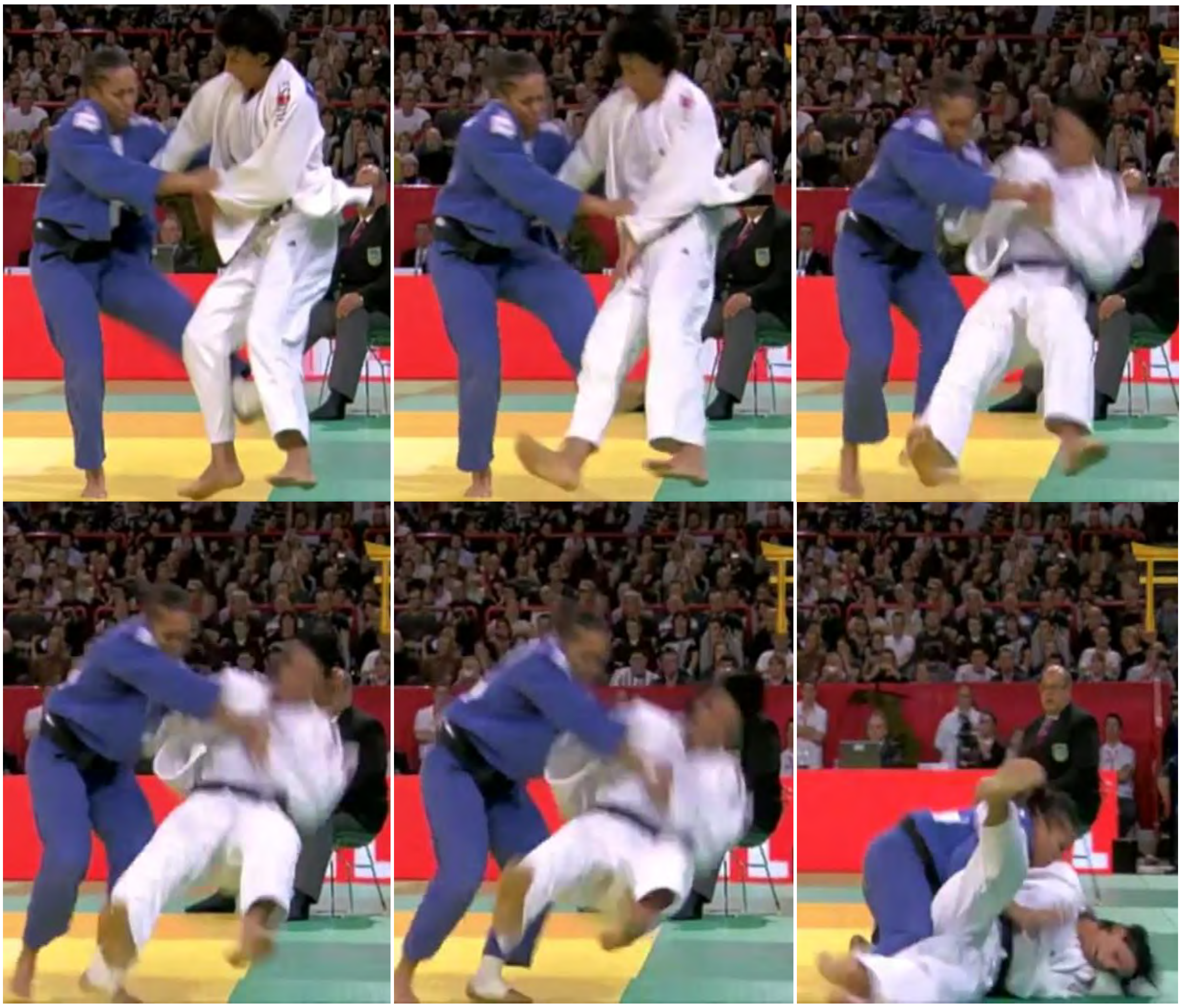


Fig 8.2.hh.ii.ll.kk.mm.nn.oo. Distance Shortening and Couple applied in a frontal plane at First Contact

Fig8.2.pp.qq.rr.ss.tt.uu.vv.zz.ww. Couple Application in the frontal Plane at First Contact

Fig 8.2.α.β.γ.δ.ε.ζ.η.θ.ι.κ.λ.μ. Shortening distance and Application of Couple forward in the sagittal plane with clockwise rotation at First Contact. Rotational Harai Tsurikomiashi

Fig.8.2.ν.ξο.π.ρ.ς.σ.τ.φ. Shortening distance and Application of Couple backward in the sagittal plane at First Contact -Jumping O Soto Gari.

8.3 Breaking Symmetry and related Histories

Standing Judoka typically has two feet in contact with the ground. If feet are close together, they feel less stable than when the feet are spread apart—increasing the distance between the feet increases what is termed **base of support**, defined as the area within an outline of all ground contact points.
The importance of the base of support in determining the judoka stability and ability to move effectively is the basic fundamental of Judo in paragrah1.1.6; 1.1.8; 3.1; 3.2; we already discussed special judo locomotion and basic and advanced judoka balance.
In situations of imminent contact, we try to enhance our **stability**; when we want to move quickly, we try to increase our **mobility**. In preparation for impending contact by an opponent, a Judoka will try to brace himself by widening his base of support and bending his knees. If, on the other hand, the athlete decides to avoid the collision for throwing, he would adopt a different body posture that would enhance his mobility.
From a mechanical perspective, five factors determine the level of stability and mobility.

- *Size of the base of support in the direction of force or impending force.*
- *The height of the centre of gravity above the base of support*
- *Location of the centre of gravity projection within the base of support*
- *Body mass or body weight.*
- *Friction.*

In summary, high stability (low mobility) is characterized by a large base of support, a low centre of gravity, a centralized centre of gravity projection within the base of support, a large body mass, and high friction at the ground interface. Low stability (high mobility), in contrast, occurs with a small base of support, a high centre of gravity, a centre of gravity projection near the edge of the base of support, a small body mass, and low friction.
In judo, as we saw, if it is not possible to apply Kano's unbalancing concept, as in the case when the opponent's upper body part turns or bends to the side, it is necessary to consider the breaking symmetry concept, connected to the stability and mobility nuance,
In fact, when COM shifts and changes position inside the body, both the body's stability and mobility are altered.
"Breaking symmetry" changes the body's stability and slows down the opponent's capability to shift and avoid, in this way making the application of a successful throw easier.
The biomechanical explication splits the *advanced kuzushi concept* into two steps: first, before slowing down the opponent by breaking his symmetry by applying perfect timing and then following this step, a body collision will occur, which helps the throwing movements.

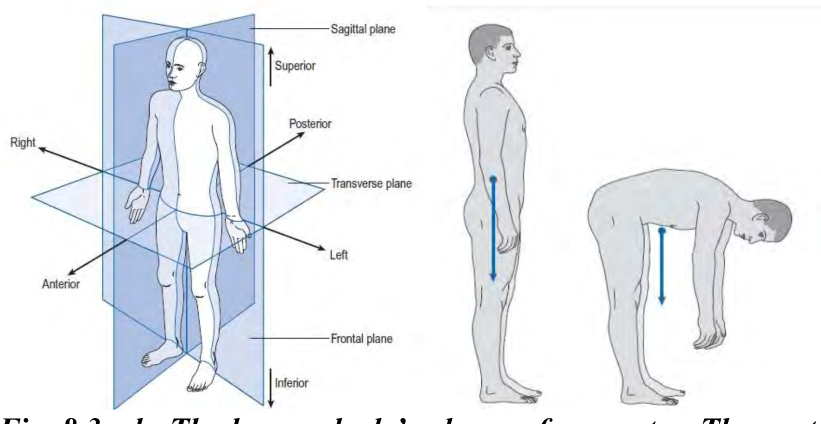


Fig. 8.3.a.b: The human body's planes of symmetry. The centre of mass (COM) inside and outside the body.

Fig8.3.c. Bad management of Symmetry by white Athlete

Fig.8.3.d. God management of Symmetry by both Athletes

Fig.8.3.e. Bad management of Symmetry by both Athletes

8.4 How to enhance effectiveness in a direct attack

Rotational Enhancement

Considering the two biomechanical tools that are the physical basis of judo throws, it is possible to obtain such results from the analysis of high competition applications:

Lever Techniques are enhanced in their effectiveness in four ways :

1. The rotational movements, strictly connected to the Lever techniques mechanics achieving victory (Ippon) in competition, can be extended to the unbalance phase (Kuzushi)
2. The rotational movements can be applied in a totally new way putting away even the unbalance that is basic in the Lever techniques.
3. The Lever tool can be hybridized with the application of a Couple to lower the energy consumption and to overcome some strong defensive resistance.
4. Plunge Tori more often enhance his technique by a collision and simultaneous plunge of his body to the tatami.

Couple Techniques are enhanced in their effectiveness also in three ways :

1. The Couple tool, in principle, doesn't need an unbalance, allowing the uke's body to rotate around his centre of mass; it is enhanced utilizing the Uke's body smaller resistance directions (normally summarized in Diagonal attacks).
2. The vertical rotational movements in the transverse plane with the axis in the sagittal plane can be added to the Couple application with Transverse Rotation, an axis in the frontal plane to overcome some defensive resistance, mainly in the trunk and leg group of Couple techniques (like Uchi Mata or O Soto Gari).
3. The rotational movements can enhance the throwing action changing the inner mechanics of Couple into Lever applying a Torque, with the direction change of one force or the time delay of his application.

Angular movement is rotational movement. When an athlete rotates, it always turns around an axis. In judo fight, the axis is always imaginary, like when the body rotates in the air, free of support or around himself. In this last case, the axis of rotation passes through the exact centre of gravity of the body. The centre of mass moves into the body every time the body changes its shape.

If the arms are raised overhead, or one leg lifts up higher, or the trunk bends, the Center of Mass moves away from the original position into the body.

When the athlete's body is in the air rotating, it always rotates around its exact centre no matter where that centre is located.

The concepts of angular motion are similar to linear motion, but the terms change in order to identify an association with rotation specifically. It still takes force to overcome inertia in order to produce momentum. The force that produces rotation is called Torque.

Torque is required in order to rotate a body if on the athlete's body acts two forces parallel equal and opposites, we speak about Couple (of forces). Also, a Couple can rotate a body.

Instead of having to overcome simple inertia (weight or mass), in a rotational situation, it must overcome angular inertia.

Not only the mass resists the movement but also when you are trying to turn a body, the length or the distance of the body has an effect on his resistance to turning.

The longer or most distant the body is, the more difficult it becomes to turn the body.

So, in the rotational application of judo, there are two factors that constitute the angular inertia of a body–the mass and the length or distance of the body from the rotation axis. In general, there will be more angular inertia (more resistance to torque or angular force), the more mass

the body contains and the longer it is when the torque or couple are applied. Once a force (torque) of sufficient magnitude (enough to overcome the angular inertia) is applied to a body, angular momentum will be produced. The total amount of angular momentum will depend on the angular inertia (i.e., how much mass and how distant the body is) and the speed (angular velocity) at which the body is turning. It is important to understand how Torque was created. Athlete's body can rotate or by a combination of two forces (in physics terms – a Couple), or by applying what is called an eccentric force (i.e., a force that is not directed through the centre of gravity of a body) using a lever system around a stopping point (fulcrum).
It is important to realize that all the angular momentum variations are created while the adversary's body is still in contact with the ground, in other words, at the time of the takeoff. This angular momentum is a product of the angular inertia (mass and the distance of the body from the Tori body as active force) and the angular velocity created. Once in the air, it is impossible for Uke to change his angular momentum.
The rotational application is both from the energetic and biomechanical point of view the most effective one's application of judo throws. It is well known, from judo biomechanics, that for the Couple Throwing techniques that are energetically convenient with respect to Lever group, ideally, the Uke's body turns around his Center of Mass.
In effect, if the athlete stands still, the application of Couple on the body does not produce acceleration on the centre of mass because:

$$a_{CM} = \frac{\sum F}{\sum m} \; but \; \text{int}\, o \; a \; Coupleis \sum F = 0 \; then \quad a = \frac{0}{\sum m} = 0$$

If the athlete moves, with constant velocity co_{st}, or acceleration β, neither velocity nor acceleration does not change with the application of a Couple on his body, but the body moves with the same velocity or acceleration rotating around his centre of Mass.
On the other hand, during the Lever throws application, both the Center of Mass and athletes' bodies move in the space. However, the rotation is essential and already present in classic judo throwing techniques because the need to throw on the back the adversary for regulation compels Tori to apply a final rotation or a complete rotational movement to obtain victory in the competition.

Fig 8.4.a.b.c.d Classical application of vertical rotatory movement for Ippon by Suwari Seoi

Rotational applications are useful also both to spend less energy and to overcome the natural defensive capabilities of the body.
The basis of this upset is grounded both on the mechanical confirmation of the human body and the laws of Newtonian Physics.
It is interesting to highlight that the athlete's body is not able to defend itself both from the diagonal and rotational application of throwing forces.
The muscular structure is unable to resist diagonal/rotational forces, and the human body is unable to resist so much against such solicitations.
Some rotational application falls into innovative and chaotic throw-building.
There are too many ways to apply rotational forces into the Couple of athlete's systems. Perhaps this was the first stumbling block that stopped this kind of lengthen after Kano death. The rotational complex could be organized on many bases, but the mechanical basis of judo throwing techniques helps us to choose the right way to build up these new Innovative or Chaotic techniques.
In order to apply useful rotational techniques, it is essential to study the Center of Mass motion; then, these new techniques must push the Center of Body Mass along circular or pseudo-circular paths.

Rotatory modification of Couple techniques
As previously stated, rotatory movements are already present in the final part of some Couple throws. Now it is interesting to analyze some rotatory variations that are utilized in competition to enhance the effectiveness of these techniques.
But what is the better way to single out the effective rotatory variation in the Couple group?

- To consider the defensive inabilities of the adversaries' bodies!

The only right way, biomechanically speaking, is to evaluate the human body structure.
Analyzing human body structure means selecting the direction in which the muscular structure is less able to resist throwing force applied by Tori.
Single out these weaknesses helps to identify the trajectories of a better use of the energy that can be converted in trajectories of the adversary's centre of mass in space.
The last statement, considering the inner mechanics of Couple group techniques (rotation of Uke body around his centre of mass), means to apply some further special rotation enhancing the effectiveness of throws.
One other way is to hybridize the couple mechanics into the lever by the non-simultaneous application of the couple.
Resuming the rotational application of Couple Group techniques needs a severe change in their application and in their nature to enhance their effectiveness in some special situations.
During the application of throwing techniques, it is important to remember the importance of Tori's head and neck in defining the direction of the throw. These movements are ruled by the vestibular system, proprioceptive neck reflexes, and mechanics of the system.
All throwing techniques of Couple groups increase their effectiveness in the rotatory meaning only with drastic changes in their application, or modifying direction, or applying special consecutive rotatory motion, or varying the inner mechanics of the techniques.
In the first, applying Couple in specific diagonal directions.

Fig.8.4.e.f.g.h.Diagonal application of some Couple throws Innovative O Uchi Gari, No Name, Ko Uchi gari, Harai Goshi. (many Throws are with plunge)

The second one is the application of consecutive rotation into the transverse (horizontal) symmetry plane to enhance the effectiveness of Couple techniques applied by trunk and leg. In this group, it is possible to find two of the most utilized throws Uchi Mata and O Soto Gari; that biomechanically speaking, are the same basic way to apply the Couple Tool,
Although Classic Japanese vision looks at two different movements or techniques,
There are the basic and same ways to apply the Couple in trunk leg group, like O Soto Gari and Uchi Mata the different names hail from Uke's front, back difference.

Fig 8.4.i.k.l.m. Vertical rotational movements in the transverse plane with the axis in the sagittal plane, applied by Tori, helping the throwing action in Uchi Mata. Biomechanics helps to infer that the same trick could be applied to O Soto Gari.

The third way to enhance the Couple tool effectiveness in competition is to drive the Uke centre of Mass along circular and pseudo-circular paths. Remembering basic mechanics, the application of the Couple tool ensures that the Uke's body moves around his Center of Mass without translation in space.
Center of Mass movement in space is the trait of Lever application that, biomechanically speaking, is the application of a Torque and not a Couple on the Uke's body.
To carry out the third statement means to change the inner mechanics of this class of Judo techniques. How is it possible to realize this change? Easily in two ways!

1) Mechanics of technique can be changed from Couple to Lever, putting back one of the forces of Couple. Simultaneous application on the body of equal forces makes a Couple, different time application of the same equal forces on the body makes a Torque. Then translating the Center of Mass along some pseudo-circular paths applying two times the forces of Couple can enhance the effectiveness of some techniques.

Fig8.4.o.p.q.r.s.t. Application in two times of Couple forces drive Uke Center of Mass along with a pseudo-circular path is very effective rotational Lever throw born both of De Ashi Arai and O Uchi Gari.

In effect, remembering that Couple is the simultaneous application of two parallel forces equal and opposite if the Athlete applies the two forces in a non-parallel way or with a sensible time delay, the mechanics of throws changes from Couple to Lever.
This happens especially with the application of rotational enhancement in competition with vertical rotation in the transverse plane and symmetry axis in the sagittal plane (rotational application to techniques like Ko Uchi Gari, O Uchi Gari, Okuri Ashi, De Ashi, etc.) that more often are applied instinctively by athletes in high-level competitions.

2) The different dynamical situation that helps the changing of one of the Couple forces, in a second time, changing the mechanics of techniques must be considered, sometimes, not a very effective enhancement of Couple, but a variation is arising from the specific dynamics of the situation.

Mechanics of technique can be changed from Couple to Lever changing also one of Couple force direction.

Fig.8.4.v.w.x. Application of diagonal attack and changing the direction of one Couple force changes from Couple O Soto Gari attack to lever O Soto Otoshi attack.

Rotational variation of Lever techniques

Essentially Couple techniques in the competition are based on the “simple” and toneless application of Couple by arms and legs in the human body’s three-plane of symmetry. Energy Rotational application in Lever techniques, due to their mechanical essence, is more complex than application in Couple techniques because, in Lever system, there is more degree of freedom.
For this kind of technique, the complexity of movement and the mechanics of throws also flow in higher consumption of energy
A correct biomechanical approach suggests that, because the interaction between athletes is a process inside the Couple of Athletes System, it is necessary to break the system and to analyze Tori and Uke as separate bodies.
In such meaning, it is necessary to consider the possible rotation axis connected to the two bodies.
Then to apply a rotational variation of the Lever technique means for Tori the opportunity to rotate in many different directions and symmetry planes to take vantage of the weakened Uke’s defensive capabilities.
The play is ruled by the Tori arms that induce different distances between the two bodies.
In such a way, it is determined not only the rotational mass of the system (Momentum of Inertia) $M= m \times r^2$, but it is also the connected force and energy.
Essentially lever techniques in the competition are based on the following rotation movement that can be changed in inclination bending the body along the 360° in the transverse plane.

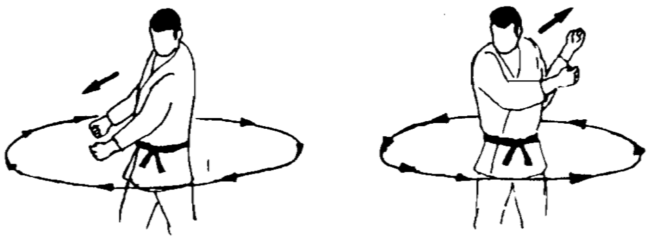
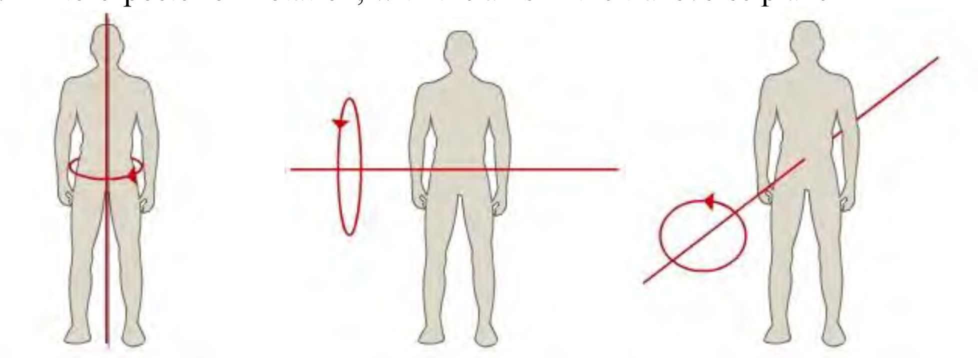


Fig 8.4.y. Basic Rotatory movement that is connected to Lever techniques

The basic application of rotational movement in the Lever techniques group is always present in classical throws, considering Tori plane of symmetry taking a firm contact point (fulcrum) on Uke's body, they are :

A. Vertical Rotation, with the axis in the sagittal plane
B. Transverse Rotation, with the axis in the frontal plane
C. Antero-posterior Rotation, with the axis in the transverse plane



A B C

Fig.8.4.z. Possible Rotations and related axis

Normally the most classical rotational application flow from the Rotation of Tori around his perpendicular symmetry axe lying in the Sagittal Plane of symmetry.
That is classified as vertical rotation in the previous figure A.
Most Classical judo Throwing techniques belong to this group. Among them is: O Goshi
The different axis of rotation is present in the well-known classical trick, application of a consecutive Antero-posterior rotation C with the axis in the transverse plane this trick called in Japanese language Makikomi is applied to some throw to enhance the projection effectiveness, see the next group of figures.

Fig.8.4.α.β. Vertical Rotation in Classical O Goshi (with plunge)

Fig.8.4.γ.δ.ε.ζ. Antero-posterior rotation in Classical Harai Makikomi

Enhancement of Lever techniques

From the previous analysis, it is clear that most of Lever judo techniques are inner connected to rotation movements, due to refereeing evaluation regulations, then to enhance the effectiveness of Lever techniques, it is possible to choose three main ways,

1. Hybridization of Lever mechanics introducing a Couple instead of a Torque changing in this way the energy of the technique
2. Plunge: Tori enhances his technique by a collision and simultaneous plunge of his body to the tatami, but the plunge is utilized practically on all throws for Ippon.
3. Application of rotational dynamics in a totally new way, preserving the lever mechanics

Fig.8.4 A.B. Hybridization of the lever with a couple

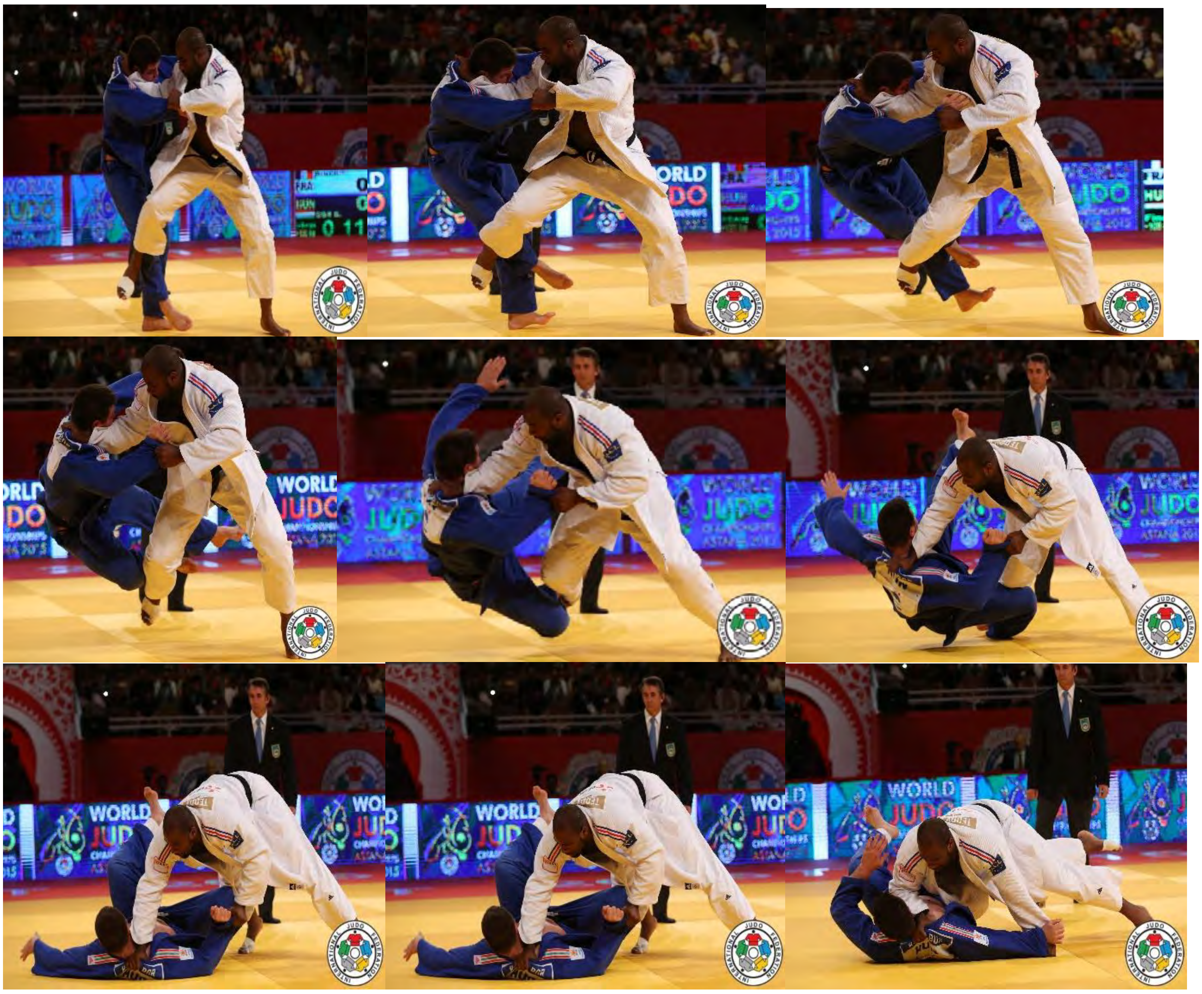


Fig.8.4.Γ.Δ.Ε.Ζ.Η.Θ.Ι.Κ.Λ. The partial plunge of tori applying a diagonal Couple on Uke

Fig. 8.4aa.bb.cc.dd.ee. Example of Fall down by dynamics of throw and plunge to throw

Fig.8.4.η.θ.ι.κ.λ.μ. Hybridization with Couple and Rotation of the Lever technique Hiza Guruma makes the Lever tool less expensive in energy terms.

The second method to enhance effectiveness is very interesting, and it is grounded on the full-strength rotational application, like Ueshiba's method for Aikido.
Even if the whole mechanics of the technique does not change at all, the techniques are applied in a totally different way, both more effective and less energy wasting.
The first important improvement is that they do not need to unbalance. The most important thing in these new-style Lever techniques is to tie tightly with a contact point the adversary's body and to turn swiftly in one of the three planes of reference, keeping intact the contact point. As an example, the next figure shows the application of the basic and totally rotatory idea at the classic throws called Morote Seoi Nage, that in this variation could be called as an understanding attempt ***"Spinning Seoi Nage",*** this vertical rotation with the axis in the sagittal plane allows Uke's body fall without unbalancing, which is essential in the classical application of Lever techniques, and also useful in children teaching and training because doesn't charge the spine with a heavyweight. In the following, there are shown two applications of pure rotation: the first one applying a whatever stopping point during rotation to throws, the second one applying a pure rotation, keeping the contact point firmly, as some Aikido throws.

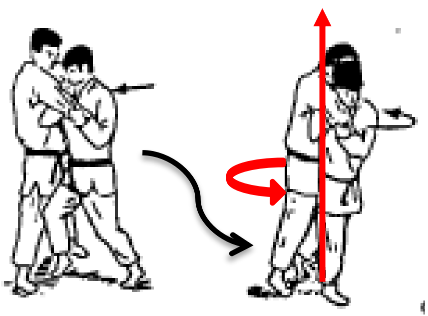


Fig8.4.ν. Spinning Seoi

Fig.8.4.ξ.ο.π.ρ.ς.σ.τ.υ. Fast Vertical Rotation, with the axis in the sagittal plane, utilizing a leg as stopping system: Chaotic throw - no name.

Fig.8.4.φ.χ.ψ.ω.ϊ.ϋ.ό. Fast Antero-posterior Rotation, with the axis in the transverse plane, binding tightly only one arm. Mechanics Lever (point of application of force left arm, stopping point friction under feet) this technique is structured with the same mechanics of some Lever Throw from Aikido, like Kata te dori ko kyu nage.

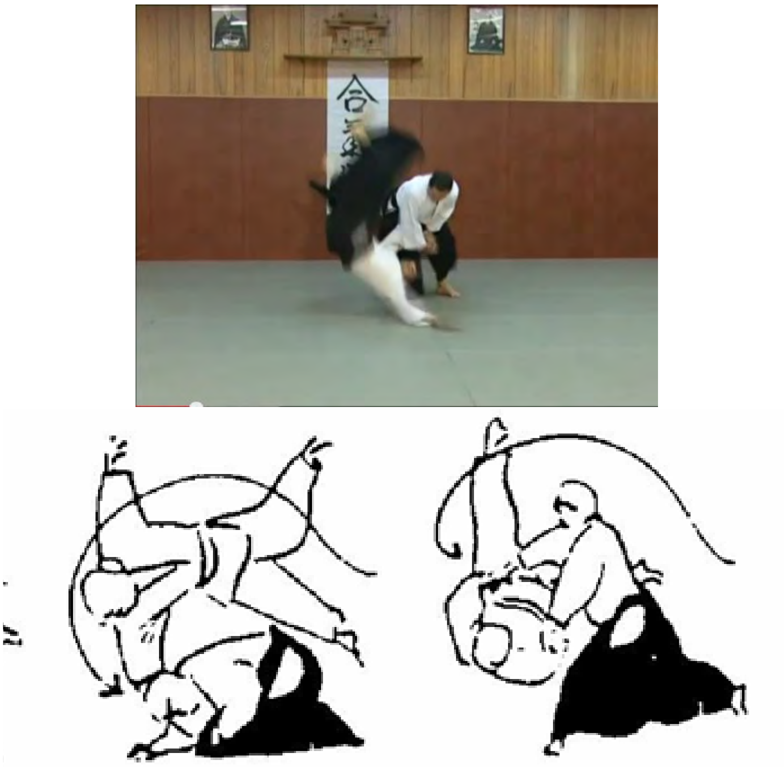


Fig 8.4.AA.BB. Some of the throwing responses from Kata Te Dori Ko Kyu Nage

8.5. How to build a Combination in competition

Combinations

Because it is not possible to consider and solve the infinitive situations that normally happen in high-level competition, we shrink our study starting not from many particular situations but from a more general definition which allows us a more flexible approach.
We define combinations of a special class of attack's initiative based on the multiple application of the same or different throwing techniques.
In biomechanical terms, this is a linear combination with repetition of the two basic tools to throw: Couple or Lever.
Like Couple+Couple; Couple + Lever; Lever+Lever+Couple; etc.
From the mathematical point, the solution of this linear combination is infinitive. Again it is not possible to develop the argument.
In-plane language, we can assert that in this class, generally, it is possible to find two main areas that we call a practical definition: repeated attack and combination without considering the number of techniques applied.
The best way to approach the argument is to consider for practicability only two throws connected.
Repeated attacks are all these attack actions in which Tori launches a direct attack, allowed to react Uke, who avoids (or blocks or applies a counter) to immediately re-attack with the same technique. This process sometimes could be useful and can surprise an opponent, especially when he is tired (end of the contest or during golden score). In fact, in that situation, very often, the opponent wrongly resumes its original position, and a second attack can destabilize Uke, obtaining the full point.
Combinations are always repeated attacks applied by Tori, but more often, the combination is the result of deep home preparation in the field of tactics.
Tori undertakes a series of true actions, all with the same sincerity, concluding with one of them. The study of the combination is strictly connected with the better use of the symmetry breaking produced in the Uke standing posture.
His theoretical development would be as follows: Tori with a true attack must cause sincerity reaction, Uke reacts, or bends, or turns in one direction, which makes it vulnerable to different attacks of Tori. Tori finding instantly the vulnerability makes an attack obtaining a projection.
More often today, in high-level competitions, athletes act only in two ways, they use the combination in the same direction or in the opposite direction, because they are the most natural and the main study in the world, but the breaking symmetry concept needs a whole changing of approach because it is connected in a subtler way to directions that are useful to take the initiative and score a point.
Biomechanics let us analyze the basic properties that must be followed to obtain victory.
If we analyze in deep the basic mechanics of combinations in the light of Couple of Athletes, it is easy to single out their intimate connection with Couple system shifting velocity.
But how is the main biomechanical parameter that allows us to build effective combinations?
In a dynamic situation, when the shifting speed changes, the only useful biomechanical parameter is the relative distance between athletes ruled by arms elongation. In fact, this parameter changes in the function of the specific throw utilized to obtain more or less contact to the adversary body.
In biomechanics Couple of Athletes, System can be modelled as a spring-mass system than changing the spring elongation, the distance between athletes' changes.

Now it is possible to understand the close connection among Competition Invariants, shifting velocity, type of throws (biomechanical throwing tool applied) and connected attack directions.
On this basis, it is possible to group all throwing techniques into three classes:

1. Throws applied at a short distance (chica ma waza) connected to still or very slow speed of Athletes System,

2. Throws applied at medium distance (ma waza), normal speed,

3. Throws applied at long distance (to ma waza) from normal to high speed of Athletes system.

It is important to remember that shifting velocity ranges between 0,2 to 0,5 m/s, and it is closely connected to the positions of the grips that fall and are classified into a Competition Invariants group.

Fig 8.5.a Competition Invariants group (gripping position in competition) Connected to shifting velocity and throws. The first three today are allowed only for instant attack

If Classical, Innovative and Chaotic Throwing Techniques are analyzed not only on the basis of the inner mechanics of throws but both at the light of the best relative distance positioning to throw and at the light of lengthening /shortening distance and possible shifting velocity.

It is possible to group all techniques in a new operative classification based on distance, and this let us find three specific groups (Chica Ma Waza, Ma Waza and To Ma Waza).
These groups showed both in normal judo language and in biomechanical language the basic blocks that could be connected to build all possible combinations, without any specification about the directions or the applicative angles

.*Combinative Classification of Throws (in the function of attack distance)*

Chica Ma Waza

(tight body contact – applied by body rotation at zero/ low velocity and strong grips-)

• Uki Goshi	• Lever
O Goshi	•
Seoi Nage	•
Koshi Guruma	•
Kata Guruma	•
O Guruma	•
Tsurikomi Goshi	•
Tsuri Goshi	•
All Innovative henka	•
All Chaotic throws	•
• Hane Goshi	• Couple
Harai Goshi	•
O Soto Gari sideway	•
Uchi Mata	•
All Innovative henka	•
Very few Chaotic throws	•

Ma Waza

(medium distance applied with classical or double central grips)

• Osoto Gari	Couple
Ouchi Gari	
All Innovative Henka	
• Sasae Tsurikomi Ashi	Lever
Harai Tsurikomi Ashi	
Uki Otoshi	
Sumi Otoshi	
O Soto Otoshi	
Hiza Guruma	
Ashi Guruma	
Tai Otoshi	
All Innovative Henka	
All Chaotic Throws	

To Ma Waza

(applied at first contact, some are possible also with one sleeve grips only or theoretically without grip, all are Couple group techniques)

De Ashi harai/barai	Couple
Ko Soto gari/gake	
Ko Uchi gari/barai	
Okuri Ashi harai/barai	
Uchi Mata with one grip	
O Soto Gari sideway Jumping	
All Innovative Henka	

Judo Combinations: A Biomechanical Principle

A. To Change inter-athletes distance/contact, both switching technique and final direction applying a linear combination of the two tools (Couple and Lever)

Four Main Application Ways

1. Generally speaking, combinations for athletes specialized into Ma Waza (long-distance throws) that need timing are organized on the basis of changing distance, from long one to shorter one with the support of the right change of direction.
2. For athletes specialized in Chica Ma Waza (short distance throws), combinations are grounded on changing direction left/ right and vice versa or forward, backward, or forward, forward, or backward, backward. Right/side and backward /side changing are useful and effective but less frequent also in high-level competitions.
3. Athletes who prefer Ma Waza (medium distance throws) can more freely apply both change direction and shortening distance. Obviously, sutemi are closing combinations throws, in whatever directions.
4. Balance is essential in every combination and direction changing, both for Ma Waza and Chica Ma Waza, more often Tori and Uke are not well balanced on the first attack but balanced as Couple System by their dynamic balance; Tori must fix with the unbalance action of his attack Uke body's position both on one or two legs in order to be able to change attack directly into the weak defensive side of Uke; this is possible when the unbalanced Uke, reacting to resist at a strong attack, becomes rigid and still.

Biomechanical analysis helps to systematize the combination connecting the two tools to throws to the shifting velocity of Athletes Couple System.

V=0

Couple
Couple techniques (To Ma, Ma and Chica Ma) Waza < Lever

Couple
Lever techniques (Ma and Chica Ma) Waza < Lever

V= low/medium

Couple
Couple techniques (To Ma, Ma and Chica Ma) Waza < Lever

It is not possible to apply Lever techniques at low/medium speed. Tori needs to stop Uke, and then it comes back to the first situation

V= high ***Couple***
Couple techniques (To Ma Waza) < Lever

It is not possible to apply Lever techniques at high speed. Tori needs to stop Uke, and then it comes back to the first situation

It is also possible, though difficult, to combine multiple techniques (three or more) to bring your opponent into a non-defendable position. The better way to enhance such kinds of linear combinations is to study how to connect throws that apply different biomechanical tools (couple and lever) with the same leg; important to note that these connections are feasible only if the Couple of Athletes System is fixed.

Translating in plain terms, this means organizing combinations like Uchi Mata into Ko Uchi Gari into Tai Otoshi, or O Uchi Gari into Uchi Mata into Sumi Otoshi etc.

Combination Examples from high-level competitions
The Biomechanical theory of Combinations is grounded on a practical point of view, as the pragmatic western vision of Initiative, today for one high-performance coach is very important to give sound and easily understandable information to athletes improving their fighting capability.
In the following figures, there are few examples of combinations, explained on the basis of the previous principle and with the utilization of the previous technical methodological classification reporting for clear connection the Japanese names of throwing techniques., the utilization of terms like shortening or lengthening distance must be understood as the change in contact athletes' bodies, switching different throwing techniques classified in function of the distance of attack.
All these combinations sequences have been taken by high judo competition during the last forty years.

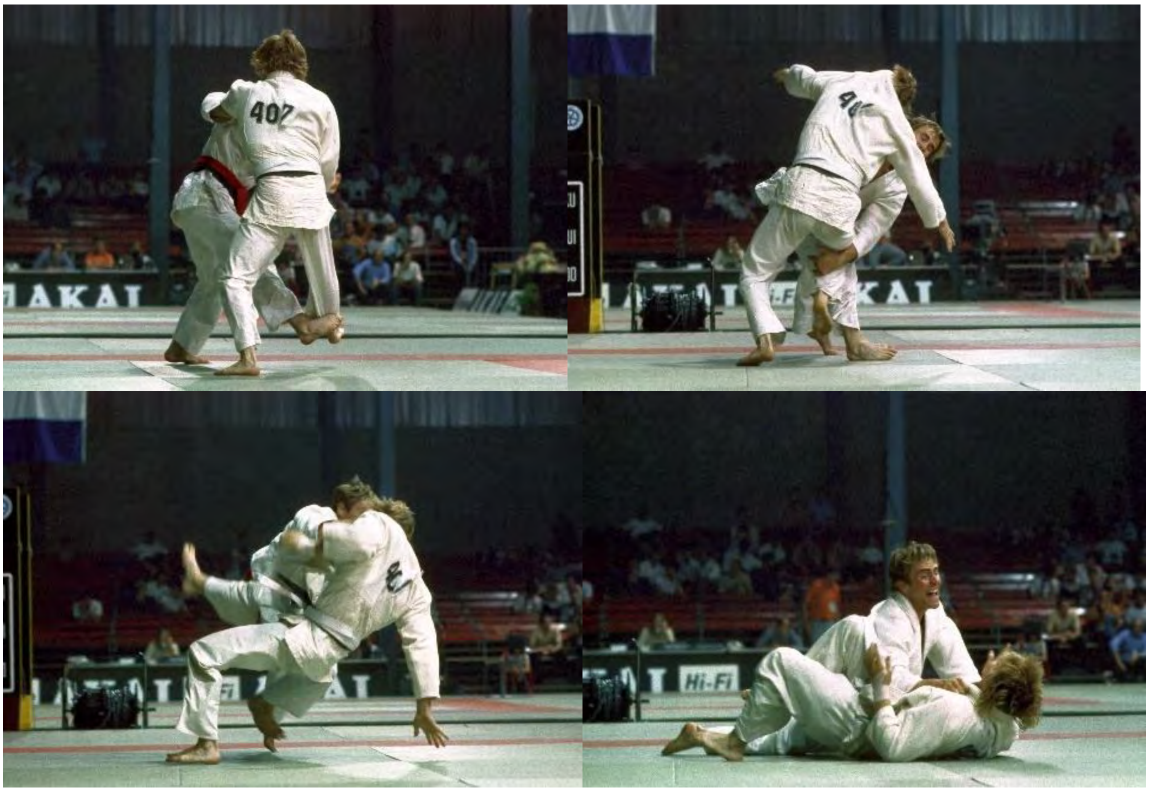


Fig 8.5.b.c.d.e. Example of combination based on the shortening distance between athletes To Ma Waza into Chica Ma Waza (Ko Uchi Gari into Kuchiki Taoshi today not allowed by referee regulations.) Adams against Doherty (Finch)

Fig.8.5.f.g.h.i. Example of Chica Ma Waza into Ma Waza lengthening of distance with three changing of direction on a still and rigid Uke applying three Lever with same leg or three throws (O Soto Otoshi, sideway O Soto Otoshi, sideway O Soto Guruma)
Nomura against Yekutiel (Finch)

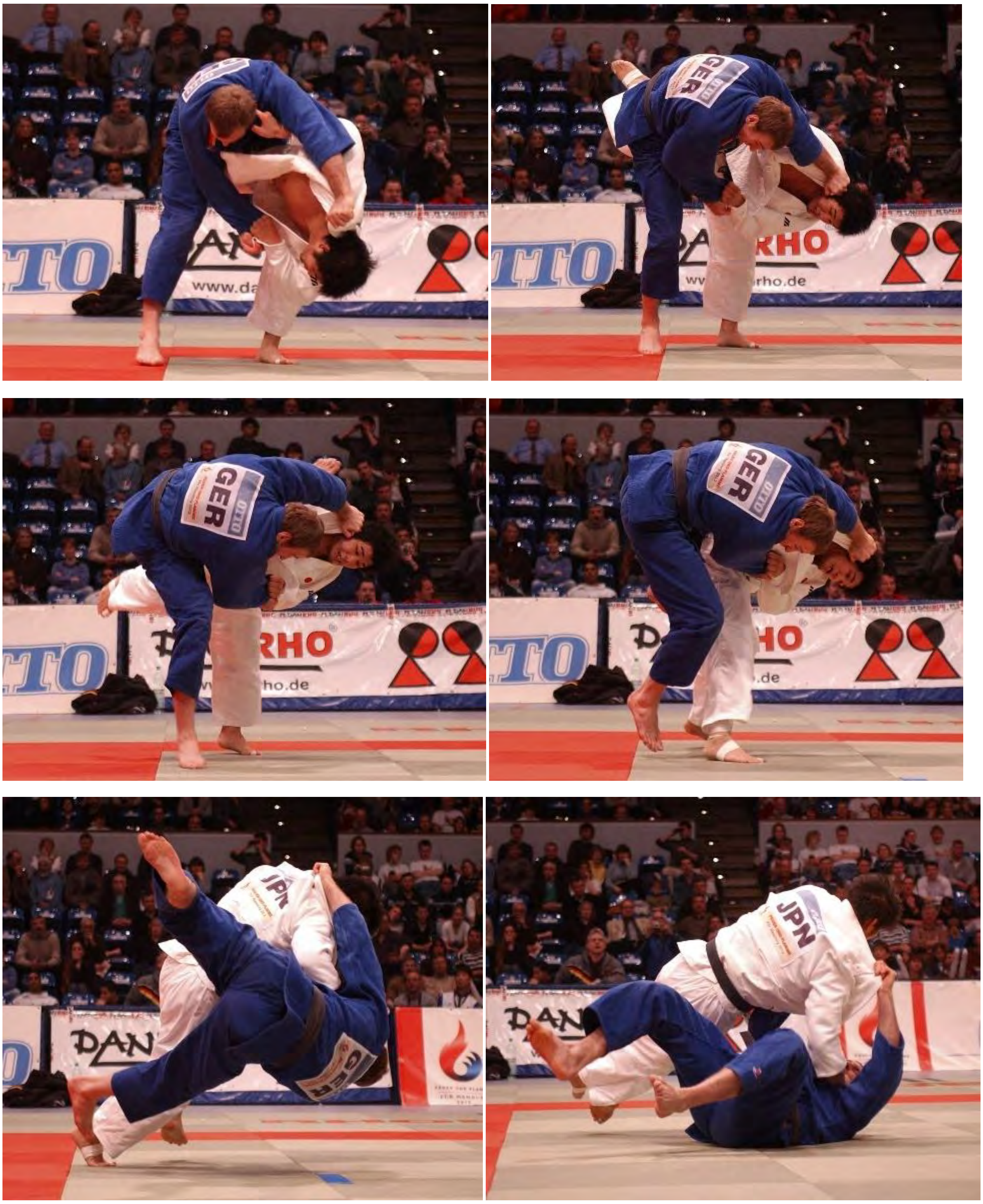


Fig 8.5.l.m.n.o.p.1.q Example of Chica Ma Waza into Ma Waza lengthening of distance with the application of horizontal rotation and changing of Couple into Lever Tool. (Uchi Mata into Sumi Otoshi)

Inoue against Hubert (Finch)

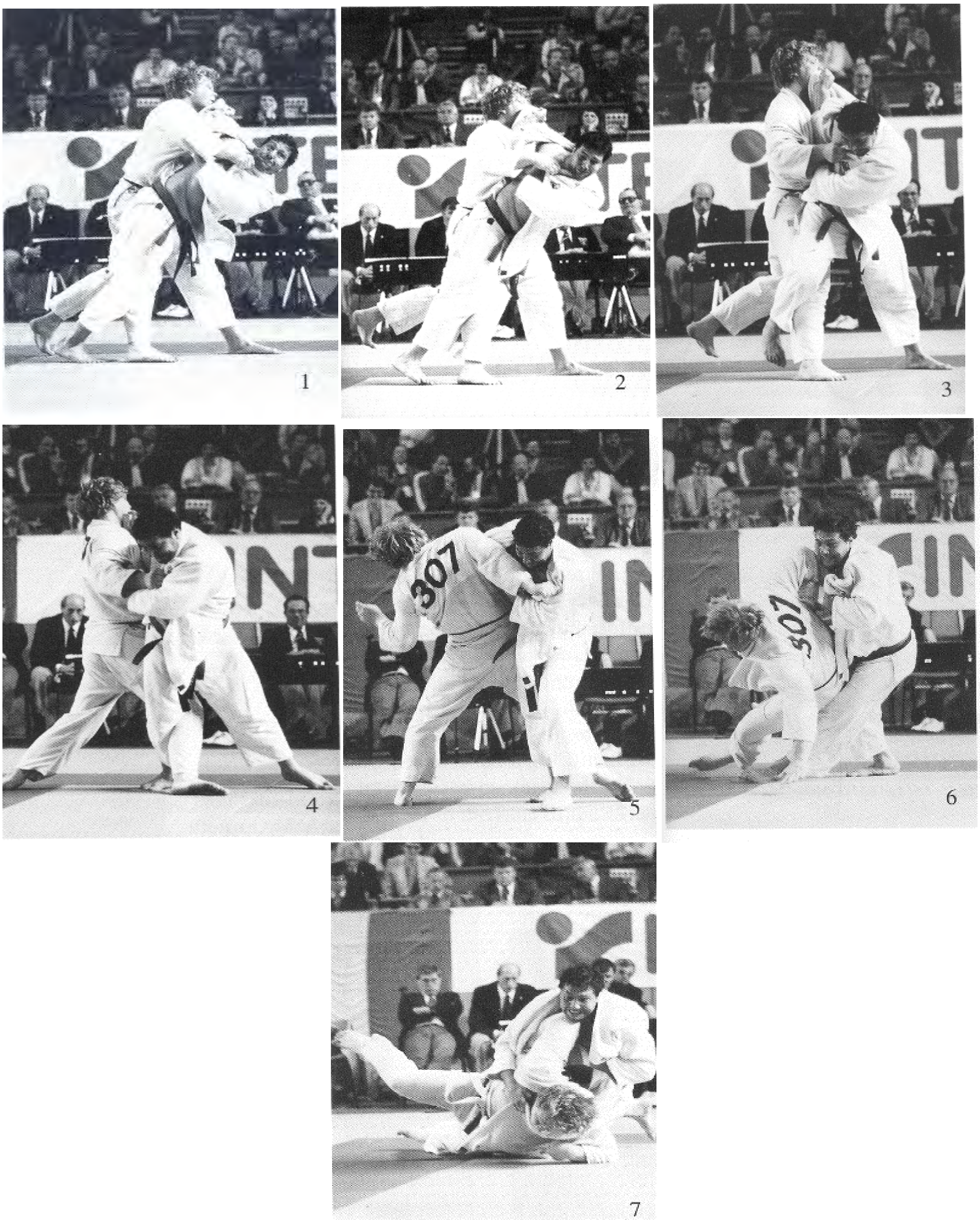


Fig 8.5.r.s.t.u.v.z.x. Example of Chica Ma Waza into To Ma Waza lengthening of distance with changing of direction on a still rigid uke's leg, applying a combination of three Lever and one Couple or four different throwing techniques. (Seoi into sideway O Soto Otoshi, O Soto Otoshi and Ko Soto Gake)
Angelo Parisi. (Finch).

Fig 8.5αβγδεζηθικλμνξ Very similar to the previous Example: Chica Ma Waza into To Ma Waza lengthening distance on a still rigid Uke, Tori applies a defensive blockage two Lever and one Couple with the same leg, or three techniques (Seoi into O Soto Otoshi into O Soto Gari) Pinske against Mammadov (Finch)

Fig8.5.οπρςσ. Interesting combination Backward-Forward Ma Waza into Ma Waza O Soto Otoshi- Tai Otoshi Maret Olympic Games Brasil 2016

The biomechanical analysis of the previous situations let us determine some interesting findings:

1. The only dynamical situation to build up complex combinations (2 or more techniques connecting Couple and Lever) is at zero shifting velocity of athlete's system.
2. In such a specific dynamical situation, the fastest way to connect more techniques is to utilize the same one leg support position, changing the goal at the moving "acting leg".
3. In terms of "breaking symmetry" [7], Tori must break Uke's symmetry stopping his body in unstable equilibrium on one leg, increasing his stability on it in order to totally block his mobility.
4. The previous position will be assured if Tori adds his own body weight on the stopped side of Uke's body.
5. Ten in such a situation change direction to applied forces is the only function of Tori's trunk rotation.
6. In a theoretical way, combinations can be closed by every Sutemi, but as a practical solution in a high-level competition that can't happen because too dangerous. In fact, in such high dynamical situation, it is possible to mistake something and undergo a hold (Osaekomi)
7. The only Sutemi sometimes applied in competition is Tani Otoshi because the mechanics of technique brings a final position safer for Tori.
8. More frequently is utilized as a final combination tool, both from female and heavyweight categories, the Makikomi trick connected with Lever techniques.

In general, strategic terms, to take the initiative is advantageous also if no score is added at his own basket, in fact taking into consideration that currently analyzed athletes represent the world's finest competitors in judo, it is very logical that their level of ducking attack (avoidance) is very high. Very often, a large number of attacks does not always bring judoka direct points, but often leads to opponents' punishment due to" passivity", and thus gaining an advantage. In addition, one should take into account that a large number of unsuccessful attempts as throwing opponent and contact to the ground with parts of the body that are not scored (Kinsa) are both took into account by referees in their evaluation in case of judgment and filled as heavy psycho-physical pressure.

8.6 Action-Reaction attacks.

Theory
When Judoka chooses to attack first, he can build an attack to cause an initial reaction of the opponent, and he can exploit the utilized force by his opponent's action to its advantage.

Pull/Push: Judoka, when attacks using a pull/push, this causes a reaction of the opponent. So, the judoka can transform its action creating a rear/forward unbalance.
The principle of action-reaction is the purest application of the Kano explication. "… if your adversary pushes you to pull, and if he pulls you push…".
Actually, it could be based on the implementation of a movement trap to cause a natural adversary's reaction.
Feint Principle: Tori simulates an attack to react Uke in a direction that may operate to apply a decisive technique. The first attack, which is a preparation for the next attack, may be more or less involved; what matters is the apparent sincerity with which Tori must run for Uke gets caught lure.

Practical application in high-level competition
In high-level competitions today, it is not possible to apply, simply and directly, the previous method.
Today athletes built a strong defensive system, and experience in high-level fight furnishes them with a sound way to understand the adversary's intention, then nor simple push/pull actions, nor simulated attacks can obtain the expected simple reaction, sometimes, for example, Uke reacts with not the expected reaction but with an unexpected (prepared) avoidance movement in a safer direction for him.
Then the only practical solution for Tori is to connect two well prepared and effective ***real*** attacks, the second of which is in the direction in which Uke may operate the only natural defensive action.
More often, there are connected two couple techniques applied by the same leg, or a Couple and Lever always applied by the same leg for saving attack time, making the action-reaction trick more efficient and effective.
It follows four direction of action / reaction: forward / backward , backward /forward, left / right and right / left.

Action Reaction Examples from high-level competitions

The Biomechanical theory of Action-Reaction is grounded on a practical point of view. As the pragmatic western vision of Initiative, it is simply connected to the application of two real attacks previously prepared in such a way.
Tori applies a first real attack that can be stopped (in the better way) in only one direction and connects the first one to an effective second attack in this specific only direction, often there are connected two Couple techniques applied by the same leg, or a Couple and Lever always applied by the same leg for saving attack time, making the action-reaction more efficient and effective
Today for a high-performance coach is very important to prepare a sound and easy understandable tactical trick for the athletes to improve their fighting capability.

In the following figures, there are two examples of action-reaction tactical tricks, with the utilization of the previous technical methodology applied in high competition.

FiG.8.6.a.b.c.d.e.f. Example of To Ma Waza into Ma Waza shortening of distance with the application of backward/forward action-reaction on a natural, simple reaction, using two Couples with the same leg. (O Uchi Gari into Uchi Mata)

Inoue against Bryson (Finch)

Fig.8.6.g.h.i..j.k.l.m. Example of To Ma Waza into Ma Waza shortening of distance with the application of backward/forward action-reaction on a natural, simple reaction, using two Couples with the same leg. (rotational O Uchi Gari into Uchi Mata)

Peters against Kubanov (Finch)

Fig.8.6.o.p.q.r.s.t.u.v.w .Example of Ma Waza into Chica Ma Waza shortening of distance with the application of backward/forward action-reaction on a more complex rotational avoidance, using two Couples with the same leg. (O Soto Gari into Uchi Mata) Maret against Van der Geest (Finch)

The biomechanical analysis of the previous high-level competition situations let us determine some interesting findings:

1. Normally action-reaction attack is finalized at only two techniques connected by opposite attack directions.
2. Also, for the action-reaction attacks, the most effective situation is at zero shifting velocity of the athlete's system.
3. In such a specific dynamical situation, the fastest way to connect two techniques is to utilize the same one leg support position, changing both directions of forces applied and goal at the moving "acting leg".
4. The breaking symmetry frequently applied for these actions is to bend or turn Uke's body stopped on his two feet.
5. The attack directions more often utilized are backward/ forward, forward/backwards, less frequent (but always possible) are left sideway/right sideways and vice versa.
6. In terms of double central grip, the flexibility to apply double attack directly on the right and on the left by Ma Waza is frequently connected with forwarding/backward change of direction.

8.7 Optimization Tips for Coaches

This paragraph is a little bit theoretical but gives us useful information on the Coaching application.
The hard problem is the Optimization of a complex Sport like Judo. In such a group, patterns are everywhere changing, the motion is very complex, and situations happen only with statistical frequency.
Then the ***objective function***: **Optimization** is very hard to find or to build.
Judo is a Dual Situation Sport, and its global optimization is very complex and sometimes not affordable.
But there is a way to overcome the structural difficulties. Along with the line of the Cyclic Sports Optimization, it is possible to apply Optimization by the differential method, or in easy words: dividing Judo, step by step, in appropriately selected subsets.
It is interesting to understand that these subsets chosen on the basis of the dynamics of movement of Couple of Athletes System are able to give us information about optimization of the "Attacker" that is a component of Couple of Athletes System then associating to each subset a specific ***objective function*** it is possible to optimize all techniques to the best performance.
For Coaches, the best way to perform practical Judo optimization is to apply qualitative Biomechanics in two situations and three areas:

Situations

Teaching lessons - Couple condition Static.
Competition– Couple condition Dynamic.

Areas

Couple Statics ⟶ Optimization = ***Minimum*** Energy
Couple Dynamics ⟶ Optimization = ***Maximum*** Effectiveness
Couple Long Development Dynamics ⟶ Optimization= Strategic (Overall ***Minimum*** Energy) Effectiveness

Teaching Lessons - Statics - Minimum Energy Optimization

The most feasible and easy approach to this complex sport is to analyze first the Couple System in a static situation for optimization. This means still Athletes and shifting velocity of Couple zero.

In a Static, fixed Situation if Coaches analyze Judo Interaction (throws, old-down, joint-break and choking).

Biomechanics let to optimize (as suggested by Kano) on the basis of Minimization of Energy expenditure.

Osaekomi waza (old down), Kansetzu Waza (Joint break), Shime Waza (choking) are performed, in accord with physics laws, with less energy consumption.

If Coaches analyze Classical throws classified into five groups and arranged into the Go Kyo (five principles) at the light of Biomechanics find that they can be grouped as already known. in only two classes:

1. Lever System More Energetically expensive
2. Couple System Less Energetically expensive

The static action of throwing techniques goes through some specific phases: Unbalance, Positioning and Throw, or in Japanese tradition (Kuzhushi, Tsukuri, Kake) -

In the Couple Group, Uke's Center of Mass (COM) turns around himself. All these throws are, theoretically speaking, gravity independent, less expensive, ***Fully Optimized.***

In the Lever group Uke's Center of Mass (COM) shifts in space, throws are gravity and friction dependent, more expensive, ***Not Fully Optimized***.

However, they can be further optimized by *changing length at the arm of the lever,* with ***Objective function Optimization*** Minimization of Energy.

For example, from standing Seoi [Ippon Seoi Nage] to Kneeling Seoi [Seoi Otoshi], till to Drop Seoi [Suwari Seoi], a passage that is only the Optimization of the same Lever throw.

Competition: Dynamics- Maximum Effectiveness Optimization

If Coaches analyze dynamic situations (competition), Optimization is grounded on the ***objective function*** Minimization of Energy Expenditure is a necessary condition but not sufficient.

In fact, it makes it appropriate to expand the Optimization goal with a wider ***objective function*** not simply connected to a minimum of energy but which also considers different energy consumption in the function of Maximum Effectiveness. ***Maximum Effectiveness*** means not only that minimization of energy is working like static situation,

The classical application of Kano's Throws is possible in competition if there is a big gap between athletes.

Fig 8.7.a.b. Optimization of energy in classical throws

But Coaches are obliged to consider also not full energetically convenient actions that could be Optimum as very effective like the following action is shown.

Figg. 8.7.c.d.e.f.g.h. Effectiveness Optimization, expensive but effective throwing action

Coaches must optimize and replaces Kano’s theoretical unbalance concept or application with the practical exploitation of the “breaking symmetry.”
The “Breaking Symmetry” concept, as already seen, is a more subtle and practical way to optimize the application of Judo throws in highly dynamic situations.
Practical Effectiveness Optimization passes through the use of specific complementary tools that are meant to improve the efficiency of throwing techniques, although at the expense of energy.
These complimentary tools are essentially based on the exploitation of the weak points of the human body from the biomechanical point of view or on the movement specific application
The main tools in Throws Practical Effectiveness Optimization are

1. Crosswise attack direction.
2. Makikomi and/or Fall down
3. Push + Torque
4. Central Attack with many solutions by different throws
5. Change lever in couple and vice versa
6. Rotation in symmetry planes
7. Pure rotational application.
8. Use of Chaotic technical variation *like* (Reverse Seo i)

8.8 Some thought on Seoi Family

Considering well known the mechanics of throwing by Seoi in static or classical teaching conditions,
The problems that can arise in the real dynamic competition are numerous: at first, the difficulty in overcoming the defensive strength of arms arranged in Kumi Kata (grips), then because more often the Kano kuzushi (unbalance) concept is not always applicable, the thrower comes face to face with the adversary's break of symmetry, then needs to apply the inward rotation with perfect timing, followed by a collision with the right angle connected with the right line of throwing force applied.
These entire, not only as quality, needs a very high coordinative capability but is applied against an adversary that not agrees with these attempts.
To solve this situation, not easily solvable, more often the application of throw is partially perfect, and athletes utilize some complementary tools to simplify or to refine the outcome of Seoi.
These complimentary tools will be subdivided for Standing Seoi, Kneeling Seoi, or for sly applications like Totally Rotational Seoi and Inverse Seoi.

Standing Seoi complementary tools in a direct attack

Acting against gravity (lift) detaching feet from the mat + Mawarikomi
Makikomi Prosecution
Lever applied with a Couple of enhancement
When the detached rotary application

The first tool was, among other habitually utilized by the astonishing Japanese expert of Seoi throw during eighty: Toshihiko Koga. The following figures show the basic Koga method. We don't speak about his method to break the adversary grips because we are studying tools connected to throws.

Fig.8.8.a.b.c.d. Basic Application of the lift tool by Koga

Koga System

Fig.8.8.e.f.g.h.i.k. Ippon Seoi with lift Koga System

Fig.8.8.l.m.n.o Seoi + Mawarikomi with lift Koga System

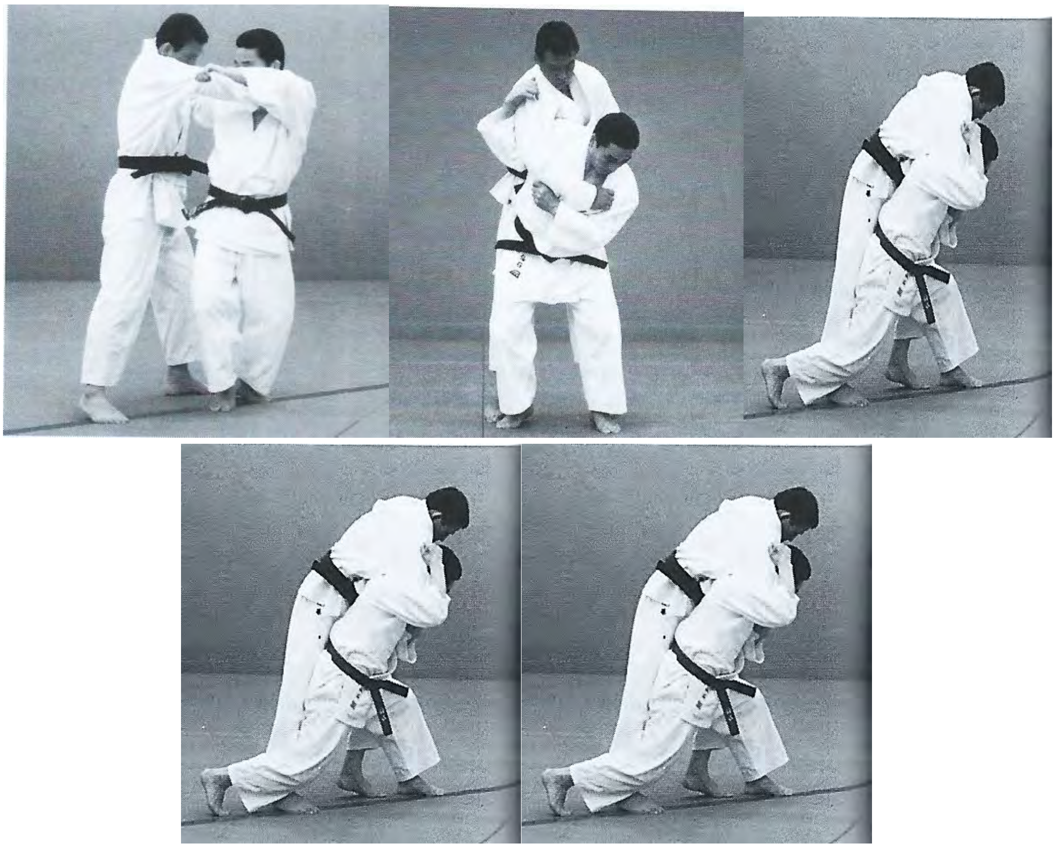


Fig.8.8.p.q.r.s.t. Standing Seoi with Makikomi Prosecution

From Ippon Seoi to Uchi Makikomi

Fig 8.8.u.v. Seoi enhanced by Couple application

Kneeling Seoi enhancement in a direct attack

On kneeling, Seoi like Seoi Otoshi, one of the most efficient systems to increase the throw effectiveness is to apply to throw forces with a special trajectory: starting in an oblique direction and closing with a half circle, helped by a body's twisting torque.
In such a way, the defensive capability of the adversary will drop down faster.
This trick was also often utilized by another renowned Seoi Expert, Sozo Fuji.

Special kake trajectory

Fig.8.8.u.v.w. Hidari Seoi Otoshi Koga in Fuji style

Tools to enhance the effectiveness of Suwari Seoi (Drop Seoi) in a direct attack

Acting against gravity (lifting) detaching feet from the mat to avoid any possible defence
Acting against gravity (lifting torque) refining throwing action to obtain Ippon
Twisting Torque Application
Crosswise Application
Modern application with grips applied on one arm

Fig.8.8.x.y.z.à. Suwari Seoi with lift up torque to refine the final action

Fig8.8.aa.bb.cc.dd. Suwari Seoi enhanced by a horizontal twisting torque application

Fig 8.8.ee.ff.gg.hh.ii.jj.kk.ll.mm. Enhancement of Suwari Seoi by a crosswise application

But way athletes need to apply such complementary tools to enhance technique effectiveness? Usually, during high dynamic competitions situations, using Suwari Seoi is challenging to manage the throwing force final direction easily for two reasons

A) Dynamicity of a throwing action
B) High defensive capabilities of athletes

These two are the main reasons to apply tactical support tools to refine competition in competition because Tori has little control of the Uke movement during the fall down. This is the way the end is a situation of multiple direction choices for Tori. His is the main difficulty to manage this throw, as shown in the following figure.

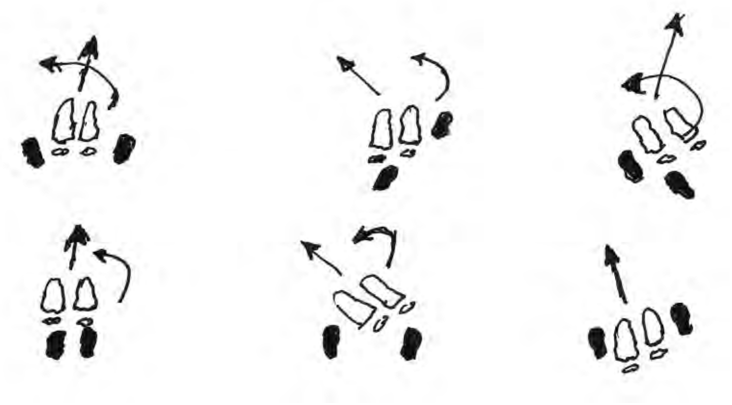


Fig8.8.oo. footprints (wTori legs/ b Uke's feet) showing the multiple direction choices of throwing force

New ways: Reverse, Rotational, Spinning, Grip on one arm, One arm Applications

In the last years, the research of a new way to enhance the effectiveness of judo throws also developed in Japan interesting, unorthodox solution to competitive situations.
A worldwide well-known new application is the so-called Reverse Seoi, which seems the evolution of Ude Gaeshi presented both in Kudo *Dynamic Judo* and Sato and Okano *Vital Judo* with some slight differences.
These new applications need careful acrobatic training and precise timing for application.

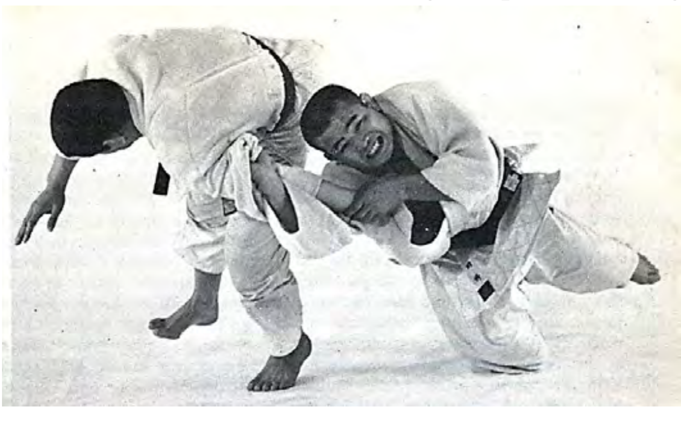


Fig 8.8.pp. Ude Gaeshi

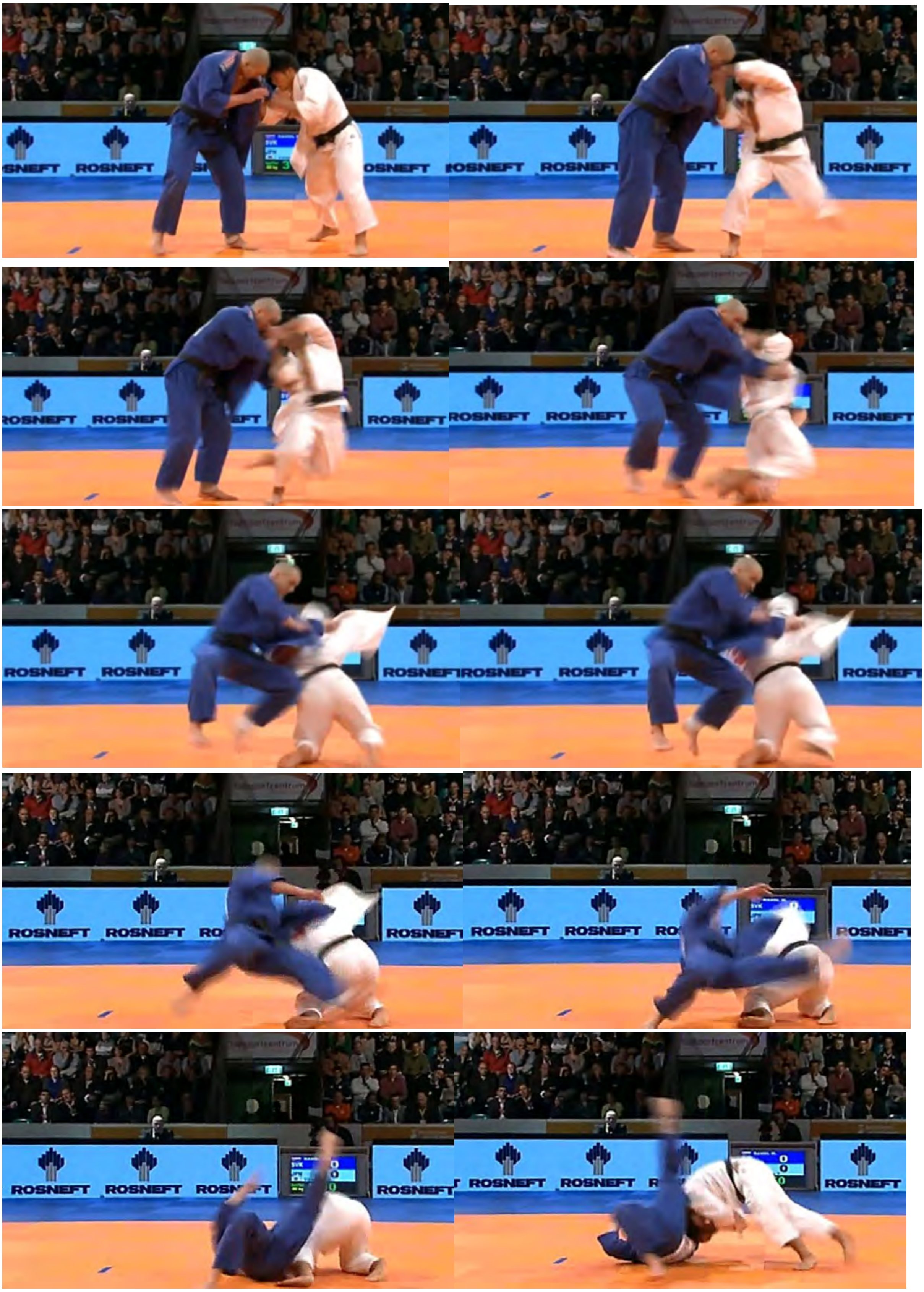


Fig 8.8.qq.rr.ss.tt.uu.vv.   Reverse Seoi applied with a 180° of rotation

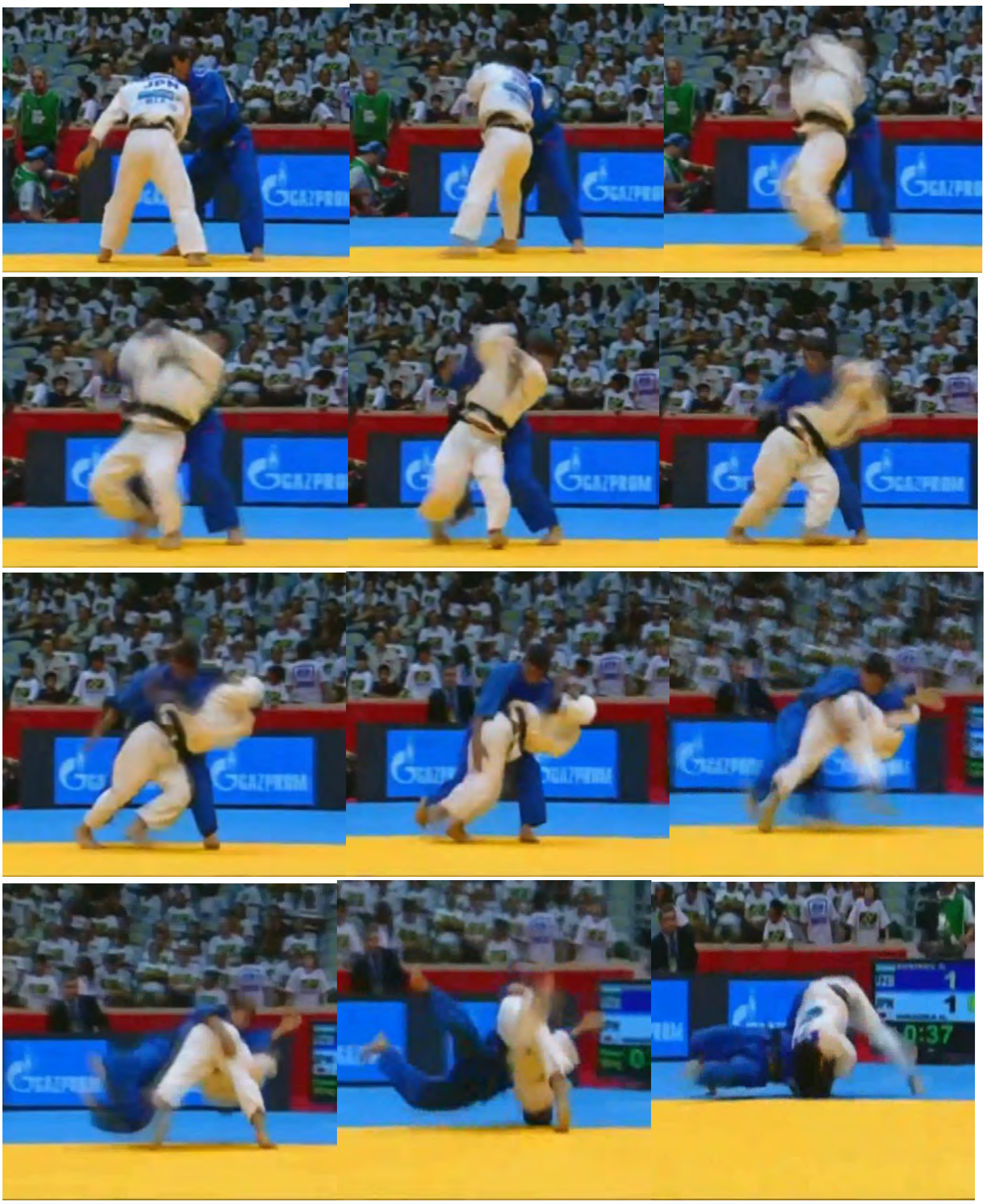


Fig 8.8.ww.xx.yy.zz.*a.b.****à.ù.ò.ì.è.é, Reverse Seoi with 360° rotation by a pivot on the head***

Fig.8.8.α.β.γ. Incredible Modern application of Suwari Seoi with one only arm, a clear example of strong physical conditioning

Fig8.8.δ.ε. Two modern applications of suwari seoi with grips applied on one arm and two throwing directions

Standing Spinning Variation

This not usual kind of Seoi is very effective. Moreover, in light of his mechanical properties, it is possible to perform it without Kuzushi.
The application of Rotational Dynamics changes the basic Biomechanics of this Seoi throws.
It is a unique form of standing Seoi. It is always a lever technique, but not with the minimum arm, although with the maximum arm.
This means not high expensive but with minimum metabolic energy.
This very unusual Seoi is very tricky and very effective. However, it is easy to stop it.
However, in one only way, that is for the inverse, very easy to change this attack attempt, with Ko Uchi or O Uchi as you prefer. The figure shows similar spinning morote seoi, but obviously, it is easy to change the basic grip; the only attention is strictly connected to the two bodies by this arm action.

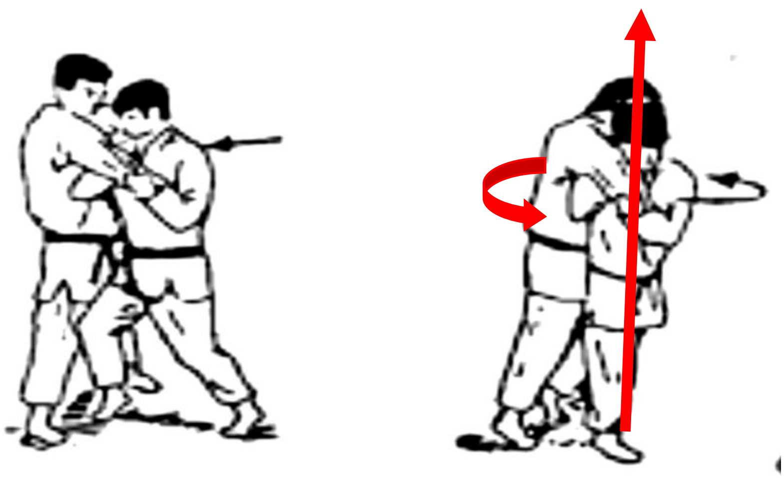


Fig.8.8.ζ. Spinning Seoi

The comparative analysis of Seoi throw made in the light of Biomechanics let us summarize some remarkable properties beneficial for Coaches and Teachers.
Such properties are the basic properties of these throws without complementary tools applied

.

Standing Seoi

1) <u>Energetically expensive</u> (the arm of the lever is shorter).
2) *<u>Most important Kuzushi</u> (the Uke stable standing position needs kuzushi).*
3) *<u>Difficult Tsukuri</u> (a % of Tori's body that fits the Uke's body). %U>%T means a good Kuzushi*
4) *<u>Hard in overcoming Uke's grips</u> (best to utilize rotational actions)*
5) *<u>Needs high rotational speed</u>*
6) <u>Easier to avoid</u>

Kneeling Seoi

1) *Energetically less expensive (the arm of the lever is longer).*
2) *Less important Kuzushi (the drop-down movement acts as kuzushi).*
3) *Easier Tsukuri (it is Uke's body that fits Tori's body). Usually, %U>>%T*
4) *Useful in overcoming Uke's grips (arms are less able to stop up and down movement than push/pull actions).*
5) *Useful in increasing rotational speed*
6) Most difficult Avoidance vs drop action

Suwari Seoi

1) Energetically very favourable
2 Lesser important Kuzushi (the drop-down movement acts as kuzushi).
3) No Tsukuri (it is the Uke's body that fits Tori's body)).
4) Need good timing and coordination
5) Need a continuous fluent action
6)Applied with a large variety of grips
7) Difficult to handle the right direction of the force in function to Uke defensive movement
8) Very difficult Avoidance vs drop action

Reverse Seoi

1) *Energetically favourable*
2) *Less important Kuzushi (the drop-down movement acts as kuzushi).*
3) *Null Tsukuri*
4) *Useful in overcoming Uke's grips*
5) *Need high rotational speed*
6) Most difficult Avoidance vs drop action
7) Inverse Trajectory (difficult to handle).
8) Applied as a psychological trick

Spinning Seoi

1) Energetically very favourable
2) Null Kuzushi
3) Contact Point Tsukuri
4) Rotatory Trajectory (easy to handle).
5) Need high rotational strength
6) Easy Avoidance but natural Renraku
7) Applied as a psychological trick

8.9 Some thought on Uchimata and Couple techniques

Direct Attack: complementary tactical tools.

In high-level competitions, the most important parameter for the specialist of the Uchi Mata family, more than Seoi Experts, is attacked ***Timing*** when techniques are applied in a Couple of Athletes moving situation.
The timing for these techniques is essential to achieve better positioning to apply the Couple Tool.
In terms of mechanics, these techniques are a monotonous application of couple based on the rotation around the coxo-femoral joint.

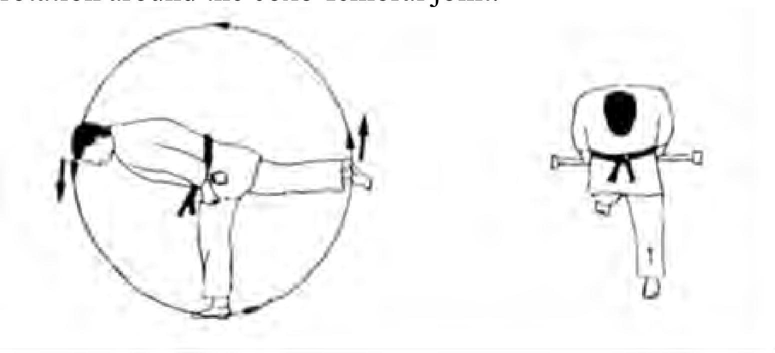


Fig.8.9.a.Couple application in the forward direction

We call this movement monotonous because it is the source of many throws applied with some nuances and small angles differences and 180° of difference, namely: Uchi Mata, Harai Goshi, dynamic Ashi Guruma, O Soto Gari, etc.
However, the increased defensive and acrobatic capabilities of worldwide champions make, also with good timing, complicated to achieve the best relative position to apply Couple.
Then to solve these situations, athletes perform complementary tactical tools that enhance the effectiveness of throwing techniques applied by direct attack.
The Uchi Mata Family (Group of Couples applied by Trunk-leg) has many possibilities to enhance his effectiveness with these complementary tools.

Rotational Application
Sideway Application
The Couple applied in the Sagittal Plane could be most effective if followed by a Couple used in the transverse plane.
The Couple applied in the Sagittal Plane could be most effective if a continuous torque follows it in the same plane.
The Couple applied in the Sagittal Plane could be most effective if used to change the time of forces application, like a lever.

It is well known that rotational movement is already present in the final part of some techniques of the Couple group. It is helpful to study some rotational variations that could be utilized in competition to enhance throws effectiveness.
How is it possible to find the right complementary tool?

- I am considering the adversary's defensive capability!

Analyzing the human body structure means finding the right direction in which human body muscles cannot resist the throwing action.

To understand that means to identify trajectories of a better use of Energy, which are connected to the shifting's paths of the adversary's Center of Mass in space.
When we are considering Couple Mechanics, it is clear how to enhance techniques.
All couple techniques increase their effectiveness or with rotational variations or with swift changing of their specific mechanics applying the Couple forces not simultaneously but in two steps, modifying the attack direction, or applying in a row subsequent rotation.
For example, applying Couple in specific Adversary bodies diagonal directions:

Fig.8.9.b.c.d.e. Diagonal applications of Innovative throws belonging to Couple groups: O Soto Gari, Ko Uchi gari, and a new Uchi Mata Henka (?).

a

b

c

Fig 8.9.f.g.h.i.k.l.m.n.o.p.q.r.s.t.u. Three different ways of rotation in the Transverse plan are applied by Tori to help Uchi Mata throwing action. Biomechanics suggest that the same complementary tool can be applied to O Soto Gari, Harai Goshi and Dynamic Ashi Guruma in competition.

The High defensive skill in high-level competition makes the perfect Couple application very hard. The third way to enhance the effectiveness of the Trunk-Leg throws is to drive the Uke Center of Mass along a pseudo-circular trajectory ended it with a movement like Mawarikomi. Or a plunge with a support point that applies a lever component that makes it easier to throw on his back Uke.

Fig8.9.v.w.x.z.à. The plunge in Uchi Mata with head pivot

Fig8.9.v.w.x.z.à. The plunge in Uchi Mata with forearm pivot

If we remember the inner mechanic of Couple Group, the Uke’s Center of Mass is ideally fixed in space. In contrast, the translation of the centre of mass in space is a characteristic of Lever Group. All this implies that in some typical situations, enhancing Couple techniques effectiveness means to change Couple in Lever.

The effectiveness of judo throwing techniques in a dynamic situation is, among other complementary tools, grounded on the chance to change Couple continuously in Lever and vice versa.

In Biomechanical terms, a true champion will understand when to change the mechanics of his throw to win!

Biomechanics let us understand how it can happen and clarifies that this would be possible in two ways:

1) The mechanics of a Couple throw can be changed in Lever, delaying the application of one force. The simultaneous application produces a Couple and, consequently, a torque. The application at a different time has momentum and, therefore, a torque, with other energy consumption.
Then the application of momentum moves the Uke's Center of Mass along a pseudo-circular trajectory, increasing the effectiveness of Couple Throws in some specific situations.

Fig.8.9.ò.ù.ì.è.é.aa.The forces application in two times (momentum) moves the Uke's Center of Mass along a pseudo-circular trajectory, increasing the effectiveness of Couple Throws with a rotational Lever in some specific situations: Ashi Arai and O Uchi Gari.

All that is usual in high-level competitions with the application of this tool with rotation in the Transverse Plane (horizontal) with a vertical axis.
These actions could be seen as a rotational application of techniques, like Ko Uchi Gari, O Uchi Gari, Okuri Ashi, De Ashi, etc.

2) Sometimes, in the complex dynamical situations in high-level competitions, the tool applied can be evaluated as a dynamic solution of not wanted or prepared movements but the result of dynamic without effective “control” from Tori.

The change from Couple to Lever is produced by a time delay and a change in the direction of forces because not parallel forces create a Momentum and not a Couple.

Fig 8.9.aa.bb.cc. Diagonal attack with a Couple Throw followed by a change in the direction of one force, this situation changes the Couple attack with O Soto Gari into a Lever attack with O Soto Otoshi.

New ways: Inverse applications and Chaotic variation

How is clear, the “Couple Group” forecasts simpler movements than “Lever **G**roup”, in other words, or proper closing distance, or inward rotation with added trunk –leg Couple application. This simple arrangement is the first difficulty for coaches and athletes to find or invent new applications, the so-called “Chaotic Variations”.Only two kinds of different actions came to light; the Inverse of Uchi Mata, born in the Russian school, today significantly utilized in high-level competitions. These applications are grounded on the Trunk-Leg Couple but performed with inverse movement in Sagittal Plane.

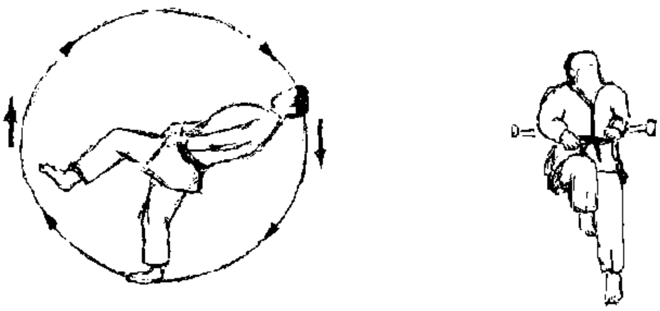


Fig 8.9.dd. Basic movement of inverse Uchi Mata and/or inverse O Soto Gari

The less mobility of the spine in the back direction produces a less fluid and more expensive movement.
Like classic Uchi Mata and O Soto Gari, the way to close distances (GAI) is practically two: Right trajectory, Rotational trajectory with 180° of rotation
The mechanics of Inverse Couple entails an external trajectory when Tori apply an Inverse O Soto Gari.
In other interesting notation, trajectories of contact (GAI) in these Inverse Throws are even inverted: in Inverse O Soto Gari, the sweeping leg is applied at the back of the leg (gluteus area). The contact trajectory is with external rotation; the other side Inverse Uchi Mata is used after a right contact trajectory (GAI).
This is the biomechanical explication of these Russian Throws that today are well managed by Japanese Athletes.

Fig. 8.9.ee.ff.gg. gyaku- (or ushiro-) Uchi Mata by Shota Chochosvili (Finch)

Fig 8.9.hh.ii.kk.ll. Inverse O Soto Gari

Fig.8.9.mm.nn.pp.qq.rr.ss. The modern form of Inverse O Soto Gari is a mixed between enhancement by a couple of Ura Nage and simple Couple application (last figure classical Ura Nage)

Different evaluation is performed for the "Chaotic" variation of the Trunk-Leg Couple Group because the action movements, as already explained, are more straightforward than Lever actions. In effect, every throw is simply (GAI + Couple); it is complicated to build new and Chaotic variations. However, in this group during these years in high-level competitions, some "Chaotic "variations have been developed. One by French Athletes, as we see in the following figures.

Fig 8.9.α.β. French Chaotic Variation (Ko Uchi Gake ?) of Trunk-Leg Couple [21]

In these last times from eastern countries, energetically very expensive techniques were introduced two new Trunk-Leg Chaotic Variations, based on one internal sweeping, always with attack front or back. ***See Fig.79-80***

Fig.8.9.γ.δ. East Countries interpretation of Trunk-Leg Couple "Chaotic Variations."

Grips and Trajectories (rectilinear or inward rotation)

It is interesting to underline that grips for the trunk-leg Couple group have a value lower than Lever techniques (es. Seoi).

Realistically speaking, in this situation, their primary function is to connect Uke's body to its trunk because superior force is more effective in this way. The central double grip can help lift and Couple application in the Frontal plane (es. Okuri Ashi Arai). In contrast, in the case of a straight attack, grips will have the function of strictly connect the two bodies in one movement. (es. O Soto Gari, O Tsubushi).

Fig8.9.ε.ζ. Grips action in O Soto Gari, O Tsubushi

During throw with inward rotation, Grips also apply a Counterclockwise Couple (or vice versa) to adapt Uke's trunk to the general motion.

Fig.8.9. η.θ. Grips action in Uchi Mata, the central Uchi Mata from the theoretical perspective, is less energetically expensive.

As a standard rule, the opening of adversaries' grips is based on the movement of downward pressure followed by an instantaneous impulse upwards and a simultaneous sliding within or under the opponent's grips.

Fig.8.9. ι.κ.λ.μ.ν.ξ. The increasing simultaneous application of the two forces (Couple) approaches more and more practical technique to the theoretical ones.

Biomechanics Group Couple (trunk – leg) showed that this group of techniques considered among the most effective in the high-level competition is also energetically less expensive than those of the Lever and are also bio-mechanically simpler, relying only on closing the distance and Couple application. (GAI + Couple).

However, their intrinsic simplicity hides a different complexity from those of the Lever, which, remember, they need high motor coordination to be effective. The techniques of Couple carried out at whatever speed of displacement of Uke require a particular timing ability. Therefore, their specific qualities are:

1. ***Increased simplicity of the technique.***
2. ***Almost monotony in the technical movements.***
3. ***Unbalance is preferable but not essential.***
4. ***Independence from Kuzushi.***
5. ***Often Tsukuri is easier than in Lever.***
6. ***Energetically more favourable than Lever.***
7. ***Specific Rhythm and Timing.***
8. ***Very effective in any weight class.***

8.10 How to build new throws

It is clear from all Biomechanical analyses that all Judo throwing techniques are built on the following use of the Body's parts and specific movements as a constitutive aspect of the total action.
In the following, we try to explain every single use to understand the basic way to build new throwing techniques called "Innovative " and Chaotic."

1. Arms
2. Legs
3. Whole Body
4. Whole Body Trajectories
5. Whole Body Complementary Tools

It is essential to study its contribution to the whole structure of the movement called basic throw, and then it is possible to change some things to produce both Innovative and Chaotic techniques.
It is better to start from the Definition of the so-called Classic Throws.
Classical Throws: All the throwing movements as shown in Kano's Go Kyo 1922, and Kodokan's Go Kyo 1985
Then they are well known and also the function of arms, legs and body.
They are the basic throw that judo people study when he is proficient at the club.: arms are posed in basic grips called Ki Hon Kumikata. Hip, leg, feet and shoulder are utilized as stopping in some specific points of uke's body to throw him. Lever Group and Couple are applied in the three symmetry planes while arms are in a standard grip.

"Innovative Throws" are all throwing techniques that keep alive the formal aspect of Classic Jūdō throws and differ in terms of grips and direction of applied forces only.
Then ***Innovative Throws*** are variations (***Henka)*** of classical *Kōdōkan* throwing techniques, which are either Couple of Force-type or Lever-type techniques biomechanically speaking. At the same time, it remains easy to recognize still a well-known basic traditional technique (*gokyō* throwing techniques) in them.
In such a situation, arms more often are applied in different points, but stopping points are usually the same. For Lever, from the other side, Couple is always used in the three planes of symmetry on the same legs, but the direction of throws can differ.
However, there are other "non-classic" solutions applied in competition. Which are different from 'Innovative' (*Henka* Throws), which we define as "***Chaotic Forms***" Frequently, these ***Chaotic Throws*** are more numerous as lever group than as Couple.

" Chaotic Throws" are characterized by the application of different grips positions, which applying force in different (nontraditional) directions while simultaneously applying (stopping points) in non-classical position. Utilizing "no rational" shortening trajectories (longer or different than the usual) between athletes for Lever group, while for Couple are applied or in different legs or ways.

Speaking for Lever Throws, it is possible to change arms or legs positions and trajectories. For Couples, it is possible to change only the way to apply couple. Grips are not essential, and trajectories possible are only the three fundamentals before defined GAI (General Action Invariant).
Now understanding the main differences, it is possible to know how they are built and how to build all-new throwing techniques

Athletes more often for the dynamic of situation easily can change, the action both of arms and legs defined ***SSAI (***Superior Specific Action Invariants) and ***ISAI*** (Inferior Specific Action Invariants ***),*** but only a thorough study, prepared before, is the result in change trajectories like the three ***GAI*** (General Action Invariants).

The title of this paragraph is how to build new throwing techniques, but how many are the judo throws?

Forty for Kano I° Go Kyo, 66 for IJF, more or less 67+ 60 variations for the last Kodokan   Go Kyo. In effect, the judo throw is infinitive.
This statement underlines one big mistake that all coaches and teachers made in teaching judo.

People study techniques, but Biomechanics teach us that there are only infinitive situations between Tori and Uke. Tori can apply both tools singled out from the basic analysis (Couple or Lever) to throw Uke.

What tool has to use? Whatever every situation can be solved indifferently by one of the two tools. Tori can apply the preferred tool in every case. Suppose we break the concept of throw as movements obliged and apply whatever tool we prefer, depending on our specific capability. In that case, every situation can be solved easily with a classical or new judo Throws.

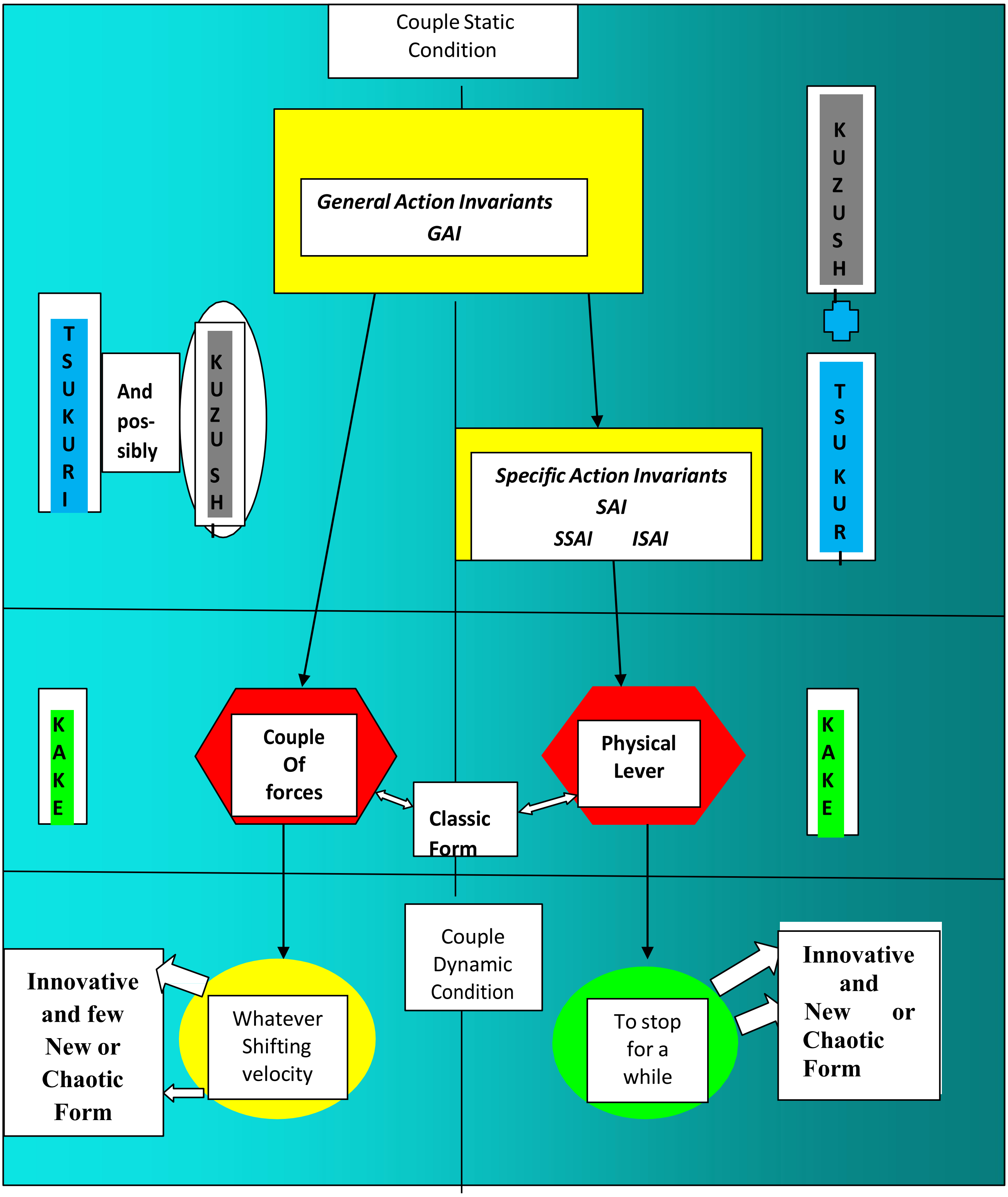
Without study, boring and repetitive movements for a long time!

A new Biomechanical vision apply whatever tool (Couple or Lever) to solve the infinitive situation

A new Biomechanical vision apply whatever tool (Couple or Lever) to solve the infinitive situation

A new Biomechanical vision apply whatever tool (Couple or Lever) to solve the infinitive situation

Diagram 1: Summary of the Kuzushi Tsukuri Action Invariants connected to Kake phase and Classic or Innovative and New (or Chaotic) Form of throwing techniques

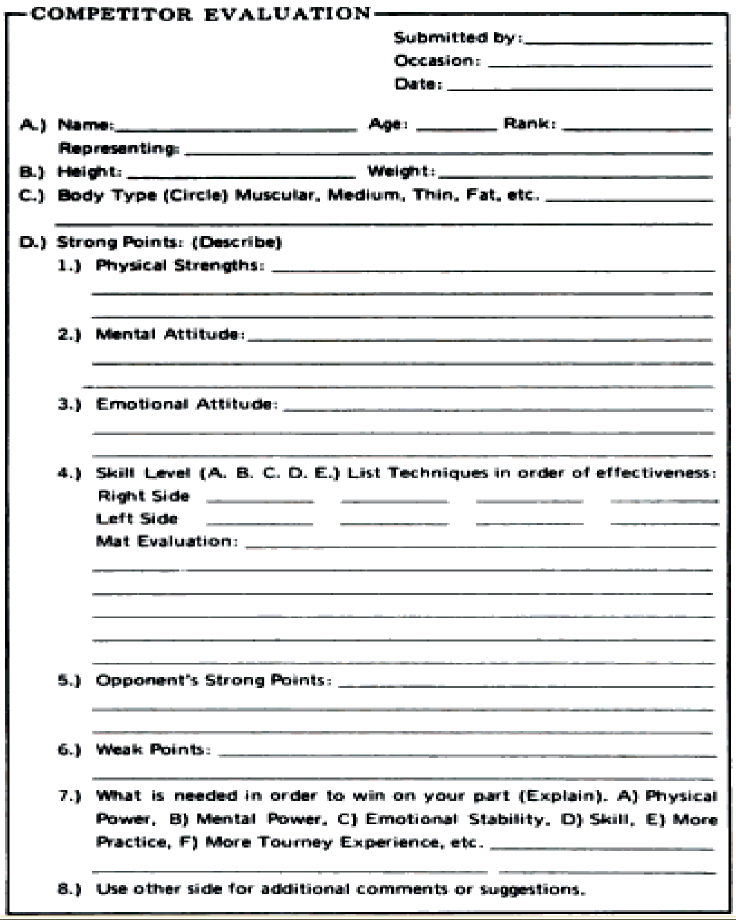



KOR
PHOTO
SABAU GABRIELA

Chapter 9 High-Level Coaching II

Match Analysis in Judo.

In these years, with the rapid evolution of science and technology in human life. With the growth of telematics and complementary technologies, the world of Sports undergoes slow but irreversible modifications in the more widespread application of scientific methodologies in every related field.
How to define Match Analysis?
Remembering the previous definition of Judo competition, we can answer: ***Match Analysis is the study of a clash of interests based on the utility theory.***
Match Analysis could be seen as the master key in all situation sports (dual or team) like Judo, to help practically the problematic task or better of National or Olympic coaching teams.
The birth of Match Analysis may refer to the single Athlete performance study for simple cyclic Sports. However, it can be considered an extension from the "simple" before described case to two interacting athletes' complex fields. Or again to a more complex system of two teams mutually interacting.
For many years Match Analysis in Wrestling or Judo, or team Sports was only some data sheets compiled by a technical observer, with special symbols or specific information on the Athlete or the adversaries.



COMPETITOR EVALUATION

Submitted by: ____
Occasion: ____
Date: ____

A.) Name: ____ Age: ____ Rank: ____
Representing: ____
B.) Height: ____ Weight: ____
C.) Body Type (Circle) Muscular, Medium, Thin, Fat, etc. ____

D.) Strong Points: (Describe)
1.) Physical Strengths: ____
2.) Mental Attitude: ____
3.) Emotional Attitude: ____
4.) Skill Level (A. B. C. D. E.) List Techniques in order of effectiveness:
Right Side ____ ____ ____ ____
Left Side ____ ____ ____ ____
Mat Evaluation: ____
5.) Opponent's Strong Points: ____
6.) Weak Points: ____
7.) What is needed in order to win on your part (Explain). A) Physical Power, B) Mental Power, C) Emotional Stability, D) Skill, E) More Practice, F) More Tourney Experience, etc. ____
8.) Use other side for additional comments or suggestions.

Fig.9.a, Judo Notational Analysis datasheet from The Judo Textbook- Hayward Nishioka & James West; Edit. Black Belt Communication 1979 ISBN 08975500636-9780897500630.

For example, in the book *Modern Judo* of Koblev, Rubanov and Nevzerov, it is possible to find the fascinating Russian Stenographic system of fight registration.

Russian coaches utilized this registration system during the sixty and seventy years to collect information on adversaries and athletes of the Soviet Union team.

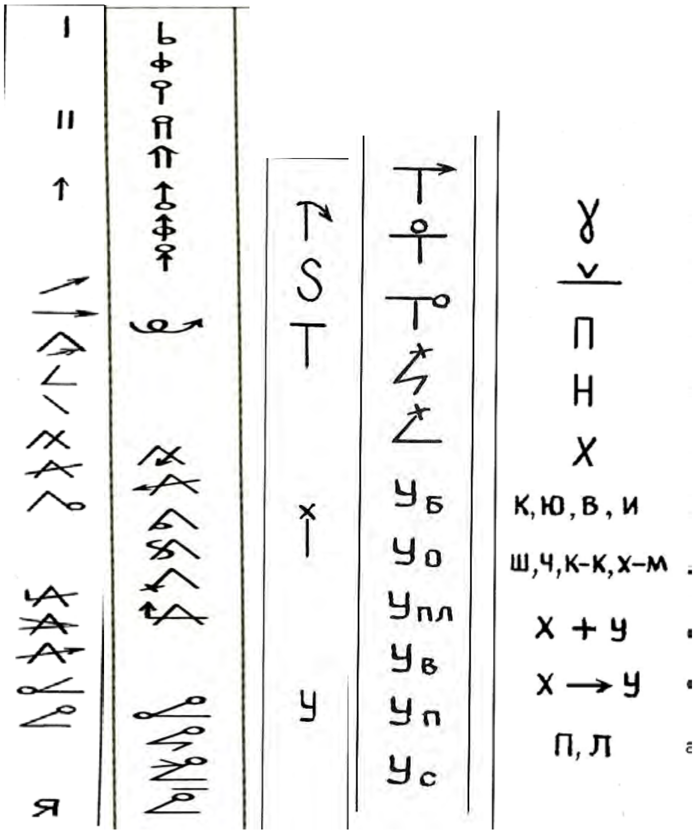


Fig.9.b, The meanings of these symbols are the following: up to down from left to right, respectively

Throws with grips to one leg, Throws with grips to two legs, Overturn from the knees, Fore sweep, Side sweep, Internal heel sweep, Fore trip, Back trip, Internal cross-buttock, Cross-buttock to two legs, External hook foot, Leg lever, Legs scissor, Interior leg blow, Hip throw, back throw, Throw over the back, Throw with heel grip, Throw with lower leg grip, Throw with upper leg grip, Throw with two legs grip(dragging down), Throw with two legs grip(lifting up), Front overturn, Side overturn, Back overturn, Sweep on adversary's pace, Internal cross-buttock with fall down, Cross-buttock to two legs with fall down, Internal hook leg to the opposite leg, Internal hook leg to the same leg, Backward thigh blow, Cross-buttock with neck grip, Kneeling throw over the back, Throw over the back with two arms grips, Throw over the back with inverse grip, Dragging down, Throw with jerk by torque, Froward sacrifice throw, Over shoulders throw, Hold, Side sacrifice throw, Sacrific- throw with belt grip over the back, Sacrifice-throw with locked arm, Kneeling throw over the shoulders, Sitting throw over the shoulders, Side hold, Head hold, Shoulder hold, Transversal hold, Hold with back, Choking, Arm lock, Overturn on the mat, Covering, Exit from groundwork technique, Koka yuko wazaari ippon, Shido chui keikoku hansoku make, technical combination x y, from the technique x counter y, on the right on the left.

The first Match Analysis advanced utilizations were simply the same data sheets treated by more robust statistical methods starting the computer age.
From year to year, in connection with the advance in technology: like tiny and portable high-speed digital camera recording, at first with the only slow motion, now equipped with specific analysis software, with the tremendous increase in power and flexibility of hardware and software, Match Analysis, today, is performed automatically using special data mining algorithm or, more sophisticated systems that singles out tactical or strategic actions from the fights recorded.
The most sophisticated software is based on the HHMM (Hidden Hierarchical Markov's Models).
However, generally until today, in the judo world, match analysis, considered motion analysis, was a powerful tool to gather data for scientific studies, mainly statistical or biomechanical ones.

Many studies result analyzed in this book are derived from match analysis in the meaning of motion analysis.
Motion analysis or better motion capture is recording 3D motion data from a human Athlete for analysis or playback. An optical motion capture system consists of infrared cameras that trace reflective markers on the subject in real-time.
The collective data from a group of cameras are then used to reconstruct the 3D poses of the subject Generally, among the most utilized systems by the university, there is the Vicon system

Fig.9.c.d, Infrared camera for motion analysis and markers on the subject

Today, the collective knowledge of biomechanics and robotics still falls short of presenting a satisfactory model that captures the full range of human movements like fighting activities are undertaken. Therefore, these works draw scientific insights from a collection of domain knowledge and strive to discover guiding principles towards a generative model of athletes technical motion as throws, hold, armlock, etc.
Much of human judo motion complexity can be modelled by biomechanical principles and Newtonian physics, less than for the whole Couple of Athletes motion on the mat (see Appendix I).
From one other way, these systems are utilized to obtain instrumental data for a coach, like real-time feedback of particular action, or a unique database on the technical skill of his athletes or about the adversaries; with a more defined capability to find matter for improvement both technical and strategic.
For Coaches, in general, it is possible to utilize the Match Analysis systems in five different valuable areas:

1. **First, Physiological area**: To obtain physiological data about the energy consumption in competition to specialize ever better conditioning methods for competition, develop personalized nutrition plans, and take care of athletes' safety.
2. **Second Technical area**; to obtain data for Technical Biomechanical improvement and Competition Invariants.
3. **Third Strategic area**: to obtain data about Local and Whole Fight Strategies.
4. **Fourth Scouting area**: to obtain data and technical information on the adversaries,
5. **Fifth Forecast area**: to try to build some forecast on the fighting outcome.

In general, performance is skill-connected, but situation sports must be considered interactive processes between two opponents (dual or team).
The behaviour in dual situation Sports like Judo depends on athletes' skill level, from the changing situations, and from random events that can happen during the fight.
A correct Biomechanical model of Judo fight must describe both the interaction between athletes (throwing or control techniques see Chapter 5 and 6) and the dynamic evolution on the mat (motion equation see Appendix I and III).

The two Physical-Biomechanical principles of Throwing Techniques (Chapter 5) were single out from the static position of the athletes. But, because the motion on the mat is pseudo-uniform, it is possible to apply the Galilean Relativity Principle to the competitive action. This means that the same principle is valid, also in motion during competition.
Match Analysis is strictly based on video analysis both in real-time and offline. In many teams, real-time match analysis is performed with a fruitful application. See Volley, Hockey, Football, some Soccer teams, and so on. However, in fighting sports, till now, the only offline application has been utilized. That depends on the “short” fighting time. The real-time video record is only “mental” made by the coach at the Tatami border.
Perhaps, the next time will be possible to develop real-time match analysis with the match analyst help, supporting the coach in judo competition.
Team-Sports Match-Analysis software utilizes many advanced mathematical instruments for offline database evaluation, from Data Mining algorithms to the Hierarchical Hidden Markov Models algorithms. This software can single out automatically hidden strategies from the thousands of images stored in a database.
For the Judo fights, these algorithms must be concentrated on specific particulars of the images, like grips, competitive invariants, the direction of the technique application, or particular techniques linked together.
Let's ask about advanced mathematical methods. Judo fight must be included in the theory of complex adaptive systems. Such systems are made by ***interactive agents*** (the Athletes) ***who*** continuously ***fit themselves to the changing situation*** (Strategy and Tactics) ***like his perception of the environment change*** (Adversary Athlete Action).
Usually, dual situation sports must be analysed, biomechanically speaking, studying both motion and interaction.
Match Analysis can be able to give helpful information’s about these specific fight aspects.
The previous competition definition accounts for us, which is impossible to use Newtonian physics to study such complex systems, like a fight.
To do that, we need more advanced technologies and more advanced Biomechanical and Physical methodologies.
We single out, Statistical Mechanics, Games Theory, Stochastic System Analysis, and Chaos Theory.
The advanced Biomechanical study of dual situation sports can give us a unified vision of such sports linked together by the motion class.
The Brownian class of motion (see Appendix I, II and III), in every application like classic, active, fractional and so on.
The differences must be found in the interaction phase, which is different in each sport.
This chapter will deepen the most critical aspect of match analysis for coaches. The present primary use worldwide applied the adversaries scouting.

9.1 Physiological Area: Input for Conditioning, Nutrition and Safety

The first goal of the match analysis is to obtain from the motion analysis data to evaluate the ***relative energy system contribution*** during judo fight.
More fitted conditioning programs will be individualized for each athlete through this approach, prescribing the ideal duration and intensity of conditioning judo activity.
The second utilization of these data is connected to ***the proper nutrition diet.*** *It must activate different energy sources (rightly restored by a correct diet) in the Athlete's body to perform an excellent high-level performance*.
If we obtain a high-level performance, we must condition the energy sources more activated during the competition.
The goal is to warrant the proper energy contribution during the performance.
In the Area of Physiological data, the quantitative Match analysis, well-performed, could help in three primary way

a. Gross evaluation of the more precise energy cost as input for conditioning
b. Control of conditioning development and effectiveness
c. Accident prevention

Usually, energy cost could be connected to the time structure of the contest.
Several researchers evaluated this field, and the most important results are shown in the following table.

Authors	Activity (s)	Pause (s)
Castarlenas and Planas (1997)	18 ∓ 9	12 ∓4
Monteiro (1995)		
1st min	25.8 ∓ 7.8	9.5 ∓ 3.2
2nd min	27.0 ∓9.0	10.4 ∓4.5
3rd min	27.0 ∓ 9.7	13.4 ∓ 7.6
4th min	22.4 ∓9.3	13.2 ∓7.3
5th min	18.9∓ 10.4	13.9∓ 9.0
Sikorski et al. (1987)	30	13
Sterkowicz and Maslej (1998)	25	10
Van Malderen et al. (2006)		
Female	19.9 ± 7.3	7.5 ± 6.2
Male	18.8 ± 9.0	9.1 ± 5.1

Tab.9.1.a time activity in fights

Although studies on the physiological demands of judo have previously been performed, Degoutte et al. found some new perspectives. First, they evaluated the energy requirements during a judo match and not in a laboratory. or special exercises.
The nutritional approach performed the evaluation. They show that a judo match induces both protein and lipid metabolism even if the anaerobic system is brought into action, with mean plasma lactate levels of 12.3 mmol/l.

The meaning of these results was that glycogen in the muscle was not the only substrate used during a judo match.

Several factors such as carbohydrate availability, training adaptation, and metabolic stress must be accountable for using these substrates. In the following figure, it is possible to see one example of first level results of Match Analysis applied to the phenomenal champion Teddy Riner from France.

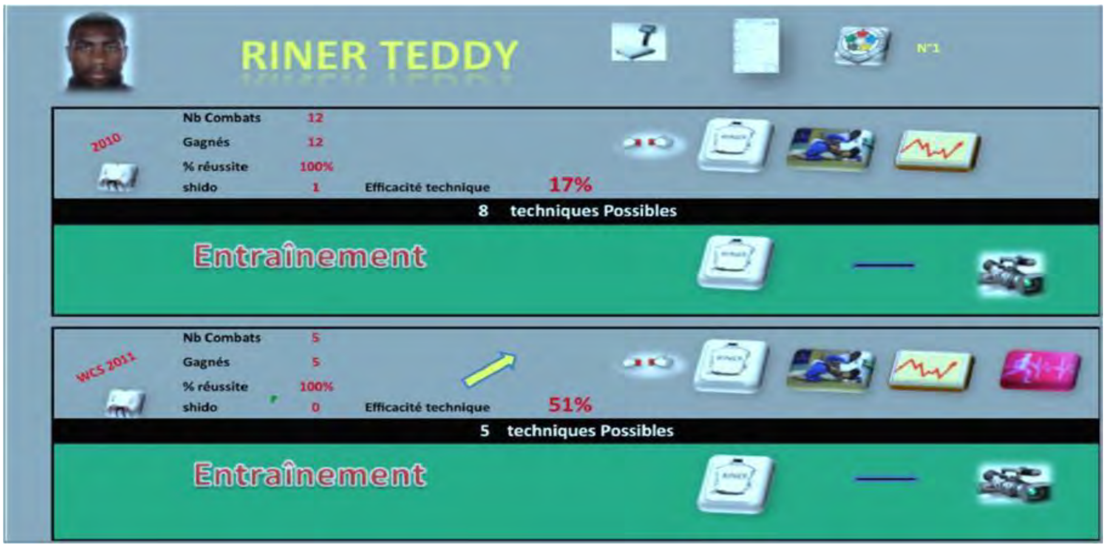


Fig 9.1.a Results of first level Match Analysis in the Judo French Federation

In general, for judo, the essential energy source is the anaerobic system, which means to mobilize many times, the sufficient energy for strong and fast contractions in short times.
This kind of energetic source is well known ATP and CP.
In addition, during the fight, for the athlete is also necessary to realize powerful contractions based on other sources, glycogen depletion with a simultaneous increase in lactate.
Aerobic metabolism affects a different aspect of performance.
It affects the better economy of muscular contraction in the fight, the fast catabolises and the fast rebuilding of performance capability during fight and rest.
It is interesting to consider that more work for conditioning purposes is today performed by weightlifting programs. This is a speedier conditioning system, but often because these programs, taken by other noncomplex cyclic Sports, fall in the linearization limit of the classical conditioning.
Perhaps, at a high level, it will be more time consuming but more effective from a nonlinear conditioning point of view to use varied and suitable judo activity like the old Japanese Dojo, with modern ergometers.
I agree with the beautiful book of Mr Pulkkinen that physiological data and energy cost taken by free wrestling style fights could be similar to judo, but only in first approximation, and those data can be used only in lack of judo data, because at a deeper biomechanical analysis the dynamics of judo competition, in term of a couple of athletes' motion and interaction, is different
Usually, it is a challenging problem to take a valuable measurement of physiological parameters during competition; because it is not possible to take blood samples during an official fight, but only before and after the competition.
The first difficulty arises from the great variety of very different physiological indicators connected to the Human body complex system.
Other difficulties arise from the nonlinearity of the human body responses. It should be considered the property of this complexity, many internal body structures and processes that interact non-linearly with each other—the possible rise of different functions and often unexpected behaviours.
The third difficulty is the basic linear approach that, as an underlined assumption, is connected till now to the physiological indicators. In a word, it is complicated to connect, unambiguously, the linear physiological parameters to the "real state" of the nonlinear human body.
The best approach for Elite Athletes could probably be to have for each athlete a database with relative energy consumption both on personal throwing and on specific groundwork taken in similar fight

conditions. These data could be used as referring data (low limit value) for extrapolating medium energy consumption for each real fight, for example, only summing the number of different judo actions performed in it. It must be added and considered for a better evaluation: the mean displacement speed of a couple of athletes (motion), each single attack velocity (interaction), and the stops during the fight.

All that could be evaluated by digital data obtained by the fight video (for considering physical parameters like speed in terms of oxygen, it is possibly referring to appendix I, and for the attack cost to the Franchini approximation, see ***Energy Cost*** in 5.2.1) for the mean defensive cost, there are very few works related, one of the most complete is the old work of Y. Matsumoto, Takeuchi and Nakamura, ***"Analytical studies on the contest performed at the All Japan Judo Championship Tournament"*** 1978 in which we can find a kind of Nage waza defence classification as shown :

Nage Waza Defence 831 contests		
Defence by using bodyweight	***Defence by deft bodily movements***	***Defence by complying with the Nage waza***
523 62.9%	181 21.8%	127 15.3%

Tab.9.1.a. defences applied in Nage Waza (Matsumoto & c.)

In terms of Oxygen consumption, little data can be collected on this argument. Perhaps the most indicative one is the old data from Matsumoto (see Table 5.4.a, 5.4.c, 5.4.d *energy cost*)
The author proposed the following equation in (Sacripanti, Amedov 2021)

$$\overline{E(O_2)} \approx \sum_{i,k}(A_i^{O_2} + A_k^{O_2}) + \sum_i D_i^{O_2} + \sum_n G_n^{O_2} + \sum_m L_m^{O_2} - \sum_s \frac{t_s}{\tau} RMR$$

$A_i^{O_2}$ = *Tachi Waza attacks with Lever Throws as* O_2 = *lever Throws can have two possible work solutions connected to the execution way:*

1) *with lifting, work as* O_2 *is* = $(F_L + \frac{1}{2} mg)\, v_L t_L$

2) *without lifting, work as* O_2 *is* = $F_L\, v_L t_L$

$A_k^{O_2}$ = *Tachi Waza attacks with Couple Throws as* $O_2 = F_c v_c t_c$
F_L= *Force applied for lever*
$\frac{1}{2}mg$= *adversary weight*
v_L= *Lever attack velocity*
t_L =*Lever throw execution time*
F_C= *Force applied for couple*
v_c= *Couple attack velocity*
t_c =Couple at time
$D_i^{O_2}$= *Defensive Work as* O_2 *both for Tachi Waza and Ne Waza*
$G_n^{O_2}$= *Ground Work as* O_2
$L_m^{O_2}$ = *Locomotion Work as* $O_2 = \mu\, v_L^2 t_L$
μ = *Friction Coefficient*
v_L^2 = *Locomotion Velocity Squared*
t_L = *Locomotion Time*
RMR = *Rest Metabolic Rate as* O_2
t_s = *Stop Time*
τ = *Regular Combat Time*

Usually, the metabolic data for situations Sports like Judo is taken either from literature or indirect evaluation. However, advanced technologies could be able to take direct data on mean metabolic consumption in competition. Following up, we show some results of the works performed by the Author in connection to Prof. Dal Monte and Dr Faina from the Italian Olympic Committee in the far 1990 at CONI School of Sports. For the first time, this work was utilized a thermo-camera by which it was possible to obtain data on the warmer muscles after a performance, with the precision of 0.1 C°. Furthermore, during these analyses were tested for the first time a connection with the oxygen consumption by a specific equation built by the Author. In the next there are shown:

Thermograms of a judo technique: Koshi Guruma. The equation
utilized. The results in terms of Energy evolution in time diagrams.

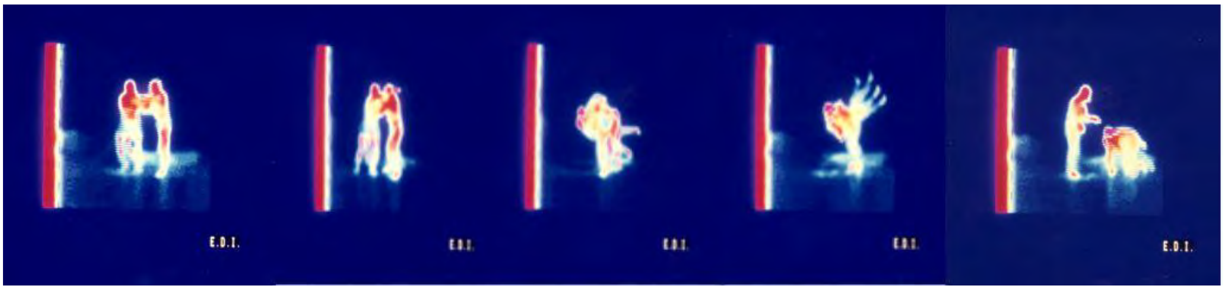


Fig 9.1.a Thermograms of Koshi Guruma 1990

$$S\sigma\varepsilon\left(\frac{T_s^4-T_a^4}{t-t_0}\right)+0.6n\frac{kS\,\mathrm{Re}^{0.8}\,\mathrm{Pr}^{0.33}}{l}\frac{T_i-T_a}{t-t_0}+\left\{e^{-\frac{4S}{lh}\frac{T_s-T_b}{T_b-T_a}}\right\}$$

$$\left\{\left[0.132\varepsilon_h\frac{4S^2k\,\mathrm{Re}^{0.8}\,\mathrm{Pr}^{0.33}}{hl^2}\frac{(T_s-T_a)^{1.2}}{T_a^{0.2}(t-t_0)}\right]+\left[0.16(1-\varepsilon_h)\frac{4S^2D\lambda\,\mathrm{Re}^{0.8}\,Sc^{0.33}}{Rl^2h}\left(\frac{M_se_s}{T_s}-\frac{M_ae_a}{T_a}\right)\frac{(T_{vs}-T_{va})^{1.2}}{T_{va}^{0.2}(t-t_0)}\right]\right\}$$

$$\left\{e^{-(0.2\varepsilon^2+0.5\varepsilon-0.7)\frac{\lambda P-\sum}{\lambda P}}-1\right\}=\frac{\partial O_2}{\partial t}$$

(Sacripanti Equation)

S= Athlete's body surface
T_s = mean skin surface temperature
T_a = mean environment temperature
σ = Stefan-Boltzmann constant
ε = skin emissivity
k = thermal conductivity of air
S_p = lungs effective surface
Re = Reynolds number.
Pr = Prandtl number
$M_{s,a}$=water vapour mass
R= gas constant

l = thoracic dimension of athlete
h=athlete height
P= Athlete weight
Sc= Sherwood number
D=molecular diffusivity in air
λ=latent heat of vaporization
e_s= skin water vapour partial pressure
e_a= environment water vapour partial pressure

$T_{va,vs}$= virtual temperature of skin and environment

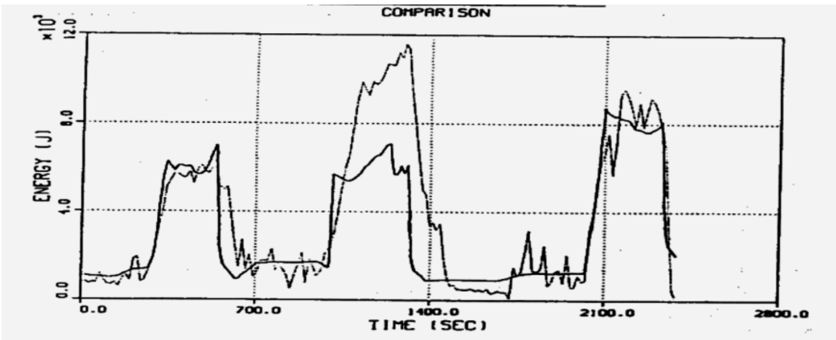


Fig.9.1.b Energy consumption recovered by thermal emission (Sacripanti)

On the evidence that energy source is oxygen, during the last time physiologists try to train athlete's respiratory systems by means of so-called **Inspiratory training.**
Inspiratory training involves resisted breath training to increase the strength, efficiency and fatigue resistance of the diaphragm.
Respiratory muscles can fatigue during exercise, and respiratory muscle fatigue can impair exercise performance through several mechanisms such as increased dyspnea and enhanced peripheral muscle fatigue.
It works by reducing the effects of the so-called metabolic-reflex (a phenomenon where the body actively reduces blood flow to the working muscles when the respiratory muscles fatigue).
In the last time applied to more simple and cyclic sports seems that respiratory muscle training increasing respiratory muscle strength and function enhances exercise performance.
It's beneficial for several cyclic sports (running, cycling, swimming, etc.)
Research suggests that training should involve 30 breaths at 50% MIP (maximal Inspiratory pressure), completed twice daily. When using as a warm-up routine, aim for 30 breaths at 40% MIP as either one or two sets.
Researchers have found benefits following 4-6 weeks of training. However, data about complex judo are contradictory. In fact, Krauspenhar Merola and his coworkers 2019 concluded his work that way. In conclusion, we found that high load IMW combined with specific judo warm-ups did not improve judo performance in elite judo athletes. But Carolina Cirino and coworkers 2021 affirms: in summary, our study suggests the use of IMPA (40) (inspiratory muscles pre-activation) as a safe, legal, and non-invasive resource that plays a positive role in the judo match.
Based on the integrative analysis by complex network model, IM PA (40) increased connectivity and the influence of physical and technical-tactical parameters and highlighted the important combat nodes to support performance in judo.
According to the centrality metrics, IMPA(15) stimulates interactions among psychophysiological, physical, and physiological parameters. These results confirm the positive effect of the IMPA in the judo modality, pointing out this strategy to prepare the organism (IMPA15) and to improve performance (IMPA40) in a judo match.
However, these presented are two pioneering studies on the argument then, as good choice, time and further studies will give us the right answer.

Athletes'Safety

Thermo-graphic data are also helpful for athletes safety. (See Appendices V-VI).

Generally speaking, high local muscles' superficial temperature at rest is indicative, for example, of subcutaneous bloodshed. In that case, it could be a preventive indicator of some trouble in the muscle fibres. Considering similar indicative data, it is possible to prevent more dangerous damage to the athlete's muscle structure. In the next figure, it is possible to see the thermal answer produced by posterior cruciate strain damage. It is the potential damage due to the wrong execution of Suwari Seoi (or drop seoi). See App. VI.

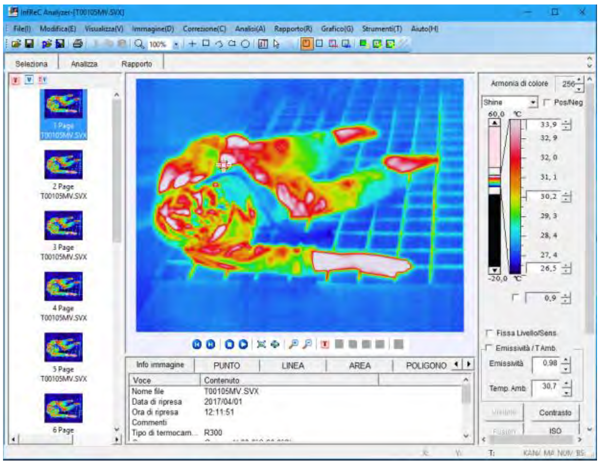


Fig.9.1.c Thermogram of Children Ukemi (see App.V)

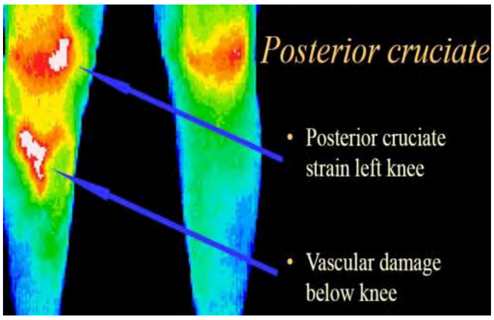


Fig.9.1.d Thermal indication of a posterior cruciate strain. (see App.VI)

9.2 Technical Area: Input for Biomechanical Optimization

Static (Minimum of Energy), Dynamics (Maximum Effectiveness)

Other essential data could be singled out from the video, first, about the biomechanical quality of athlete's techniques and second statistics and frequency that can be useful for a coach to evaluate the performance capability with some "ad hoc" indexes.
Other unique indexes can be found in the fight's structure. Some special situations more frequently happened, which we call for a convention "Fight Invariants" and "Competitive Invariants".
These special situations must be studied and repeated during the specific post-fight technical training. The athletes should utilize these repetitions for learning the better way of governing such cases (interaction) that are the most critical part of the competition. The analysis of the relative body's position that very often occur during the fights are essential.

A) Biomechanical Improvement and Action Invariants

With the slow-motion of the fight, the athlete's technical preparation can be understood and to take data for his technological improvement. This aspect of Judo Match Analysis is a worldwide part of today specialised training and improvement. The biomechanical problem of the technical progress in Judo is not only a problem of the athlete technical capability but more often of the specific positional situation produced by the adversary in the coupling system. The correct biomechanical approach considers a couple of athletes as a whole system is a stable equilibrium in which the transition phase Kuzushi Tsukuri depends strongly on the adversary position and action. It is interesting to remember that at this moment, the Nain classes singled out in Japanese judo to define the right Tori action utilized to overcome the defensive standing of Uke.

1. ***Tobi Komi (jumping in)***
2. ***Mawarikomi (spinning in)***
3. ***Hikidashi (pulling out)***
4. ***Oikomi (dashing in)***
5. ***Daki (to hug holding)***
6. ***Debana (Thwarting the opponent)***
7. ***Nidan Biki (two-stage pull)***
8. ***Ashimoki (leg grab)***
9. ***Sutemi (body drop)***

All these biomechanical actions are suitable to improve the Kuzushi -Tsukuri phase in actual competitive positioning. But today, with the growth of scientific studies in the world, these old (already practical qualitative approaches) are ousted from the very updated analysis. Instead, they utilise advanced technologies like "Biogesta saga 3D or Vicon system". With these methods, they study kinetics and kinematics of techniques and single out the "***Action Invariants***" relative to each technique to apply a very effective Kuzushi Tsukuri phase. ***Action invariants are similar movements that are possible to find every time in the Throw's Kuzushi-Tsukuri phase***. There we show exciting results obtained by a French Study on Ippon Seoi Nage. Similar results could be extrapolated from every Judo throw.

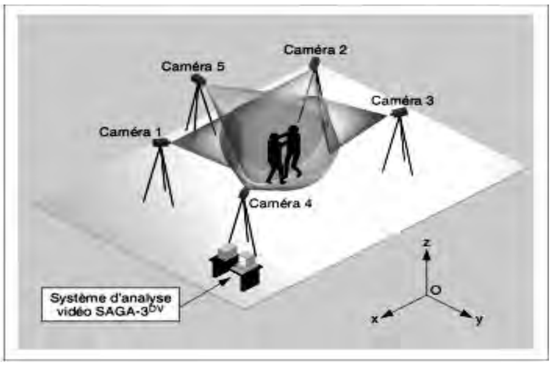


Fig.9.2.a Biogesta –Saga *3D system*

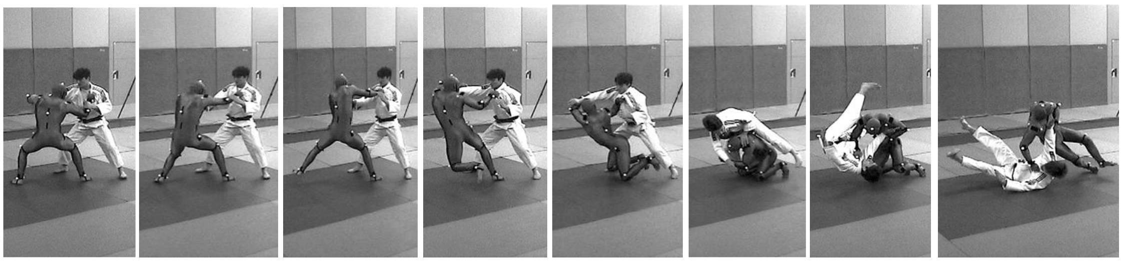
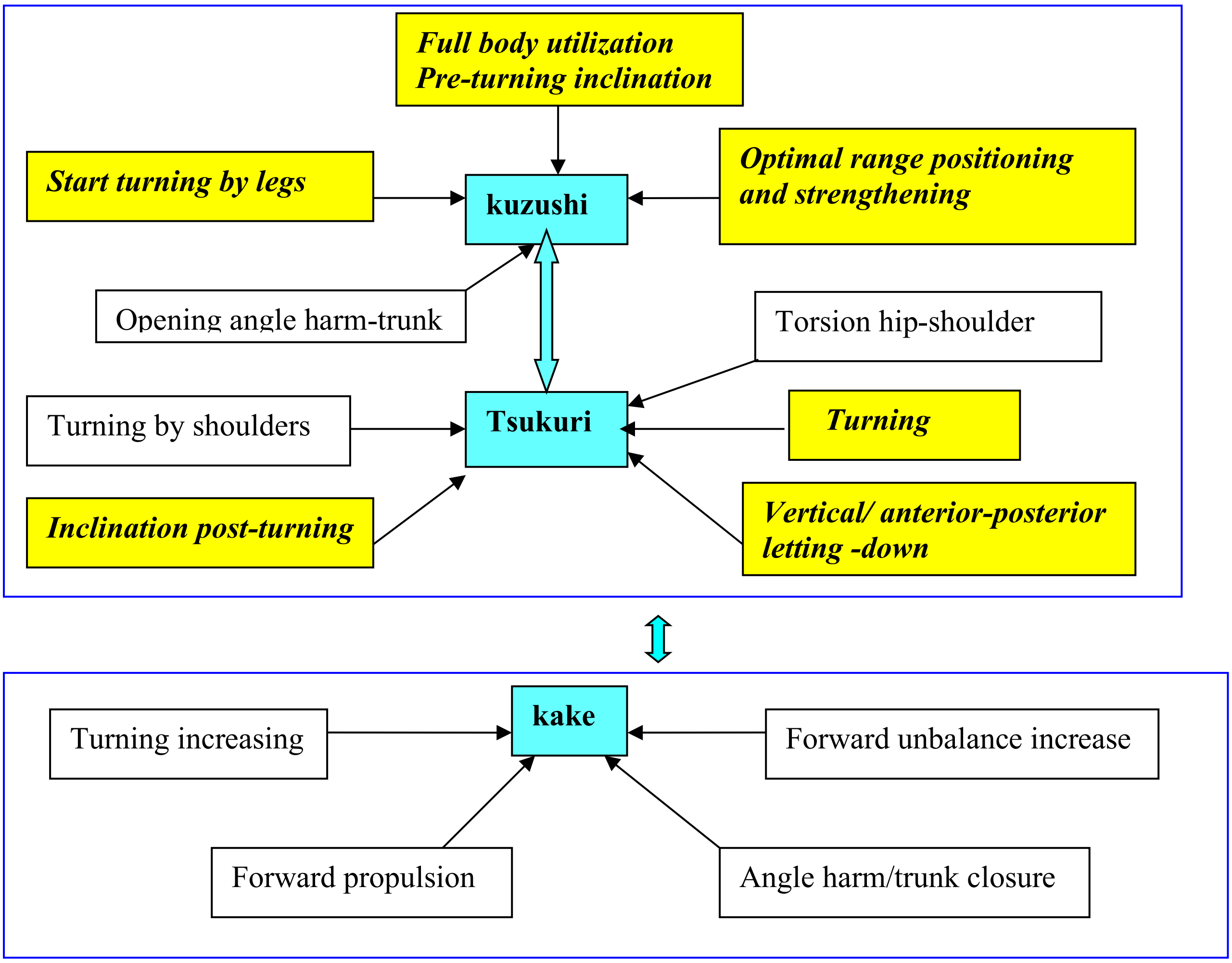


Fig.9.2.b Advanced biomechanical researches onSuwari Seoi by Saga system (Poitiers Fr.)



Diag.9.2.a Suwari Seoi "Action Invariants" identified by mechanical analysis

from: Blaise & Trilles Comparative mechanical analysis of the same judo throwing: Seoi Nage, realized by five experts of the Judo French Federation - Science & Motricité n° 51 —49-68 -2004/1

Interestingly, these Actions Invariants should be traced back to the Hamilton –Lagrange Equation and the Hamilton Action principle in advanced biomechanics.

$$S(q,t) = \int L(q,\dot{q},t)dt$$

With S = the Action; and L= the Lagrangian of the system.

If we consider in a first approximation constant the external energy of the system (gravitational field), it is possible to write:

$$S(q,t) = W(q) - Et = L(q,\dot{q})$$

$$\delta S(q,t) = \delta \int_{t_1}^{t_2} L(q,\dot{q})dt = \delta \int_{t_1}^{t_2} \left[\frac{\partial L}{\partial q} - \frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}} \right) \right] \delta q dt = 0 \Rightarrow$$

$$\frac{\partial L}{\partial q} - \frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}} \right) = 0$$

if the system is not conservative, we must write:

$$\frac{\partial E}{\partial q} - \frac{d}{dt}\left(\frac{\partial E}{\partial \dot{q}} \right) + Q = 0$$

According to Hamilton's principle, the true evolution of S(q,t) is an evolution for which the action is stationary (a minimum, maximum, or a saddle point).
Usually, in Judo Action, it is asked for the minimum; then, this is called the minimum action principle. In Judo terms, the Action Invariants should be recognized as the minimum path, in time, of the body's shift to acquire the best Tsukuri-Kuzhshi position for every Judo Throws.
This is possible in a conservative field. However, let's consider a non-conservative field. Then, it is necessary to consider for the global balance the heat Q emitted. In this situation, it is not possible to find a minimum of the action.
Then in the case where it is possible to find a minimum, the two following biomechanical principles are true:

a) ***Best is the Judo Technique, and the minimum is the Athletes' energy consumption.***

b) ***Best is the Judo Technique; the minimum is the Athletes' motion path.***

Today's current second level of match analysis tends to deeper study the most critical competitive aspect of throwing: the Tsukuri-Kuzushi phase.
Many studies have been developed in the world to understand the best way to achieve a better relative position inside a couple of athlete's systems; there are to remember, for example:
Analysis of Different Tsurite Movements of Elite Judo Competitors in the 2005 bulletin for the association for the scientific study on judo of the Kodokan; from Akitoshi Sogabe (Konan University) and others, **The Biomechanics of Loss of Balance in Olympic Sport Judo, possibilities of measurement of biomechanical parameters** by Nowoiski of the Olympic Centre in Hanover Germany 2005, or **A Biomechanical Investigation of kuzushi of O Soto Gari in Kano Cup international competition** from Komata, and co-workers 2005 **or Kuzushi and Tsukuri and the Theory of Reaction Resistance** from Rodney. Imamura (California State University Sacramento) and Iteya in the Kodokan bulletin 2007. From the biomechanical point of view, it is easy to understand that the problem is to shorten the relative distance between the Athletes into the coupling system (see also Weer analysis in the previous chapter 7). Therefore, it is essential to perform a very effective Kake phase.
Then in Gym, match analysis can be helpful for ***Teaching Lessons – in Static Situation – with Minimum Energy Consumption Optimization***
The most feasible approach is to analyze first the Couple of Athletes System in a static situation for optimization. This means still Athletes and shifting velocity of Couple zero.
In the Static Fixed Situation of the Gym (Dojo), Coaches analyze Judo Interaction (throws, old-down, joint-break, and choking).

Biomechanics allows us to optimize the Minimization of Energy expenditure (as indicated by Kano). As a result, also Osaekomi waza (hold down), Kansetzu Waza (Joint break), Shime Waza (choking) are performed, in accord with physics laws, with less energy consumption.
Biomechanics views classical throws in only two classes:

1. Lever System More Energetically expensive
2. Couple System Less Energetically expensive

The static action of throwing techniques goes through some specific phases: Unbalance, Positioning and Throw, or in Japanese tradition (Kuzhushi, Tsukuri, Kake) -
In the Lever group, Uke's Center of Mass (COM) shifts in space and throws are gravity and friction dependent, are more expensive and ***Not Fully Optimized***.
They can be further optimized by *changing the length at the arm of the lever.*
For example, from standing Seoi [Ippon Seoi Nage] to Kneeling Seoi [Seoi Otoshi], to Drop Seoi [Suwari Seoi], or from Hiza Guruma to Sasae Tsurikomi Ashi.
In the Couple Group, Uke's Center of Mass (COM), if both forces are applied simultaneously, turns around himself. Thus, in this hypothetical situation, all these throws are gravity independent, less expensive and ***Fully Optimized.***

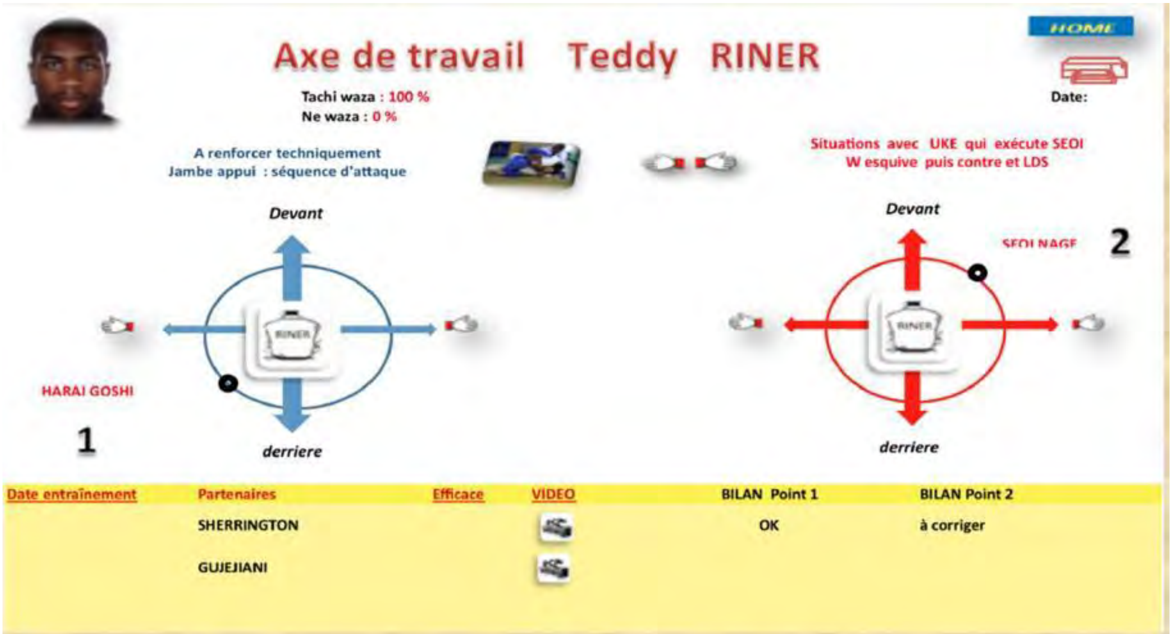


Fig 9.2.c Results of second-level Match Analysis in the Judo French Federation

A) Competitive Invariants

The basis of the Match Analysis is the statistical approach to competition data
The second important aspect singled out by Weer and other coaches was the grip skill study.
Classically, it is sufficient to see hands position and power applied to the adversary' body
But there is another subtler aspect of the fight, singled out in the first edition of this book. However, practically, this has been passed over in silence.
Let's think more profound, the motion on the mat. It results from many pushes and pulls applied by the grips, but it is impossible to use a push or pull without contact to the mat by the feet.
Thinks, for example, to apply the same push-pull forces in the coupling system, wearing roller-skates, then obviously it will be impossible to use anything!
Now, after that, it is understandable the meaning of the so-called "*Biomechanics Grips Paradox*".

What is the essential aspect of Grips (Kumi Kata)?
Feet Position is the Grips most crucial aspect!
How. Arms position is essential in defining the forces' directions to throw the adversary. However, without a solid support base, the arms position is unimportant.
This is the obvious kind of fight vision, not to see simply in a straightforward way: or the arms position, or the bodies' relative position, or the power applied to the adversary.
But the right way is to approach the system as a whole, seeing at the Couple of Athletes and not at the single athlete.
This is the right biomechanical vision, or in other words, the modern idea of the Judo competition.
From the strategic perspective, this other aspect came from the study that the coach typically performs during the competition. This perspective is discovered from the analysis of the whole system, "couple of athletes closed" (after grips stabilized).
If the competition is approached in this way, many interesting aspects of the adversary, both from the strategic and technical (throwing) point of view, are overlooked by the system analysis.
The ***Competitive Invariants*** singled out by the author are the so-called "Guard Position", which are the hold or grip positions that a couple of athletes closed system got during the fights. (see Biomechanical analysis of competition)
These positions could be classified based on two relative ranges: distance between the heads and the distance between feet in two main groups connected to the shifting velocity. Each group could be divided into three subclasses related from left to right to the shifting velocity of Couple increasing.

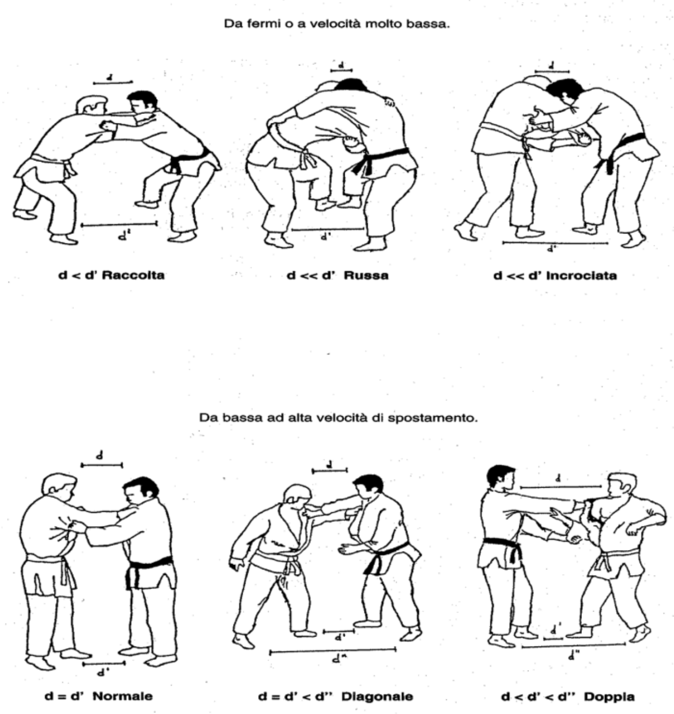


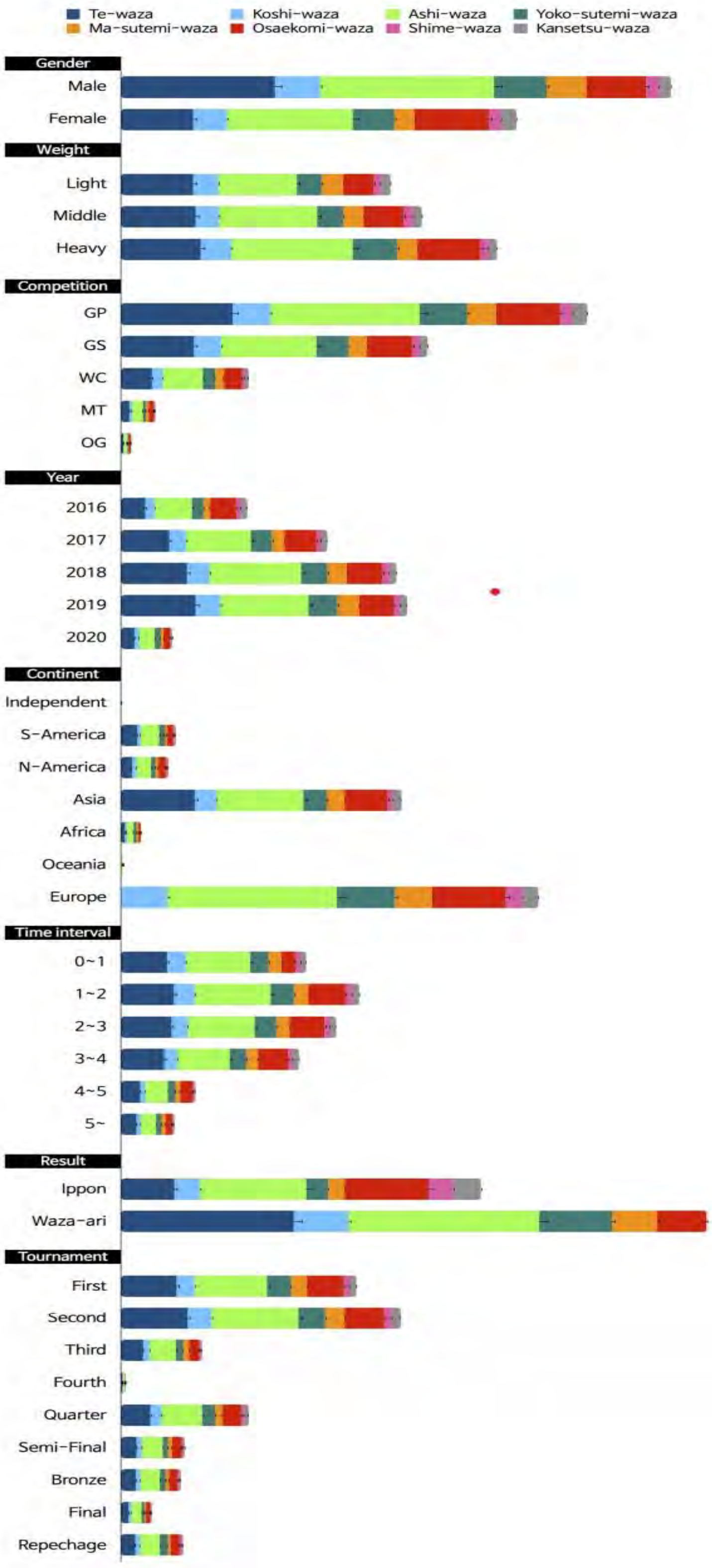
Fig.9.2.d, Six Classes of Guard Position (Competition Invariants) related to the couple shifting velocity. (Sacripanti)

These positions are strongly connected to each athlete's preferred fighting. In particular, the author founded six classes of "***Competitive Invariants***" related to the increasing couple speed. It is possible to collect all the infinite grip positions that a couple of athletes closed systems could build. Biomechanically speaking, each position is connected to the Tokui Waza that the Athlete likes to apply in such a motion situation.

Fig.9.2.e.f.g.h.i.j, The Six Classes of Guard Position related to the couple shifting velocity in real competition. (Finch, Zahonyi) Today the first three are allowed only for instant attack situations.

Then, suppose the coach sees the Guard Position (Competitive Invariant) and understands the adversary's pace motion. In that case, he can preview the biomechanical class of his preferred Tokui Waza. Remembering that the biomechanical classes are connected to the shifting speed (Chapter 3). It will be easier, for example, for the coach to recommend to his athlete to change the motion pace in such a way as to increase the difficulty for the adversary to apply the Kuzushi-Tzukuri phase connected both with his Tokui Waza and with the preferred speed. Or that it is easier to use techniques of couple of forces at high shifting speed than techniques of the physical lever.
Today with the fight evolution, elite athletes can change guard positions during the fight. The connection speed throws are always valid and valuable to contrast the pace motion changed.
Obviously, in such a situation, attempting the victory means connecting all this information in a whole fight approach. Actions Invariants, Competitive Invariants, Renraku Waza, Renzoku Waza, Kaeshi Waza, and various stances should be carried out under the most different situations every time more judoka fight in a similar way. They can be fully developed during training like Yaku Soku Geiko, or Sute Geiko, before attempting them in real competitions. Finally, at the end of this Athlete's way, the fight should be the actual proof of the completed technical training and the skill acquired.
The constant specialized Randori on the previous arguments builds a credible approach to real competition with a complete skill that will function favourably in contest application.
Then in a Competition situation, coaches must consider the ***Dynamic of the Systems-*** in such a situation coach must focalize his work and athlete activity not on the Energy Saving approach but on the ***Maximum Effectiveness Goal*** and consider ***Optimization*** also the utilization of throwing techniques not optimized as energy consumption. Suppose Coach analyzes this dynamic situation (competition) theoretically. In that case, Optimization is based on the ***objective function*** Minimization of Energy Expenditure is a necessary condition but not sufficient.
And it makes it appropriate to expand the Optimization goal with a broader ***objective function*** not simply connected to a minimum of energy but which also considers higher energy consumption in the process of ***Maximum Effectiveness***. Maximum Effectiveness is characterized by profound interconnected studies, including technical style, throwing techniques, times and other control parameters. One of these studies (Kim and Lee 2020), based on the match data of major judo world competitions in the last five years, identifies differences in general and technical characteristics according to scoring technique and scoring times. Exploring factors associated with the scoring technique is presented as a practical strategy that can be used to establish guided tactics. Were analysed all men and women who competed from 2016 to 2020. Differences in the characteristics of the world's leading athletes according to their preferred technique were indicated for a geographic area.
The results showed that the type of skill by ashi waza technique was the most common, according to other studies (Sacripanti 2019, Pereira Martins 2019, Sobarzo Soto 2020)

Athletes from the Asian continent appeared to have the longest technical time, which resulted from excellent physical strength, good endurance, and almost perfect techniques. By thorough study like this, it is possible to improve athlete's effectiveness in competition. In the next figure, we see the impressive global results.



Diag.9.2.b Technical Type characteristics, countries area, 2018-2020

Some very up to date results about all-male winners from 61 countries, in all Grand Slam- during 2021, show an interesting tendency.

Tot Contests	**3 Shido**	**Golden Score**	**Tot Throws**	**Lever**	**Couple**	**Most applied Lever**	**Most applied Couple**
841	**16,4%**	**19,4%**	**693**	**54,2%**	**45,8%**	**Suwari Seoi 23,1%**	**Uchi Mata 24.3%**

Tab 9.2.a Technical and Biomechanical Analysis of all GS 2021 (Sacripanti-Lascau) paper in progress

Time
In a first gross approximation, judo could be view as an intermittent sport, and time is the key to obtain information on the physiological needs of athletes (see 9.1 physiological area), but the structure time-motion can also be associated with the technical, strategical outcome of the contest, in this approximation, its connection with the technical application was studied by Dal Bello and coworkers 2019, and Sobarzo Soto and coworkers 2020, with the help of **FRAMI** software (see paragraph 9.4 Main Use of Judo Match Analysis Software: Adversary's scouting).
The first paper analysis for men and female athletes showed that in the high-level athletes from each weight division who qualified for the Olympic Games; competitions analyzed on the following motor actions: approach, gripping, attack, defence, groundwork and biomechanics of techniques, demonstrated significant differences between male and female.
In both following steps: pause frequencies and approach with displacements.
Female athletes used higher frequencies of techniques with different biomechanical levers for attacks (i.e. trunk leg lever attempts; waist lever variable attempts, waist lever variable effective and attempts, and malleolus lever effective and attempts), while men used more variations of gripping (i.e. left collar, left collar and sleeve, both collars, right sleeve, left sleeve and both sleeves).
In the second study performed to see the inter-differences among female weight, Competitions were analyzed following the phases: approach, gripping, defensive action, attack, also biomechanical analysis of techniques and groundwork.
Results indicated that lightweight athletes presented lower attempts to grip, right collar grip and left collar grip frequencies than other categories. Extra lightweight judokas presented lower right back grip and left-back and sleeve grip frequencies as well as the lower occurrence of techniques with arm and leg lever scored than half lightweight athletes, while half lightweight athletes demonstrated a higher frequency of techniques with waist lever variable scored than lightweight ones. These findings are interesting both for training prescription and Technical-Tactical evolution of the fight.

Biomechanical analysis of attempts and scored attacks in all female weight categories.

Attacks analysis	**EL**	**HL**	**L**	**HM**	**M**	**HH**	**H**
Arm lever	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)
Arm and leg lever	2(.0;4)	2(1;5)	2(1;6.5)	2(.0;5)	2(.0;6)	3(1;6)	1(.0;4)
Arm and leg lever with score	.1(.0;0.5)[b]	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)
Minimum lever	.0(.0;.0)	.0(.0;1)	.0(.0;.0)	.0(.0;010)	.0(.0;1)	.0(.0;1)	.0(.0;.0)
Trunk leg lever	1(.0;3)	1(.0;3)	1(.0;2)	1(.0;3)	1(.0;3.8)	1(.0;4)	.0(.0;2)
Trunk leg lever with score	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)
Waist lever variable	1(.0;3)	1(.0;3)	.0(.0;2)	1(.0;3)	1(.0;3)	1(.0;3)	1(.0;3)
Waist lever variable with score	.0(.0;.0)	.1(.0;0.5)[c]	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)
Maleolo lever	.0(.0;1)	.0(.0;1)	.0(.0;1)	.0(.0;2)[d]	.0(.0;1)	.0(.0;1)	.0(.0;1)
Maleolo lever with score	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)	.0(.0;.0)

Note:μ (1º;3º) – median (25º;75º percentiles). EL = Extra Lightweight; HL = Half Lightweight; L = Lightweight; HM = Half Middleweight; M = Middleweight; HH = Half Heavyweight; H = Heavyweight. [a] $p \leq .025$ for this weight category vs. half lightweight, half middleweight and middleweight; [b] $p = .016$ for this weight category vs. half lightweight; [c] $p = .021$ for this weight category vs. lightweight; [d] $p \leq .049$ for this weight category vs. half heavyweight and heavyweight.

Tab.9.2.b Biomechanical analysis of throws applied.

	Female	Male	Inferences		
	Med (Q1; Q3) (%)	Med (Q1; Q3) (%)	U	Sig.	ES
Biomechanical levers					
Arm and trunk/arm lever attempted	11.0 (5.0; 15.0)	33.3 (0.0; 57.1)	240600	0.186	0.04
Arm/foot lever attempted	0.0 (0.0; 0.0)	0.0 (0.0; 0.0)	231499	0.045	0.05
Arm/foot lever scored	23.1 (5.3; 70.2)	0.0 (0.0; 0.0)	239647	0.058	0.05
Minimal length attempted	0.0 (0.0; 0.0)	0.0 (0.0; 16.7)	246136	0.937	0.00
Trunk/leg lever	26.7 (0.0; 100.0)[a]	0.0 (0.0; 0.0)	194965	≤.001	0.19
Trunk/leg lever scored	26.7 (0.0; 100.0)	7.1 (0.0; 33.3)	240451	0.056	0.05
Variable/ medium length attempts	8.3 (0.0; 27.3)[a]	0.0 (0.0; 0.0)	214063	≤.001	0.12
Variable/ medium length scored	0.0 (0.0; 0.0)[a]	0.0 (0.0; 23.5)	238014	0.011	0.07
Maximal length	0.0 (0.0; 7.7)[a]	0.0 (0.0; 0.0)	231238	0.022	0.06
Maximal length scored	0.0 (0.0; 0.0)	0.0 (0.0; 0.0)	245330	0.68	0.01
Groundwork actions					
Defensive position on the ground	9.7 (0.0; 27.3)	5.0 (2.0; 9.0)	241085	.469	-0,02
Osae-waza	5.0 (2.0; 9.0)[a]	0.0 (0.0; 0.0)	232332	≤.001	-0,13
Kansetsu-waza	0.0 (0.0; 0.0)[a]	0.0 (0.0; 0.0)	242020	.02	-0,06
Shime-waza	0.0 (0.0; 0.0)[a]	0.0 (0.0; 0.0)	241710	.009	-0,07

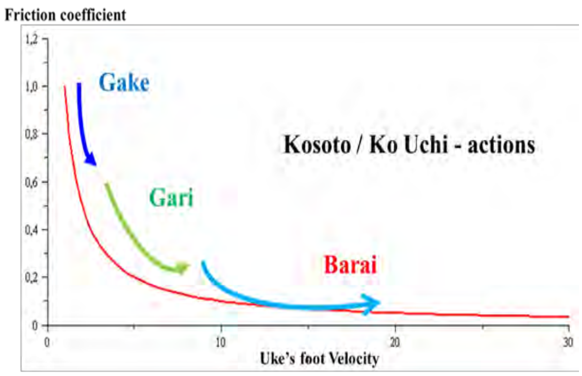
Note: Significant differences are in bold; variable and medium length attempts and arm arm/trunk lever attempts were grouped. [a] = significant differences from Male Group, $p \leq 0.05$. Sig. Significance.

Tab.9.2.c Descriptive and inferential results of the Biomechanics used during the Attack phase and groundwork actions by gender

9.3 Strategic Area: Input for Strategic Optimization

The third area in Match analysis is pointed to the Strategic Teaching associated with judo fight.
This is the most advanced and complex coaching level because the strategy is the last goal of teaching. It could be helpful to define clearly this concept.
Many know about the usefulness of the strategy. For example, in his book "The Art of War", the classic definition of Sun Zu: ***"People should not be unfamiliar with strategy, Those who understand it, will survive.***
Those who do not understand it will perish". But fewer people know that strategy was studied in a rigorous scientific way in the well-known textbook *Theory of Games and Economic Behaviour* by Von Noimann and Morgenstern.
As Von Noimann teaches; Strategy could be definite as: "***if a player begins to play with a complete plan: a plan which specifies what choices he will make in every possible situation, for every possible actual information which he may possess at that moment in conformity with the pattern of information which the rules of the game provide for him, for that case. We call such a plan, Strategy."*** Starting from this scientific definition that enables us to understand some factual aspect of strategy, we will give a more "sportive" definition of the strategy and connect the meaning of tactics very often misunderstood. Then we define **Strategy as** ***the plan*** *or the flexible connection of more plans* ***based on the coordination of physical efforts, harmonized with relative movement finalized to the fight for victory***. Instead, we define **Tactics** as ***the capability to utilize the transitory phase for success in the right way.***
Based on these definitions, it is possible to understand the significant difference between these two activities. A strategic plan can be studied and coached in advance. Then it is possible to connect it to the rational analysis of the fight. While tactical capability is essentially founded on instant intuition of technical action, it is impossible to teach it in any way (it is a unique skill gift of a Champion).
Now, let's consider the contribution of offline supports. They could contribute to the study and prepare strategies at two levels of difficulties: Local and Global.

A) "Local Strategies".
Local Strategies are based on studying particular situations that happen in small zones of the mat surface. As particular attack actions, more often connected on the solution multi exit (i.e. One attack movement able to diversify its outcome in different techniques connected to the reaction of Uke).
The more well-known example (**Central Attack**) is connected to the Ko waza. The techniques of families Ko Uchi, Ko Soto: Ko Uchi Gari, Ko Uchi Gake, Ko Uchi Barai, Kosoto Gari, Kosoto Gake, Kosoto Barai, Ni Dan Kosoto Gake, Ni Dan Kosoto Barai, they belong to the group of the Couple with the Couple applied by the arms and leg. They have the same mechanics. The only difference is that the forces used increase as the Couple is applied against increasing resistance, generated by the increased friction, between tatami and Uke's feet, due to its increasingly stable position



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Diag.9.2.a Evolution of Gake, Gari and Barai actions in function of friction

It is significant that new interpretative variants have been developed in techniques in which the actions of Gari and Gake are applied (more expensive, energetically speaking).
This is certainly due to the need to use greater force and to the fact that the new variants make the technique more flexible than the increased defensive capabilities internationally, such as some Japanese variants.
The action of Ko Uchi Gari, which is also based on the **Central Attack**, has not undergone major changes, which shows that its effectiveness is such that, even with the competitive evolution, it maintains its synthetic form, identified by the Kodokan. The interpretative phase often stops at a different application of holds. Another thing is the Korean interpretation of Ko Uchi Gari / Gake, which is performed through a **Central Attack,** a widespread of the legs and at a very low height. This position has changed the basic mechanics of the technique that from a Torque technique must necessarily change into one of the Lever with maximum arm, as the very large spread effectively prevents Tori from mowing the leg and changes the action into a simple block of the foot (fulcrum) followed by a powerful pushing action.

Fig.9.3.a Korean Version of Ko Uchi Gari

As already mentioned, the increasing use of straight GAI techniques, many of which are based on the aforementioned **Central Attack**, shows the already known tendency towards effective and energetically convenient simplification, which Athletes unconsciously operate in competitions.

Fig.9.3.b Ko Uchi Gari diagonal attack with hook foot

Other local strategies can be divided into three subclasses: Renzoku waza, Renraku waza, and Standard Strategies. The first two are surface independent but strongly technically dependent. The last one is surface dependent and technically less dependent.
The first two have already been extensively analyzed in chapter 3. However, only for revision, we speak a bit again about renzoku and renraku waza.
These technical, tactical complexes are studied from the old-time in Japanese Martial Arts.
Referring to judo, Renzoku and Renraku Waza are applied to study classical initiative (Sen) (see chapter 3). Both these studies are very advanced proprioceptive training built by the old Japanese experience. With the study of Renzoku and Renraku Waza, the Athlete eventually changes his open skill situation in a semi-open skill situation, develops his body's flexibility and open mind approach to the fight. Biomechanically speaking, Renzoku waza, defined as continuous techniques, are applied more often in the same attack direction. Typically it is possible to perform a Renzoku waza (Tachi waza-Tachi waza) attacking the opponent with one particular technique to effect it. The continued application of one technique, each attack connected by proper timing, is called Renzoku Waza, but also when The initial unsuccessful attack commits tori in a specific direction. He must continue in the same direction with another technique.
In the following figure, we can see Adams applying his special Renzoku Waza techniques: Ko Uchi Gari-Kuchiki Taoshi.

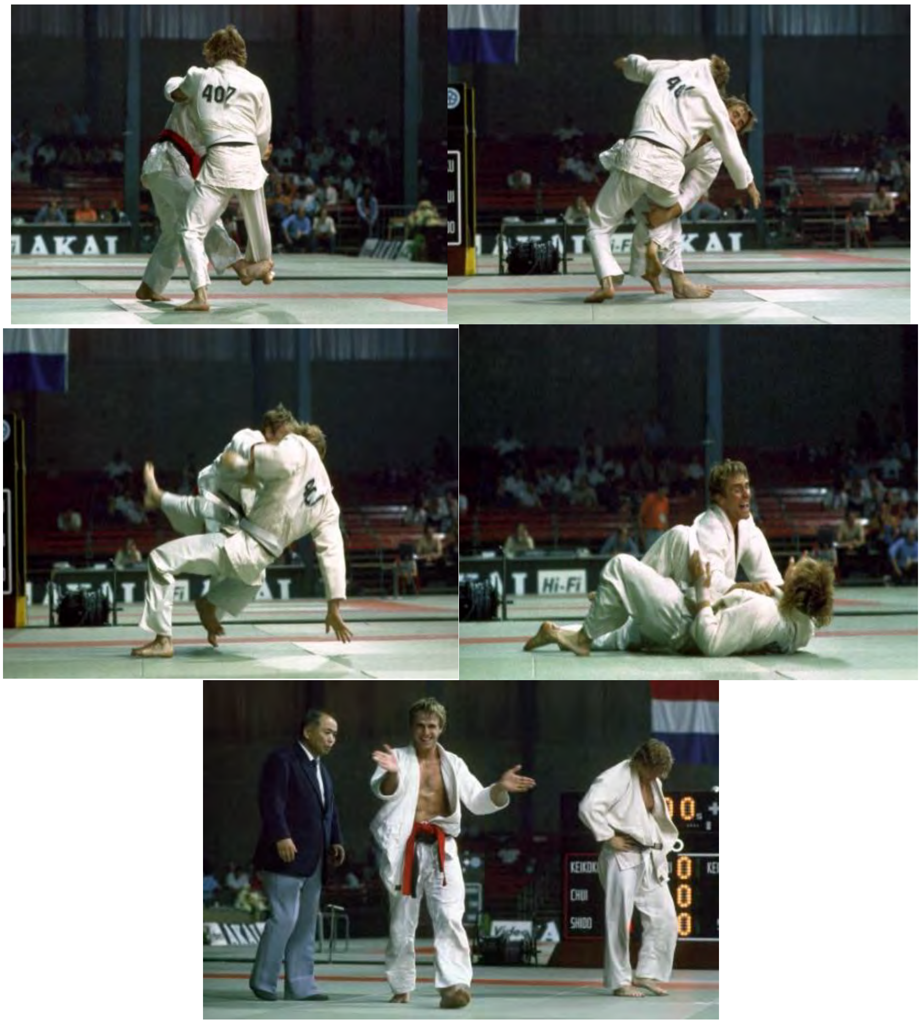


Fig.9.3.d .e.f.g.h, Renzoku Waza, applied by Adams against Doherty (Finch)

But also, the Uke’s physical and athletically capability is increased. Today in Elite competitions such as Olympics, World Championships, and Continental Championships, the fighting level is so improved that every athlete can carry out an all-out attack. The first type of Renzoku Waza (continuous attack) is every day more difficult to execute in actual competition. In the following figures, we can see a sparkling, dynamic Renzoku Uchi Mata-Sumi Otoshi by Inoue against Hubert (2003).

Fig.9.3.i.j.k.m.n.o , Renzoku applied by Inoue (Finch)

However, they are more challenging to apply in real competition, one last form of Renzoku as a continuous attack. Still, today is often used during high-level fights. In the following figure, we can see the special Ken Ken Uchi Mata form preferred by Yamashita. You can see the circular application of the same technique around 360° degrees to better balance the throwing position to overcome the Uke defensive reaction.

Fig.9.3.p.q.r.s.t.u.v.x, Renzoku applied by Yamashita (Finch)

This Renzoku movement is a common legacy in the Japanese fighting style. In the following figures, it is possible to see a variation on the theme (the rotation is applied without ken ken to help the sided throwing movement)

Fig.9.3.w y.z aa, Renzoku like movement Japanese's legacy (Zahonyi)

The other form of Renzoku is today more often applied in a real contest. The Athletes carry an "all-out" attack with tenacity. When the attack is started in real competition, there is no "in-between". However, the action will be a complete success or a failure.

In these optics, athletes prepare the Renzoku combination, culminating with the strong help of Tori bodyweight falling for almost every technique. Or with a variant of the same technique or with a unique preparation technique in the same direction. Renraku Waza is based on the use of Hando No Kuzushi (see Chap. 3.1). Building one opportune Uke reaction to finally apply techniques in whatever direction it is possible to do it. Usually, this kind of technical-tactical complex is connected to the shifting speed of the Athlete's Couple (see consideration on Competitive Invariants). This means that if a couple of athletes shifts on the mat with high speed, tori can apply, without stop, only techniques of a couple of forces. In this situation, during the motion, the couple of athletes can execute, at maximum, only two techniques, indifferently before kowaza (little technique) and after owaza (big techniques) or inversely owaza-kowaza. In the following figure, we can see a renraku based on the hando no kuzushi starting by O Uchi Gari into a circular application of Uchi Mata by Tanabe vs Kienhuisne, like the previous one Yamashita application.

Fig.9.3.bb.cc.dd.α.βγ, Renzoku applied by Tanabe (Finch)

Other combinations in front - back -side direction is possible by owaza-owaza. The following figure shows a front-back combination (O Waza-O Waza) applied by Nomura on Yekutiel.

Fig.8.3δ.ε.ζ.η.θ.ι, O waza-O waza applied by Nomura (Finch)

Tori can apply four different techniques mixed among a couple of forces and physical lever if the couple stops his motion. In the following figure, we can see four various attacks performed by Angelo Parisi. All attacks applied to the same fixed leg.

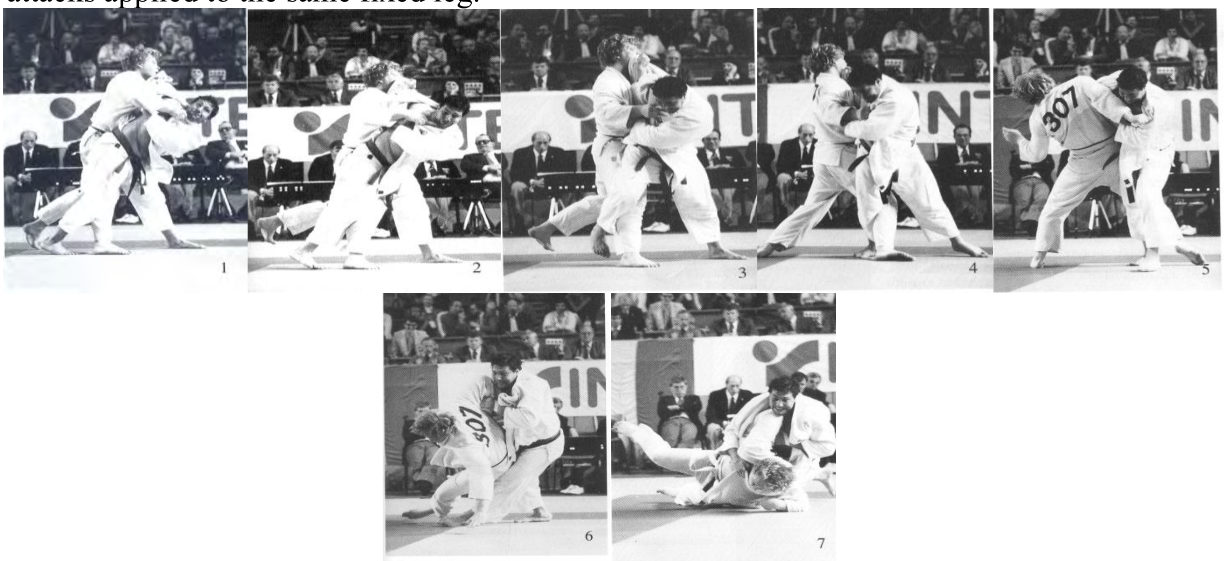


Fig.9.3κ.λ.μ.ν.ξ.ο.π, Four (!) different attacks applied by Parisi (Finch)

The last type of local strategies born from the analysis: of fighting surface and competition rules. Then it is possible to deduce as an example the following three local methods:

1. Study of the fight in the corner.
2. Study of the fight along with the fighting area limit (today there is no limit to the fighting area only in attacking dynamical situation see refereeing rules)
3. Study of the fight with a different angular position between athletes

B) "Global Strategies"

The offline analysis of the fight video could be a beneficial source for coaching about athletes, both: light and heavyweight, fighting style.

For example:
Elite lightweight Athletes generally like ***renraku*** waza with a different kind of attack.
Elite lightweight Athletes generally like ***lever techniques*** like suwari seoi
Elite medium weight Athletes generally like ***renraku*** waza with a different direction of attack.

Elite heavyweight Athletes generally like ***to attack*** with one or two direct techniques.
Elite heavyweight Athletes generally like ***to attack*** with ***couple techniques*** like o uchi, ko uchi.
Elite heavyweight Athletes are generally used ***to attack*** in makikomi variation.

Many important exceptions can be found; for example, Teddy Ryner uses many Couple group variations in his fights, more than makikomi.
With the Athletes' growing fitness and technical preparedness, every more technique is applied with lateralized direction for throwing (biomechanically speaking in the side directions, the human body structure is less able to defend himself than in the front-back side)
A straightforward example of a general fight strategy is the time evolution of attacks and penalties in a series of specific fights. In the next figures, there is one example from Calmet *"Apport des TICE dans l'observation des gestes sportifs"*. 8th JORRESCAMP (June 2006)

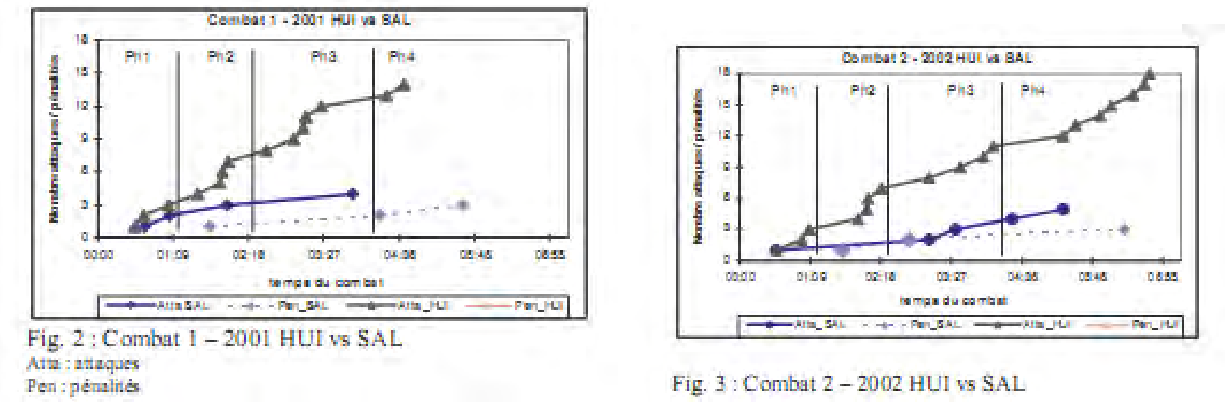


Fig. 9.3. qq.rr, Example of general competition strategy (Calmet)

From these and other analyses, a coach can build up some global strategies like:

1. Study of kumi kata changing during the fight.
2. Study of a fight with different relative ranges.
3. Study of special Tachi waza-ne waza connection.
4. In equal points condition, the study of the right strategy is founded on attack changing speed.
5. In leading condition, the study of a right defence fighting strategy.
6. In losing condition, the study of a right attack strategy is founded on technical-psychological pressure.

Fig.9.3.ss.tt, Evolution to dynamics O Soto gari

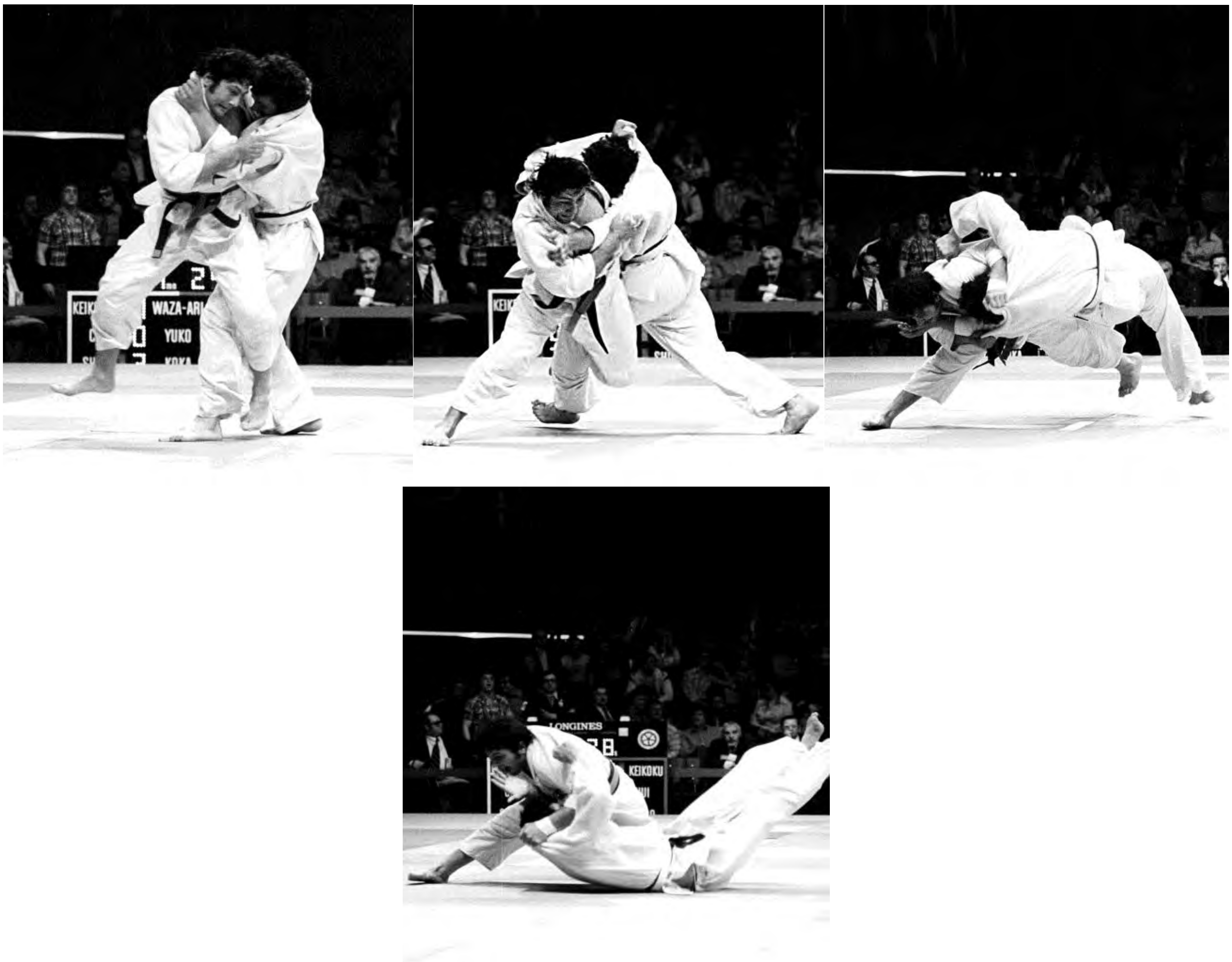


Fig 9.3.uu,vv,ww,zz Dynamic application of Renzoku by Angelo Parisi

Fig.9.3 all. Technical evolution from classic to innovative (Finch)

9.4 Main Use of Judo Match Analysis Software: Adversary's scouting.

The match analysis can give coaches and athletes much helpful information, but its use is usually partial and underused.
The primary use of the match analysis systems, at present, is only restricted to scouting the opponent's capabilities and technical ways to fight.
The video playback for scouting allows understanding the opponent's technique and what weakness he might have.
With the analysis of a video of an opponent, it is possible to see attack patterns and cues, such as personal grips or stance, that the adversary can show just when he is about to enter into a throwing technique. The knowledge of the adversary's attacking pattern gives much safety to meet the competition. Furthermore, it is easier to study counter techniques (Kaeshi Waza) based on the standard attacking pattern utilized (Tokui Waza).
In Rotterdam 2009, the author presented a paper on match analysis and knowledge obtainable by shifting patterns
As already known, match analysis started as a notational analysis; made by the Soviet Union and the US and many other countries at the end of seventy years. However, few people know that Japan already showed a futuristic vision, made a persuasive and scientifically complete approach to Judo Match Analysis.
In the historical paper of Matsumoto, Takeuchi and Nakamura, ***"Analytical studies on the contest performed at the All Japan Judo Championship Tournament"*** edited by Kodokan Scientific Bulletin in 1978, we can find much information, very advanced for that time, with a clear both scientific and coaching vision of the whole competition problem. The summary content of this paper is shown:

Execution of techniques

1st. number of times of executing techniques
2nd. decisive techniques (Kimari Waza)
3rd. number of implementations of techniques and the issue of the contest
4th. type of techniques and the result of the contest

Defence

1st. method of defence
2nd. method of defence to body weight
3rd. method of defence to different techniques

Left-handed judoka

1st. the technique used and the method of clinching to the right or left

Method of use of the arena

1st. the distance of the movement of the judoka
2nd. various movement tendencies of the judoka
3rd. the area of the arena used
4th. the position of the judoka to the inner or outer part of the arena when executing the techniques
5th. the position of the judoka in the arena when implementing the decisive techniques
6th. the outer side of the arena
7th. the use of a particular area in the arena by the judoka

Lost time

But this significant and complete paper was forgotten and became practically unknown.

The following figures, taken by Matsumoto and co-workers, show the analysis' results of using the Tatami area performed by the Japanese experts.

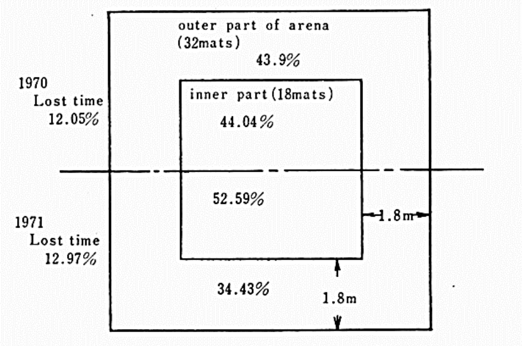


Fig. 5 Use of the arena (time)

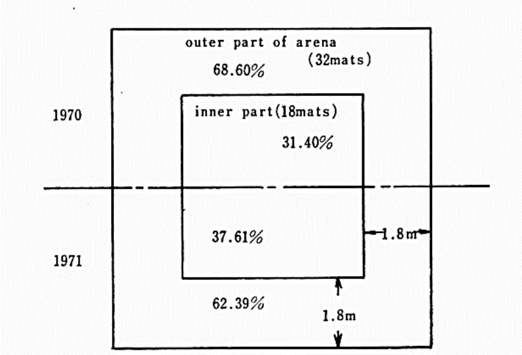


Fig. 6 Use of the arena (number of techniques)

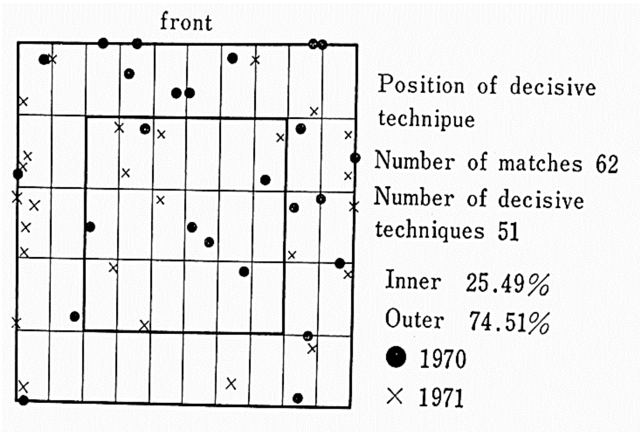


Fig9.4.a Use of the "Tatami" area in judo fight (taken by Matsumoto and co-workers).

Player tracking patterns in games are a handy tool for coaching in team competitions, such as basketball and soccer and dual matches, such as tennis and judo.
Usually, tracking is based on the study of one-point motion, for example, athletes' COM, or as in judo in the study of Couple of Athletes COM projection on the "Tatami".
The first analysis of this aspect of the competition was already realized by Matsumoto and co-workers in the historical paper previously mentioned. The following figures show the experimental tracks of 1 match with similar grips, one match with opposite grips, seven matches with similar grips and 12 matches with opposing grips.

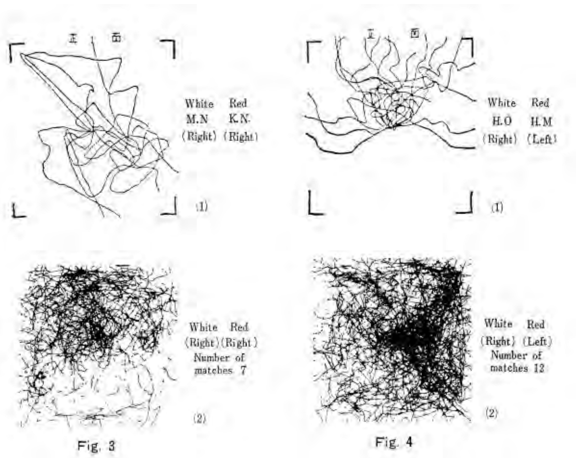


Fig.9.4.b Shifting paths and their superimposition in judo contest, experimental data. (taken by Matsumoto)

But the analysis of the paths was only connected to the position of the grip. Matsumoto and co-workers stated that: "the judoka' direction of movements, especially concerning the form of gripping, was studied, and it was found that in the contest between judoka with the same form of gripping, they revealed the tendency to circle the arena widely, Fig3. In a contest between judoka with a different form of gripping, they showed the tendency to move directly toward the outside of the arena Fig 4". They also obtained the mean distance covered by judokas (**121,1 m**) and the mean shift velocity (**0.30 m/s**). These were all the results obtained by the Japanese researchers about shifting paths.
By then, the author couldn't find any other study on this specific aspect of Judo competitions.
Are these analyses useless or less critical in content for Match Analysis?
It is possible to assert that this statement is not valid. The content of trajectories analysis is full of interesting subtle information in the light of the most advanced mathematical treatment.
The motion patterns of a couple of athletes' systems are a useful, practical tool with hidden information inside.
The shifting patterns study could be a source of handy strategic data. However, the price for extract the hidden information is a non-trivial mathematical analysis of these unique time series.
In fact, for what concern the tracking trajectories the author demonstrated 31 years ago, that the shifting paths of a couple of athletes COM projection must be considered belonging to the class of Brownian motions.
The general principle of the fBm (fractional Brownian motion) framework is that the aspect of a trajectory, expressed as a function of time, may be quantified by a nonfinite integer or fractional space dimension. Hence providing a quantitative measurement of evenness in the trajectory.
It is possible to write in mathematical form:

$$D_t^\alpha\left[x(t)\right]-\frac{x(0)}{\Gamma(1-\alpha)}t^{-\alpha}=\xi(t)$$

$$D = derivation\ operator$$

$$\alpha = fractional\ coefficient$$

$$\Gamma = Gamma\ Function$$

$$\xi(t) = Gaussian\ Noise$$

The first term is a fractional derivative. The second is connected to the initial condition of the process. The third is always the random (push/pull) force acting on the COM.
In this case, it is essential to know the mean square displacement of the point:

$$\left\langle \left[x(t)-x(0)\right]^2 \right\rangle = \frac{\left\langle \xi^2 \right\rangle}{(2\alpha-1)\Gamma(\alpha)^2}t^{2\alpha-1} \approx t^{2H}$$

From this expression, it is possible to understand that we are in the presence of different diffusion processes identified by the Hurst parameter H.
In particular, this parameter is time-independent. It describes the fractional Brownian motion with anti-correlated samples for $0<H<1/2$ and correlated samples for $½<H<1$.
If H is = to ½, we can speak of pure Brownian motion.
Athlete's Tracks (***Dromograms***) are the evolution in time of a couple of Athletes COM projection on the tatami area.
Generally, in the old Match Analysis, each technical action and throw were considered belonging to a class of Markov System. This means that it depends on the previous instant only, without correlation with the past movements.

This more advanced mathematical approach allows us to overcome this conceptual limitation and mathematical simplification.
As we have seen before, an essential feature of fBm modelling for each fighter is the long-term correlations between past and future increments. This means that the system is not Markovian and then more similar to the actual situation. The scaling regimes can assess this.

*In this way, **a fighting path can show**, if correctly analysed, **when the fighter has a specific fighting strategy or not (random motion) during competition**.*

For example, a median value of 0.5 for H indicates no correlation, suggesting that the trajectory displayed a random distribution (Brownian motion).
On the other hand, if H differs from 0.5, a positive ($0.5 > H$) or negative ($H < 0.5$) correlation with his fighting way can be inferred, indicating that a given part of the initiative is under control. Moreover, depending on how H is positioned, concerning the median value 0.5, it can be inferred that the subject more or less controls the trajectory (and the fight evolution in time): the closer the regimes are to 0.5, the larger the contribution of stochastic processes (random attacks without strategy) — in addition, depending on whether H is greater or less than the 0.5 thresholds, persistent (attacking) or antipersistent (defending) behaviours can be revealed, respectively. In other words, if the COM projection at a particular time is displaced towards a given direction, the more significant probability is that it drifts away in this direction (persistent attacking behaviour). Or, on the contrary, it retraces its steps in the opposite direction (antipersistent defensive behaviour).
Equality between these two probabilities indicates that there is no presence of a defined strategy in fighting, like simple random motion or stochastic process.
This information obtained by a pure "mathematical lecture" of trajectories; can be enhanced by adding to the previous advanced mathematical lecture other Biomechanical fighting information like:
Grips form, Competition Invariants, Action Invariants, Attack useful polygonal surfaces, Direction of displacement, Time and position of gripping action, Throws "loci", Length or Amount of displacement, Medium Speed, and Surface Area Utilization and so on.
With this added information, it is possible to obtain many valid strategic details. It is structured as a tree of knowledge with practical Data Mining algorithms to categorise potentially effective strategic connections among shifting trajectories and other Biomechanical Fighting Information.
This information, ordered by importance or effectiveness, is helpful for coaching and athletes as well.
This is one example of the more advanced information obtainable by this underestimated practical tool: Athletes' shifting patterns.

OLD EJU SYSTEM

In the following figure, it is possible to see one example of fourth level results of Old EJU Match Analysis (Adversary Scouting) applied to the Italian champion Elio Verde from the Judo French Federation.

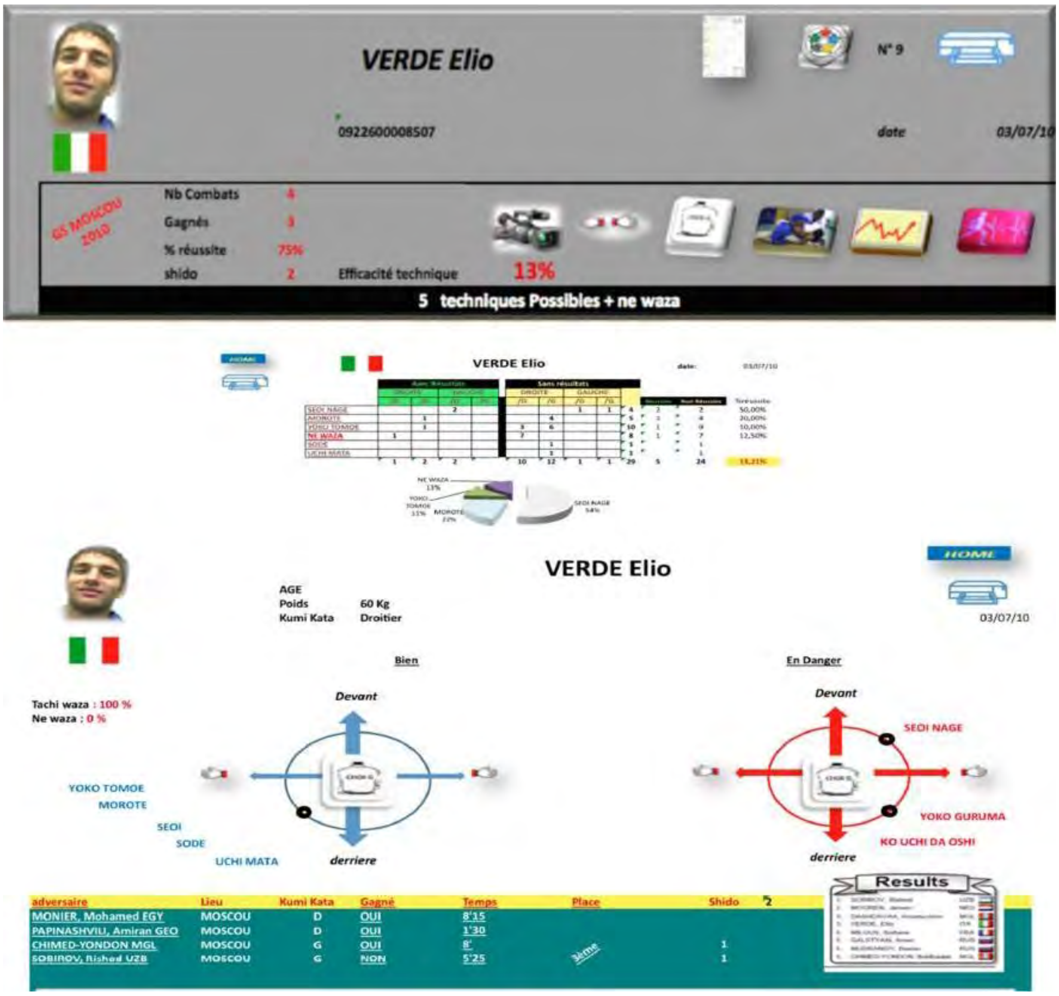


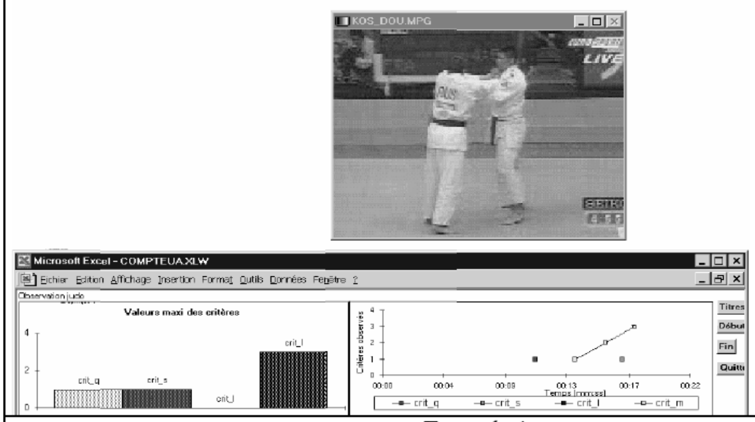
Fig 9.4.c Results of Match Analysis (Scouting) for the Italian Champion Elio Verde, made by the French Federation, see how specific and valuable the information is obtained

The previous results in the figure are a clear example of the National Federation utilization and analysis of centralized data obtained from the EJU.
It is interesting to note that for the athletes scouted. It is possible to know the strong and weak points of throwing techniques applied and suffered during the competition.
More often, such strong and weak points are also connected to spatial directions with respect to the body, the grips preferred, the effectiveness of the attack, and so on.
EJU utilizes, as before pointed out, specific software for all countries. This software, in offline analysis, just at the end of each competition, is available in one extensive elaboration of fighting data. These results are sent to all countries. After that, each country can develop a personalized analysis in its way, like the results presented in the previous figures.
Usually, National Federation use software to analyze competition performance. They create performance data, skill development, profile opposition and provide live video feedback within technical training sessions.
The software utilized is easy to use and a very effective coaching tool. The last development also provides TV connected software proven to be an invaluable and cost-effective online video system.

The Federation can provide video data quickly to coaches and athletes wherever they may be in the world.
With the development of the iPhone; IPad; Smartphone, and relative Apps, it is providing the needs of the Performance Analyst to create a complete helpful package to meet the modern requests of high-performance sport like judo

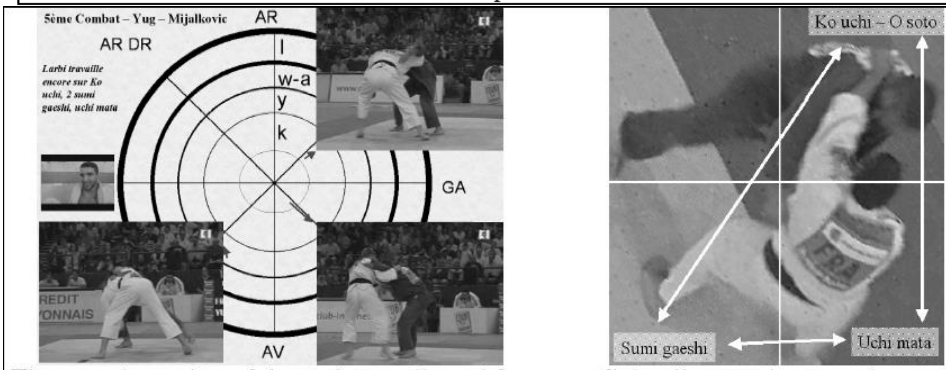
FRENCH UNIVERSITY SOFTWARE

Today different studies on adversary fight conduction were performed in every advanced federation. For example, there has been working by the university Jule Verne (Picardie France) since 2001 on the penalties in competition and on the attack system of a fighter.
In the following two figures, there are two examples of relative application.



In the example 1, the user should record by pressing on dedicated keys for that purpose, the advantages and the penalties which he observes during the progress of the digitized video sequence

Example 1



The superimposing of the actions collected for every fight allows to interpret better the system of attack of a fighter, here in the European Judo championships 2001

Example 3

Fig.9.4.d.e, Example of Franch software for Match analysis

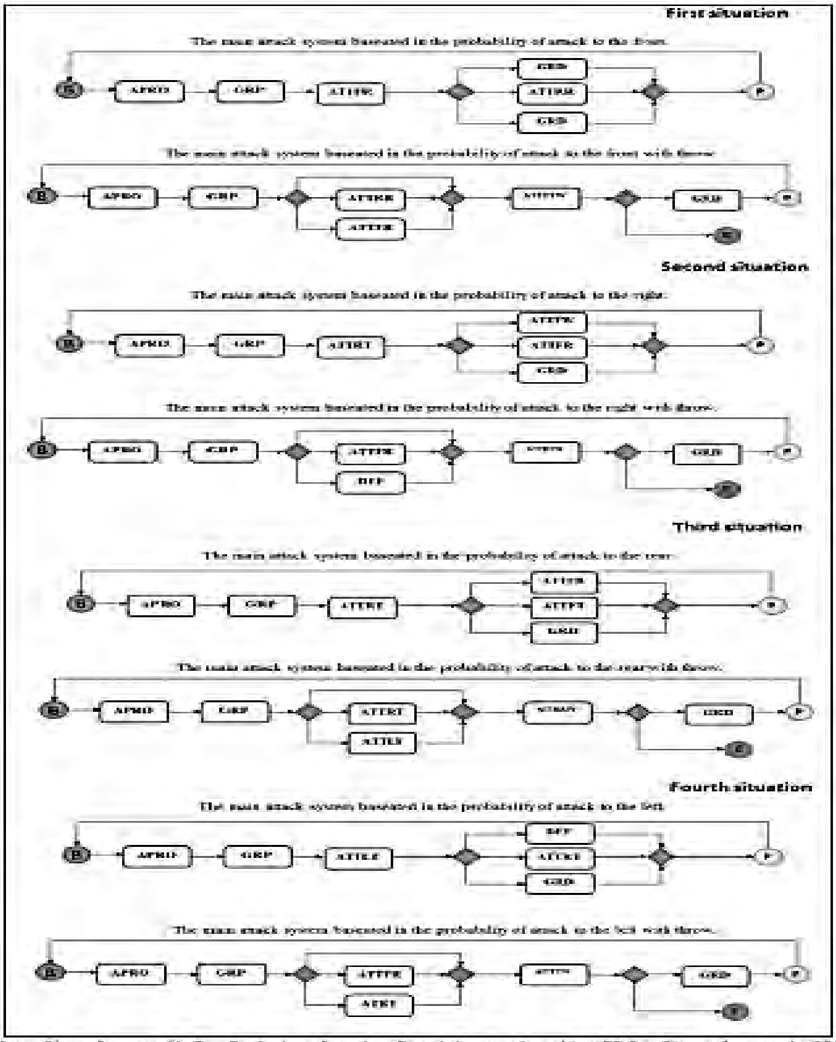
Last but not least, the adversary's scouting also gives information on the part of the mat. The pace of motion preferred by the opponent is handy information to bring out the opponent from his psychological balance.
Suppose we have a database with the adversaries' information. In that case, it is possible to apply to forecast to the data of team judo competition results.
In such a way, it is possible to have beneficial information, like spying, about the technical way of the specific team on the competitions; a very fundamental thing for a significant competition like World Championships or Olympics.

FRAMI SOFTWARE

Another exciting software is FRAMI, produced by Bianca Miarka and San Paul University in Brasil This software can analyse the time development of the fight, throws, the direction of attack, etc.
During the time, FRAMI was improved with a technical-tactical fighting model based on the multi-state Markov Model for statistical analysis of the situation.
In the following figures, some shots of FRAMI and the primary tactical system developed by the time motion model.

Fig.9.4.f FRAMI Software shot for technical analysis.

Fig.9.4.g. Scouting shot by FRAMI



Note : Circumference with B – Beginning of combat, Rounded rectangles with: APRO – Phase of approach; GRP – gripping phase; ATTFR – Attack to the front ; ATTRT – Attack to the right; ATTRR – Attack to the rear; ATTLF – Attack to the left; ATTFTW – attack to the front with throw; ATTRTW – attack to the right with throw; ATTRRW – attack to the rear with throw; ATTLTW – attack to the left with throw; DEF – defense; GRD – groundwork combat phase; PAUSE – moment of pause; Circumference with E – end of combat; Diamond – different possibilities and making decision; Arrow – relation among two phases; Double arrow – mutual relation of the phases.

Fig 9.4.h. The main tactical systems developed of the time-motion Judo combat model

Results of the model show that the main tactical systems of attacks, where attack to the front follows attack to the right most of the time, the highest likelihood to occur a projection are after the attack to the front and the correct orientations.

Now we question, for a Country or a Federation, is it better to have many match analysis software? For example, one for each sport or a centralized system that manages a large Video Data Base and has only one Data Warehousing and one Data Mining to work on the Video DataBase to present analysis for each sport.

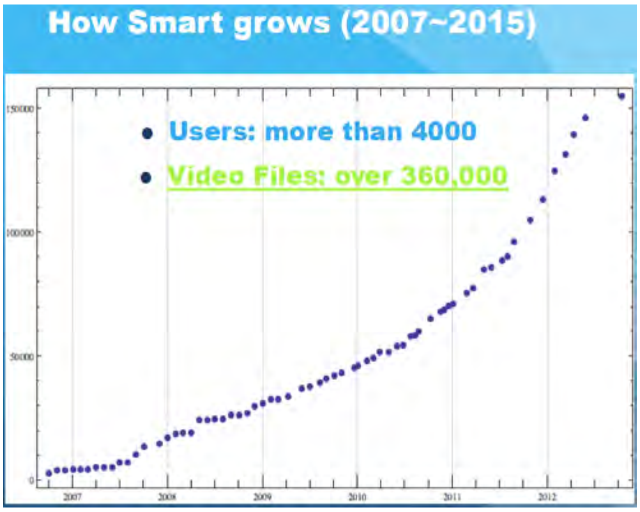
Usually, in an extensive system, Data Warehousing is the system's memory. Data Mining is the intelligence to find hidden properties in the video.

This solution is probably the best for flexibility and cost and probably also for the system's performance.

The Japanese SMART centralized system

Japan adopted such a system. The SMART SYSTEM is centralized on software for match analysis and performance analysis of many sports, produced and managed by JISS Japan Institute of Sports Science in Tokyo.

SMART started in 2007 as a video database and is content as the number of videos grows, as displayed in the following diagram.



Diag.9.4.i SMART SYSTEM Video content grow in time (from Chikara Miyaji)

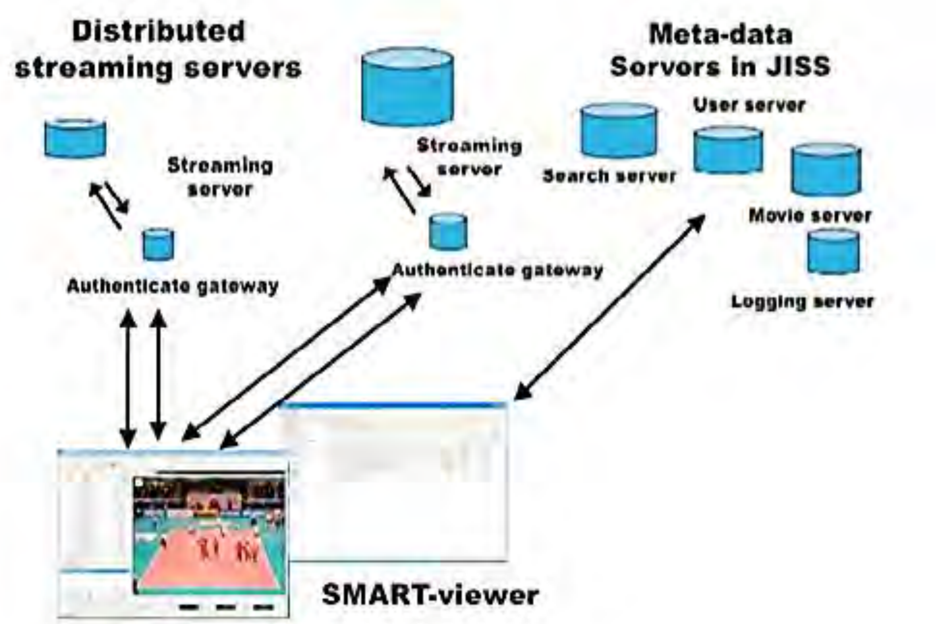
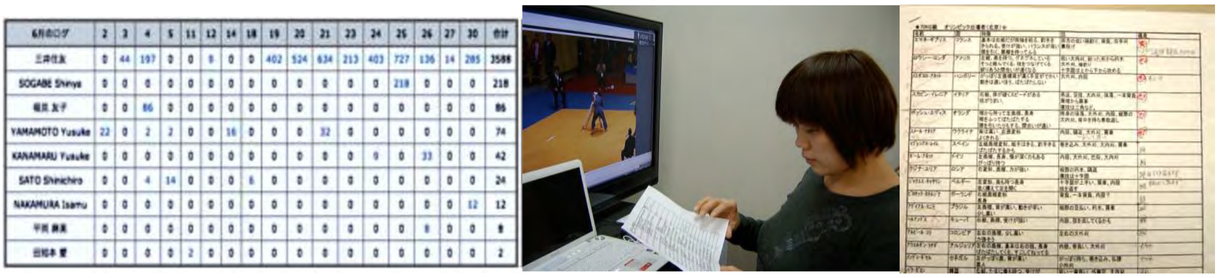


Fig.9.4.j Smart system Overview (from Chikara Miyaji)

All Japan Judo Federation is a user of this system. Archives world-class competitions, gives quick feedback at the competition and records daily training. In the following figure, there are shown some Japanese athletes that review judo competitions with SMART.

Fig.9.4.k. SMART SYSTEM for review of competitions

With this system and the High capacity of the database JISS Archive all competitions: Japan Judo Federation takes video for all significant matches; the system via the Internet shares these videos with top coaches and athletes until their Dojos.
Ms Ueno, as an example, utilizes the system checking all her rival's videos.
List up all their techniques and train with her partner to overcome rival's techniques
In the following figures, we show some sheets of the scouting action of the Female Japanese athletes.



6月のログ	2	3	4	5	11	12	14	18	19	20	21	23	24	25	26	27	30	合計
[illegible]	0	44	197	0	0	9	0	0	402	524	634	213	403	727	136	14	285	3588
SOGABE Shinya	0	0	0	0	0	0	0	0	0	0	0	0	0	218	0	0	0	218
[illegible]	0	0	86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	86
YAMAMOTO Yusuke	22	0	2	2	0	0	16	0	0	0	32	0	0	0	0	0	0	74
KANAMARU Yusuke	0	0	0	0	0	0	0	0	0	0	0	0	9	0	33	0	0	42
SATO Shinichiro	0	0	4	14	0	0	0	6	0	0	0	0	0	0	0	0	0	24
NAKAMURA Isamu	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	12
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	8
[illegible]	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2

Fig.9.4.j.m.n Ms Ueno archive researches, study, and personal comments on scouting

With the SMART SYSTEM on the internet, Japanese Coaches and also athletes can bring PCs for competition:
– Finding unknown opponent's characteristics at the competition
– Put all videos on PC or Ipad in the following figures two-shot of SMART System on IPAD

Fig 9.4.o.p. SMART system scouting sheet and IPAD scouting during competition

One very interesting application of this powerful software was presented in a paper "Characteristics Of Re-Gripping Techniques Preceding Scored Throws In International-Level Judo Competition" by Ito and coworkers. 2019.
Based on this study, athletes using re-gripping techniques target with one arm the place of the competition number and grip with another arm than the classical collar and sleeve.
For example: with at least one hand except for the place of the competition number for grabbing, this seems to facilitate scoring.
That is to say, using the re-gripping method could make a more effective variety of gripping targets that make easier scoring results of throwing techniques. In the next table are the summarized results of this study.

	Re-Gripping %	No Re-gripping %
Grip on competition number	41.5	15
Collar & sleve	32.5	69.9
Other areas	26.0	15.0
Cross gripping	24.4.	19.9
No cross gripping	75.6	80.1
Body rotation tec.	38.2	48.1
No body rotation tec	61.8	51.9
Direct attack single	74.3	71.4
Combination	7.3	9.2
Counter attack	17.9	19.4

Tab. 9.4.a Technical features of scoring rates, associated with regripping and no-regripping

THE POWERFUL IJF MULTI-SITES GLOBAL SYSTEM

In recent times the IJF has made a considerable effort to make available a powerful free software that would allow not only the National Federations but each adept at being able to carry out scouting studies, technical improvement, and more generally the competition. The system was developed by a Slovenian software house la: Datastat, with CEO Sašo Šindič, which has developed a system notable for its flexibility and power. The operation and use of this very useful system are explained step by step in detail below, made available to all judo enthusiasts and professionals.

SYSTEM FOR OVERVIEW AND TAGGING OF THE CONTESTS

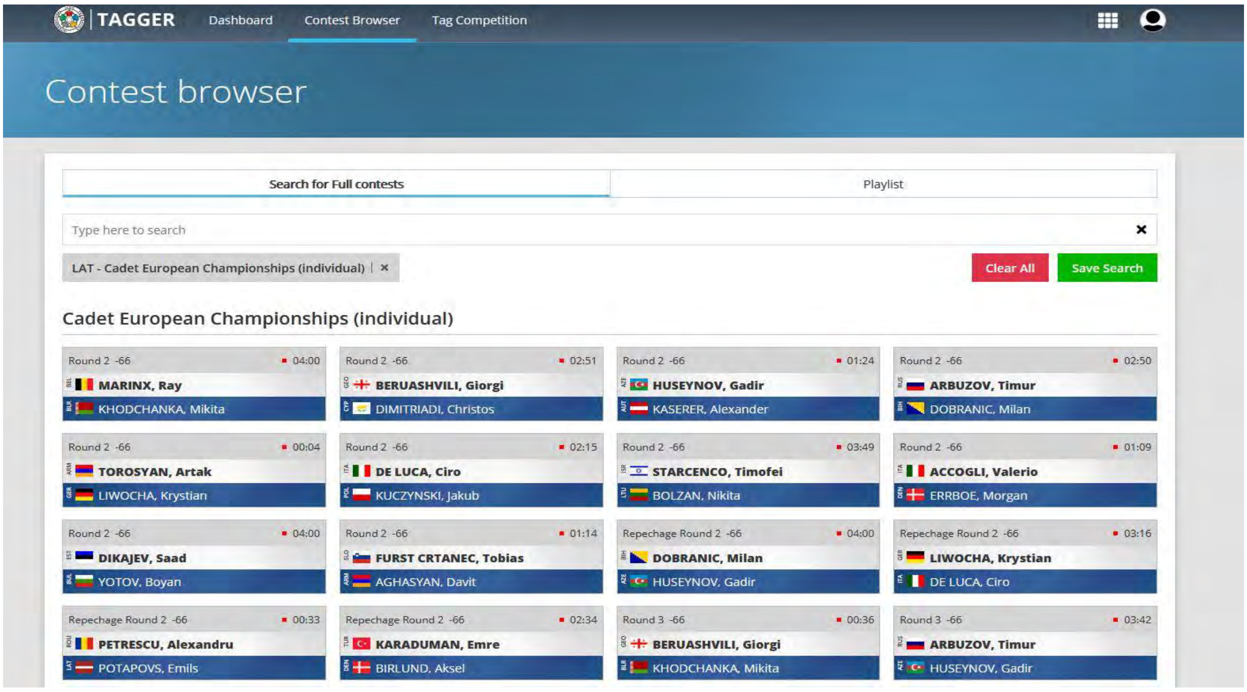
How Tagger Works, What It Offers And How We Use It:
Tagger is a software that enables us to tag all the scores in the competition and, by doing so, gather statistical data. Software is designed so that we can tag the contests in the shortest possible time. For each score, we set (determine) what happened and when. Because we analyse a huge number of contests, it is important that the system is time-efficient. A skilled IJF administrator can tag an average fight in less than 1 minute. This way, one IJF administrator can tag all the contests from one competition (usually on three mats) during the competition and immediately after the competition. The program is not completely automated because of the mistakes that occur during the competition – the mistakes on the scoreboard, modifications of referee's decisions and such. IJF administrator is also responsible for the determination of the exact time of each score.

THE PROCEDURE to edit the CONTESTS:

- Every contest on the competition is recorded. The video is streamed directly on live broadcast and at the same time stored on local storage. The data from the scoreboard is transmitted to the same unit once every second. The software combines the data from the scoreboard and the video so that it cuts the video to individual contests. This is done automatically during the competition.
- One person is a supervisor on the competition, and his responsibility is to check that all the connections work, that the videos and scoreboard data are safely stored, and he uploads the videos on YouTube or other platforms. The second person is the remote system administrator, and his responsibility is to supervise the live video and data transmissions.
- Once the videos are uploaded on YouTube, you can access them via http://tagger.ijf.org
- This software enables us to tag all the scores. IJF administrator edits and tags every contest. First, he checks that the video and data are valid. Then he sets the exact time the score was awarded and defines the penalties.
- When this is done, he publishes the data. When data are published, different systems can access the information.
- Later the Kodokan expert tags all the techniques. When all the techniques have been defined, the editing of the contest is finalised.

For now, the Tagger is accessible only for IJF administrators and Kodokan experts. But there is an additional option set in place. There is the option for official tags and for personal tags.
A personal tag is an option for coaches, competitors or researchers.
In this option, you can set any action that you find interesting and subsequently share it with others.

IJF Administrator can find the fight in the Contest Browser.



9.4.β IJF System Contest Browser

When you have chosen the fight, you can edit it.

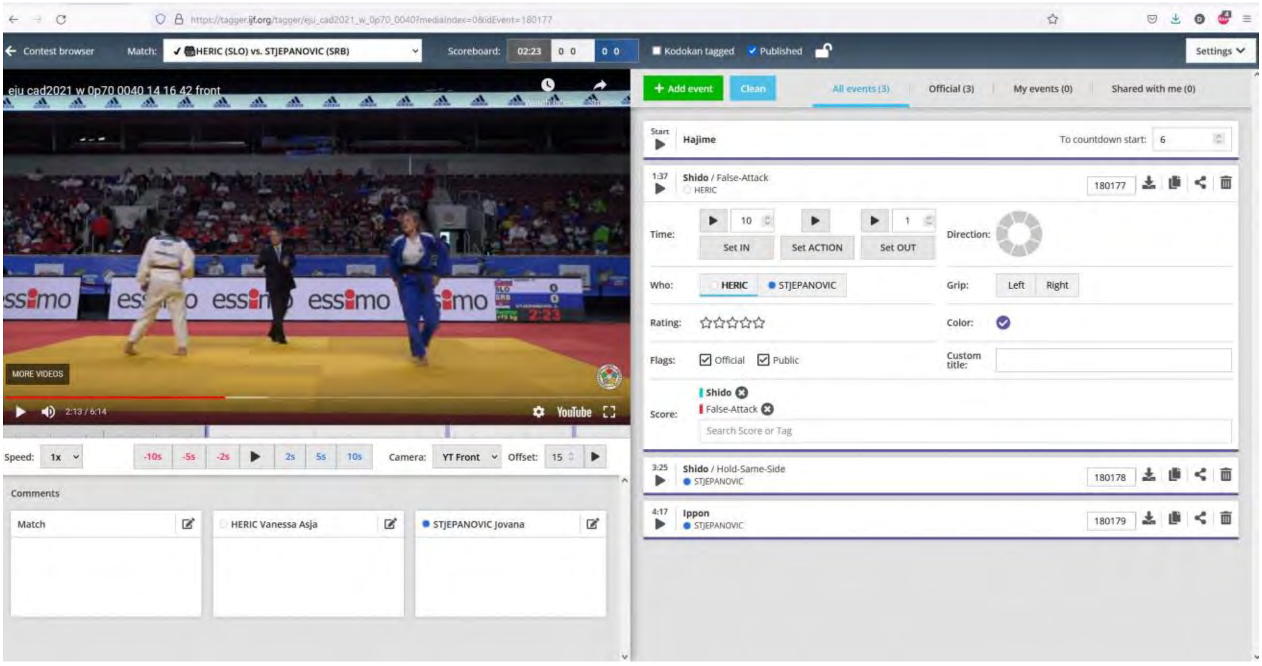


Fig 9.4.γ IJF System fight view

All the scores that took place during the contest are already marked. IJF administrator sets the exact time they occurred and corrects any mistakes. He also tags all the penalties. When this is done, he publishes the video.
Techniques are not tagged by the IJF administrator but by Kodokan experts.

The reason for this is that IJF wants the data to be as accurate as possible, so the best experts in the world are in charge of that. IJF is in constant dialogue with Kodokan, and it is universally agreed that they are the reference for technique review. When they define the techniques, they mark the fight Kodokan tagged and then the data are connected with the database.

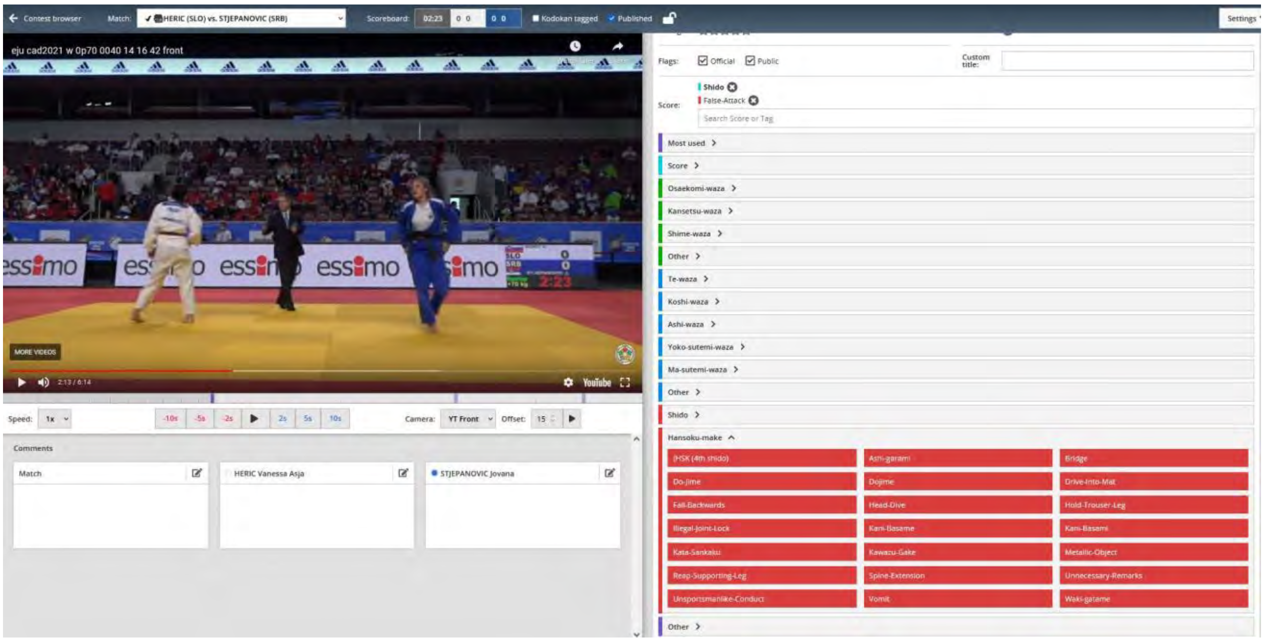


Fig. 9.4.δ IJF System Fight Kodokan Tagged

All the actions the IJF Administrator tags are predefined in the system. By doing this, we avoid the unnecessary mistakes that can occur because of spelling mistakes and such, and we also speed up the process. All the tags are based on the IJF referring rules and the official IJF list of techniques.

The system is prepared to offer users the possibility to tag their own actions (My Events). Only the user and the people he shares the tags (Shared with me) can see them. This can be a very useful tool for the coaches that prepare the tactics for their competitors. They can define if the techniques are performed to left or right, in which direction the techniques are performed, and they can comment on every technique. The system is not yet opened for users.
Once the contests are tagged, the information is available and displayed on different internet sites that are connected:

- https://www.ijf.org
- https://live.ijf.org/
- https://judobase.ijf.org/#/dashboard
- https://judo.ijf.org/
-

Each site has a different purpose, so the data are used and displayed in a different way on each site. A short description of how the information is displayed follows.

https://live.ijf.org/
The purpose of this site is to enable the judo community to follow the competitions live while they take place all over the world.

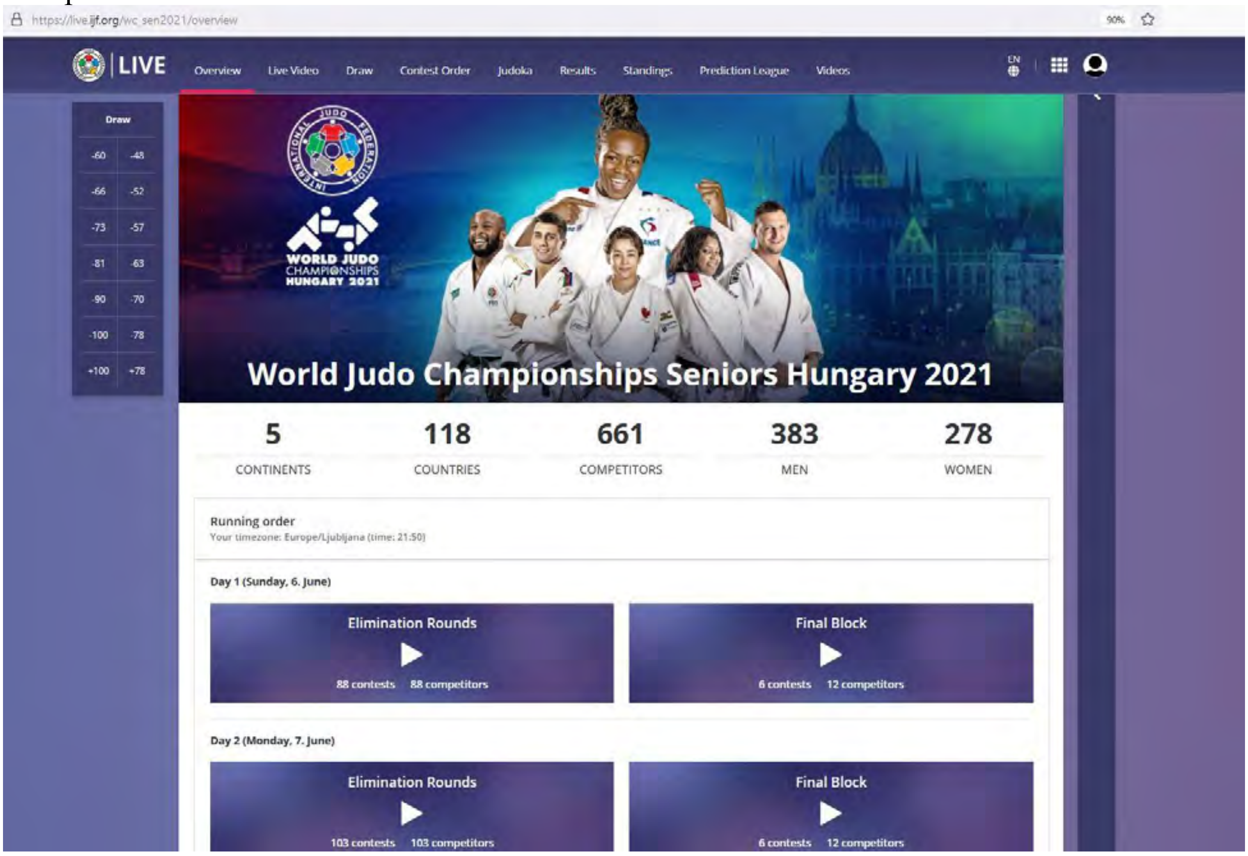


Fig. 9.4. IJF Site 1 “Live.IJF.org”

On this site, you can find all the information you need to follow the competitions live:

- Participants (countries, competitors)
- Draw
- Live streaming
- Contest order
- Results
- Video uploads with contest results and tags
- Prediction league (you can vote for winners and compare your result with others in the judo community)

Here are uploaded the contests video and results during the competition.
The contests are also tagged so viewers can easily find when the actions took place. Usually, upload and tag the contests are made in 10 – 15 minutes after the contest has finished.

It is easy for viewers to find the content they want to watch in the draw or in the contest order.

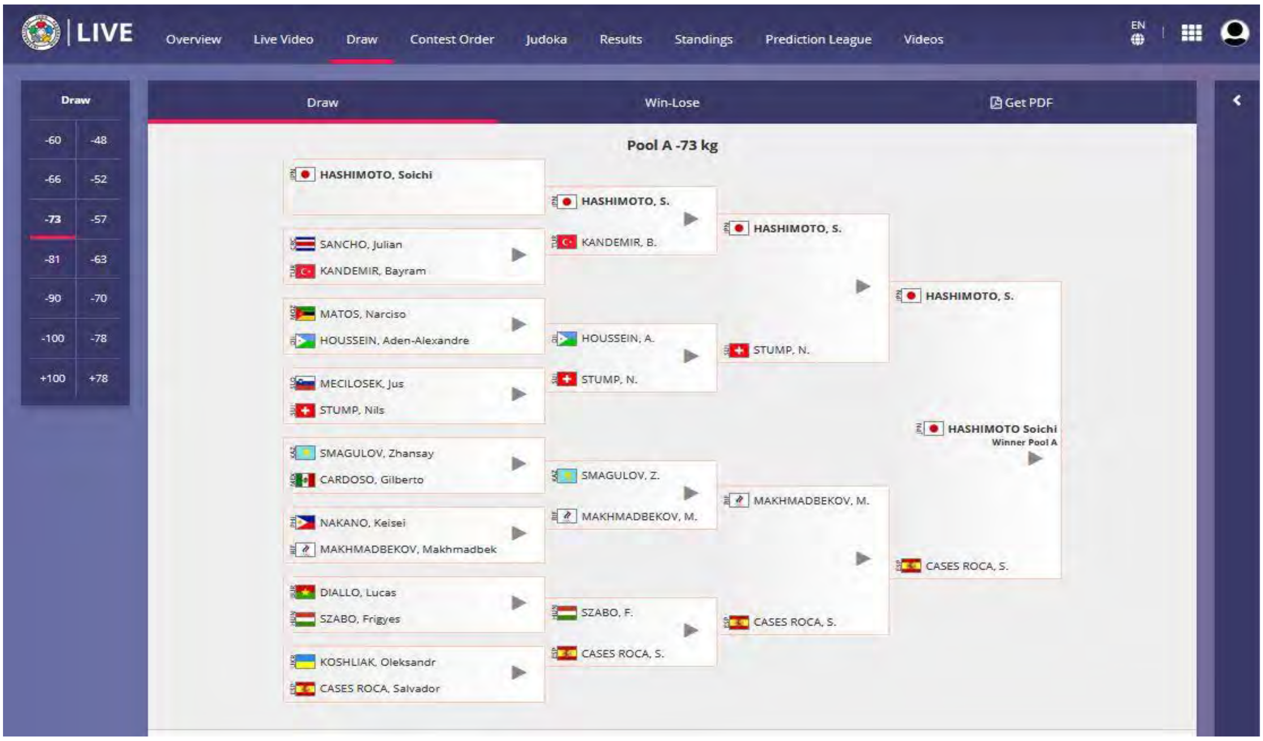
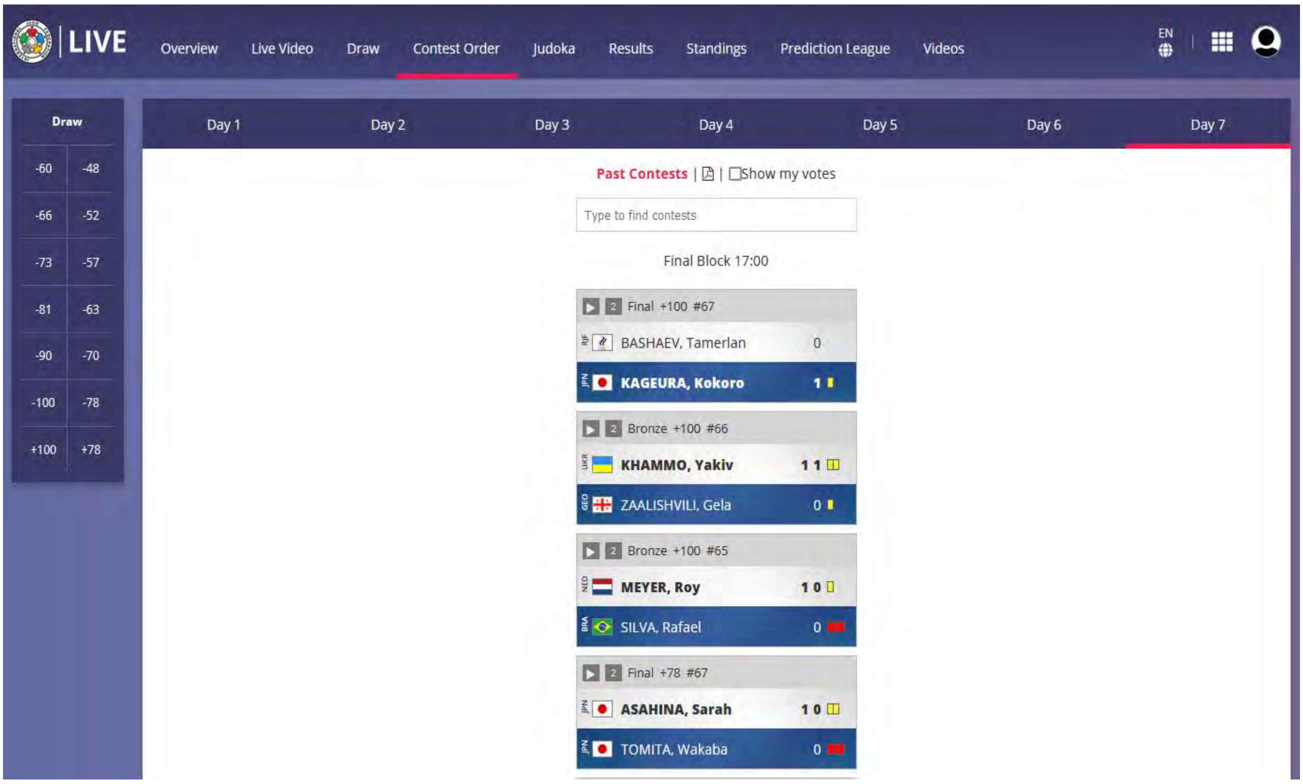


Fig.9.4.ε IJF Site 1 Draw



9.4.ζ IJF Site 1 Contest Order

If the contest is already tagged, you will see it displayed like this:

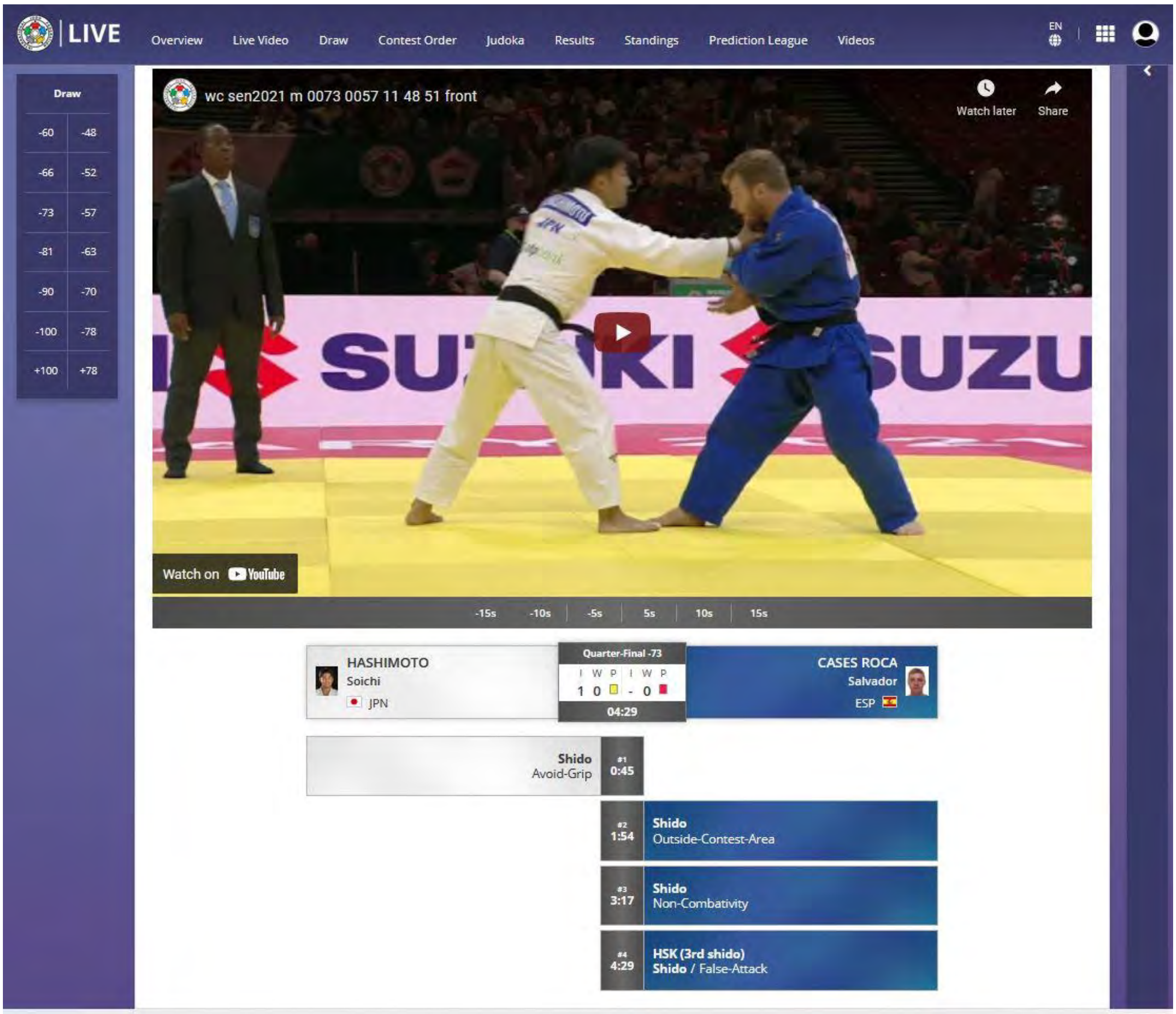


Fig.9.4.η IJF Site 1 Tagged Contest

When you click on the score, the video will start playing 5 seconds before the score is achieved.

[HTTPS://WWW.IJF.ORG](https://www.ijf.org)

This is the main site for IJF, where it presents all the activities and communicates to the judo community. Besides all other information, it also presents all the results from IJF competitions. The presentation is similar to IJF live.

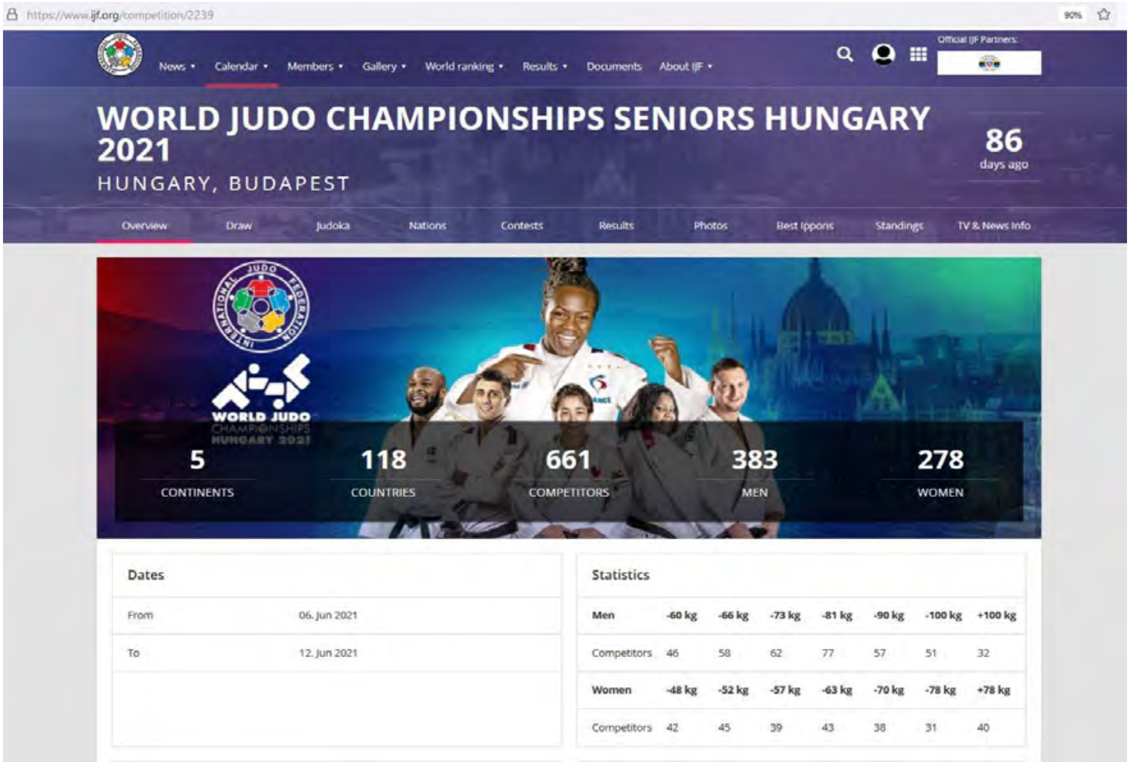


Fig.9.4.0 IJF Site 2 "Main Site"

If you want to watch a certain fight, you can find it in contests.

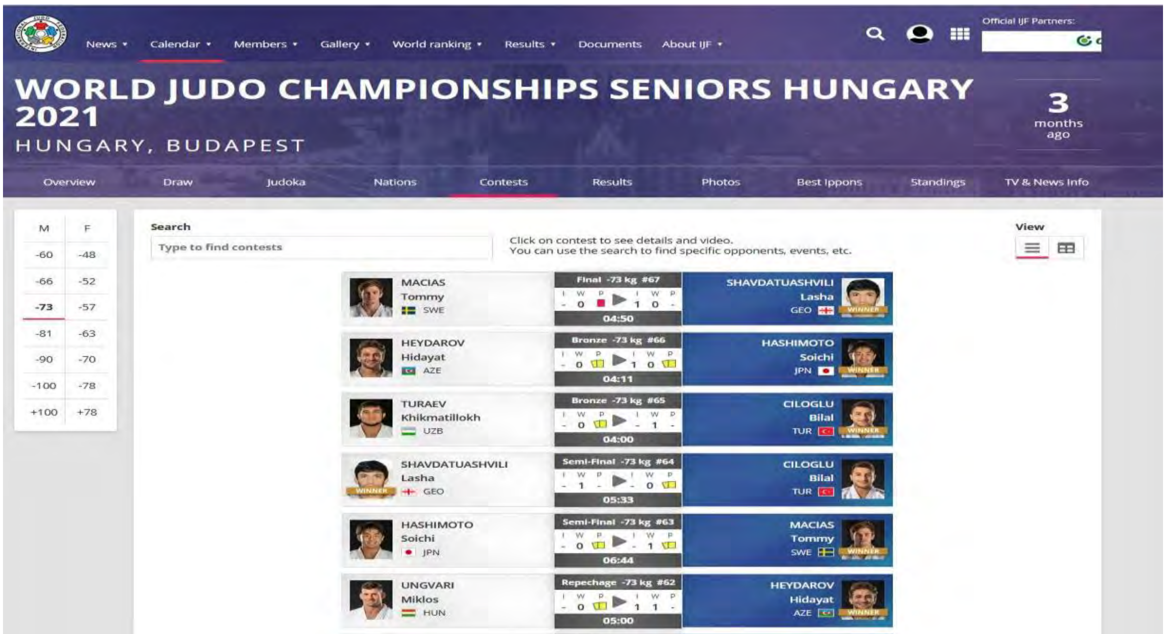


Fig.9.4.1 IJF Site 2 Fights Order

When you choose the contest, all the scores in the contest will be displayed the same way as in IJF live.

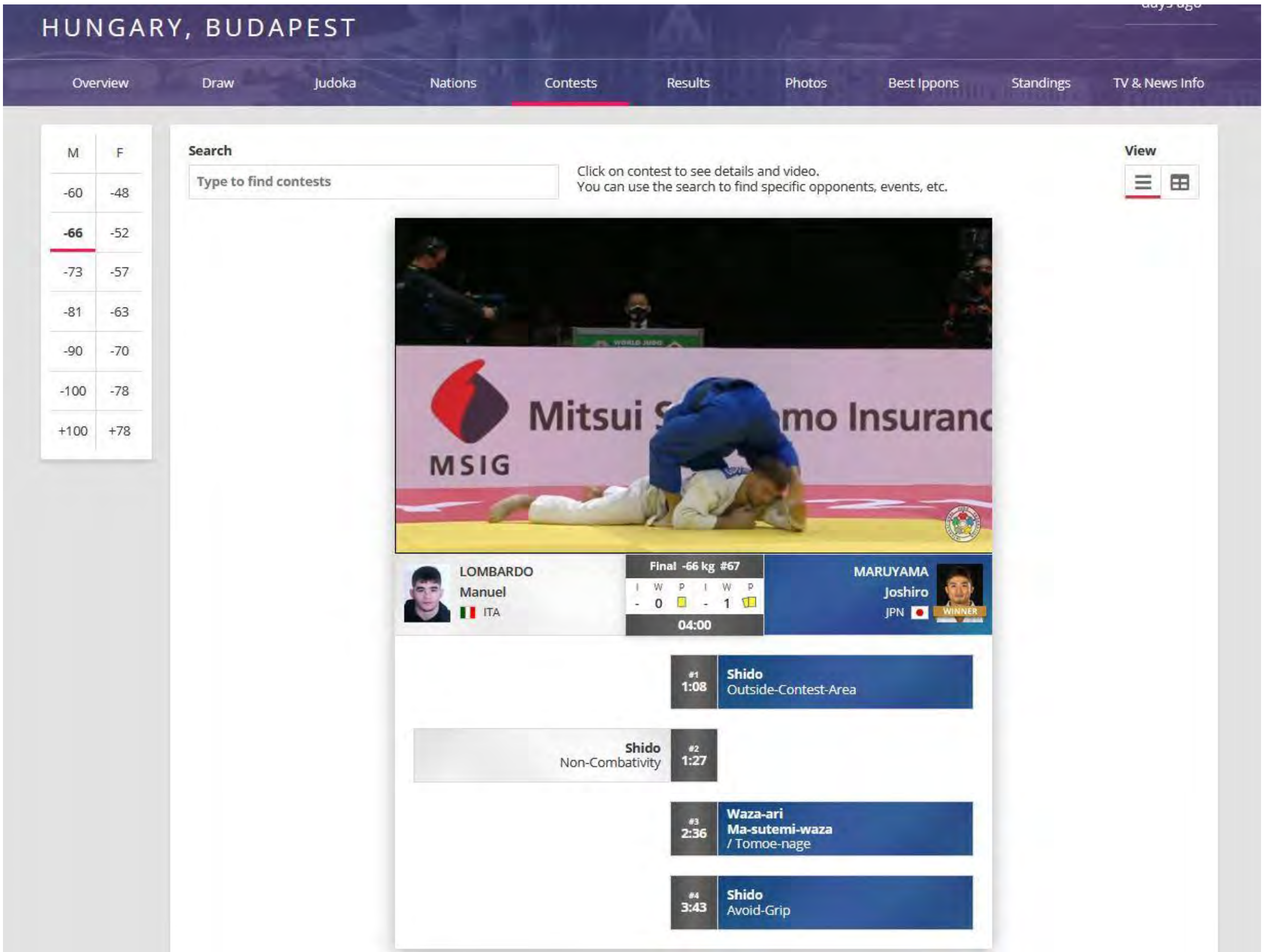


Fig.9.4.к IJF Site 2 Tagged Fight

[HTTPS://JUDOBASE.IJF.ORG/#/DASHBOARD](https://judobase.ijf.org/#/dashboard)

On this site, you can find more detailed information about the competitors, contests, scores and tags. You can watch the whole fight or search just for certain scores or techniques.

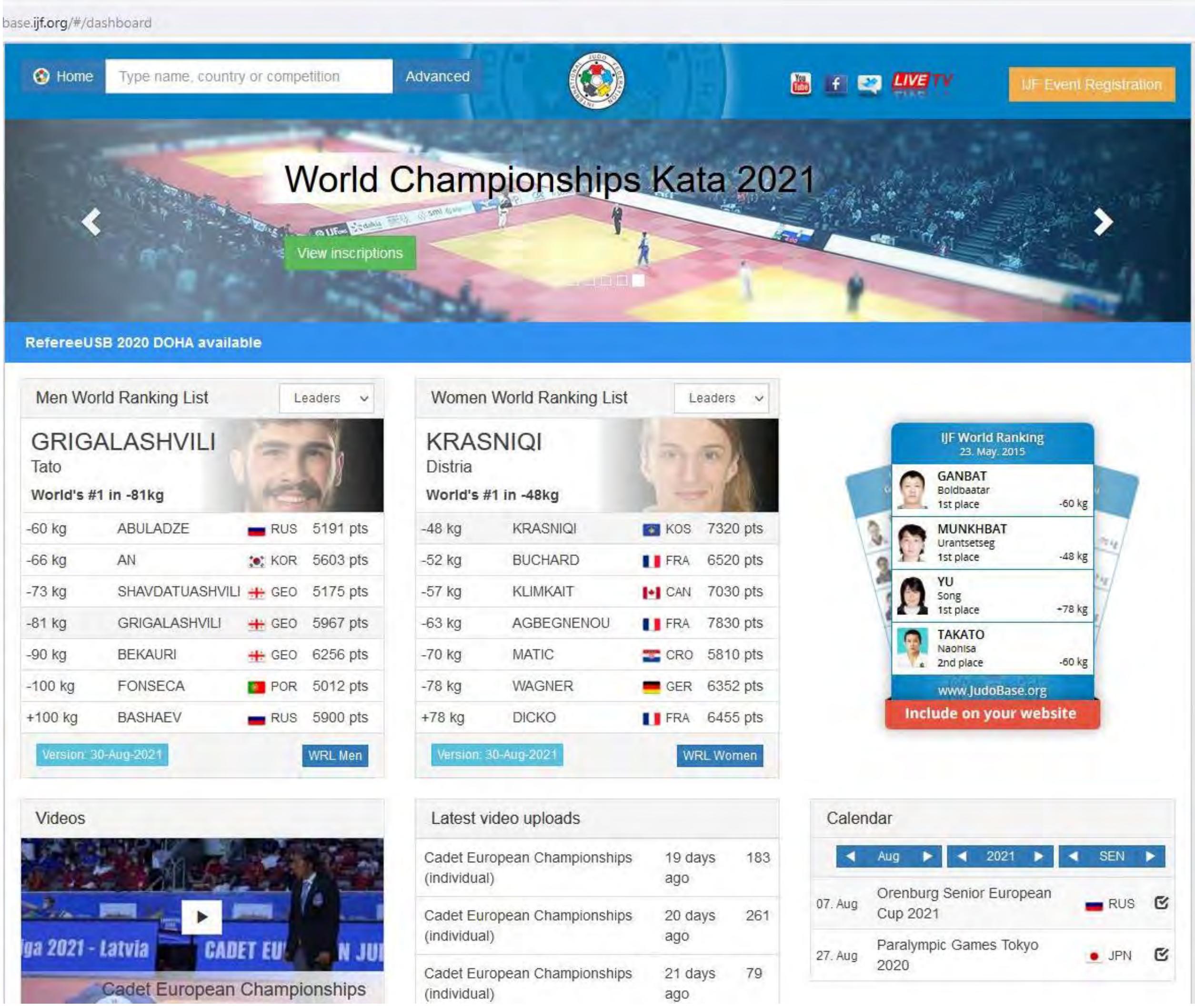


Fig.9.4.λ IJF Site 3 " JudoBase.IJF.Org"

You can search for:

- Competition
- Nations
- Competitor
- Category
- Score
- Tag

And all the combination of the above.

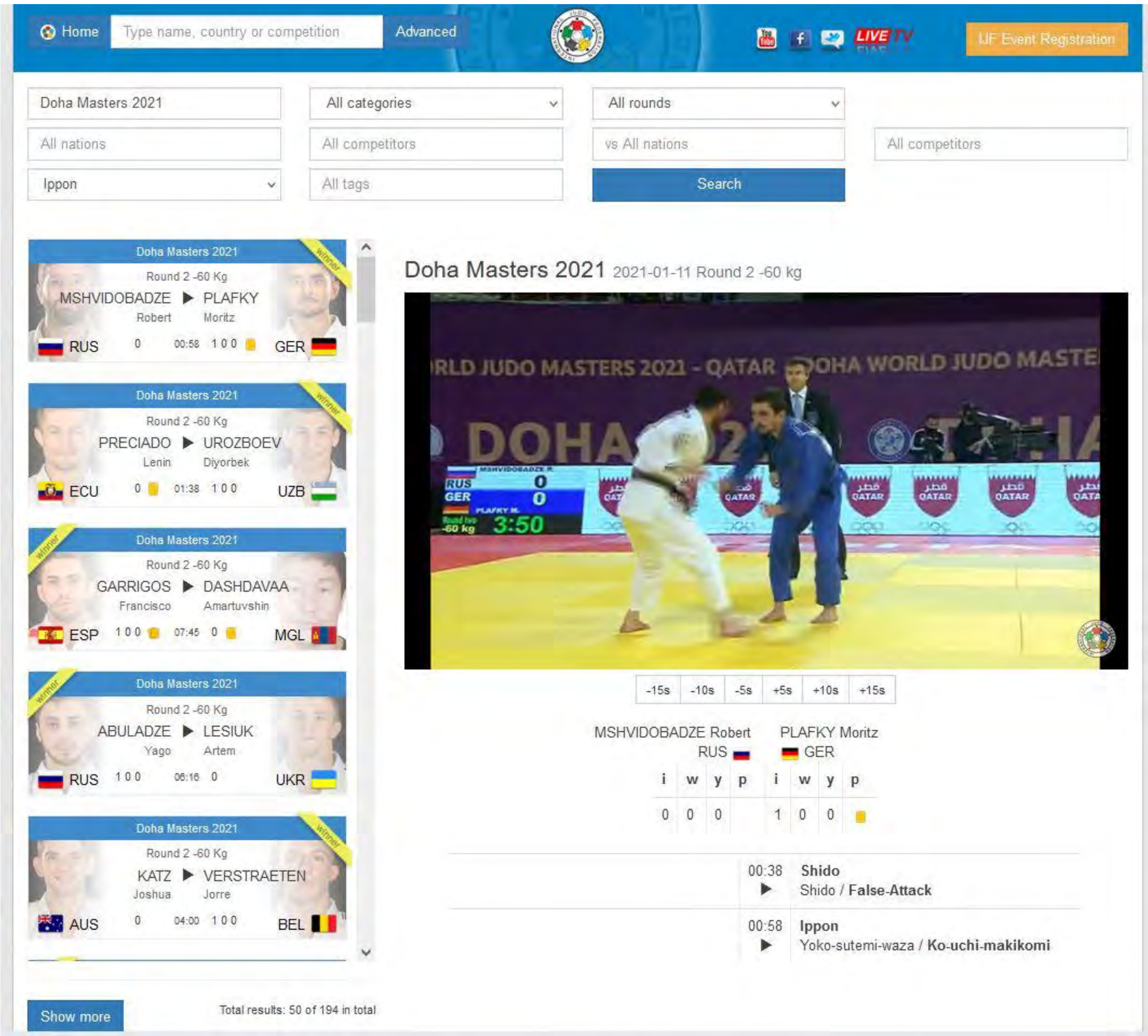


Fig.9.4.μ IJF Site 3 Example of Ippon search

HTTPS://JUDO.IJF.ORG/

This site is intended for educational purposes. All official IJF techniques are presented in a short description, video and 3D animation. They are performed by Kodokan experts. Each technique is then linked to competition examples based on Kodokan tags. You can choose to search by competitors or competitions. This way, competitors and coaches can learn basic techniques and also research different competition variations of techniques.

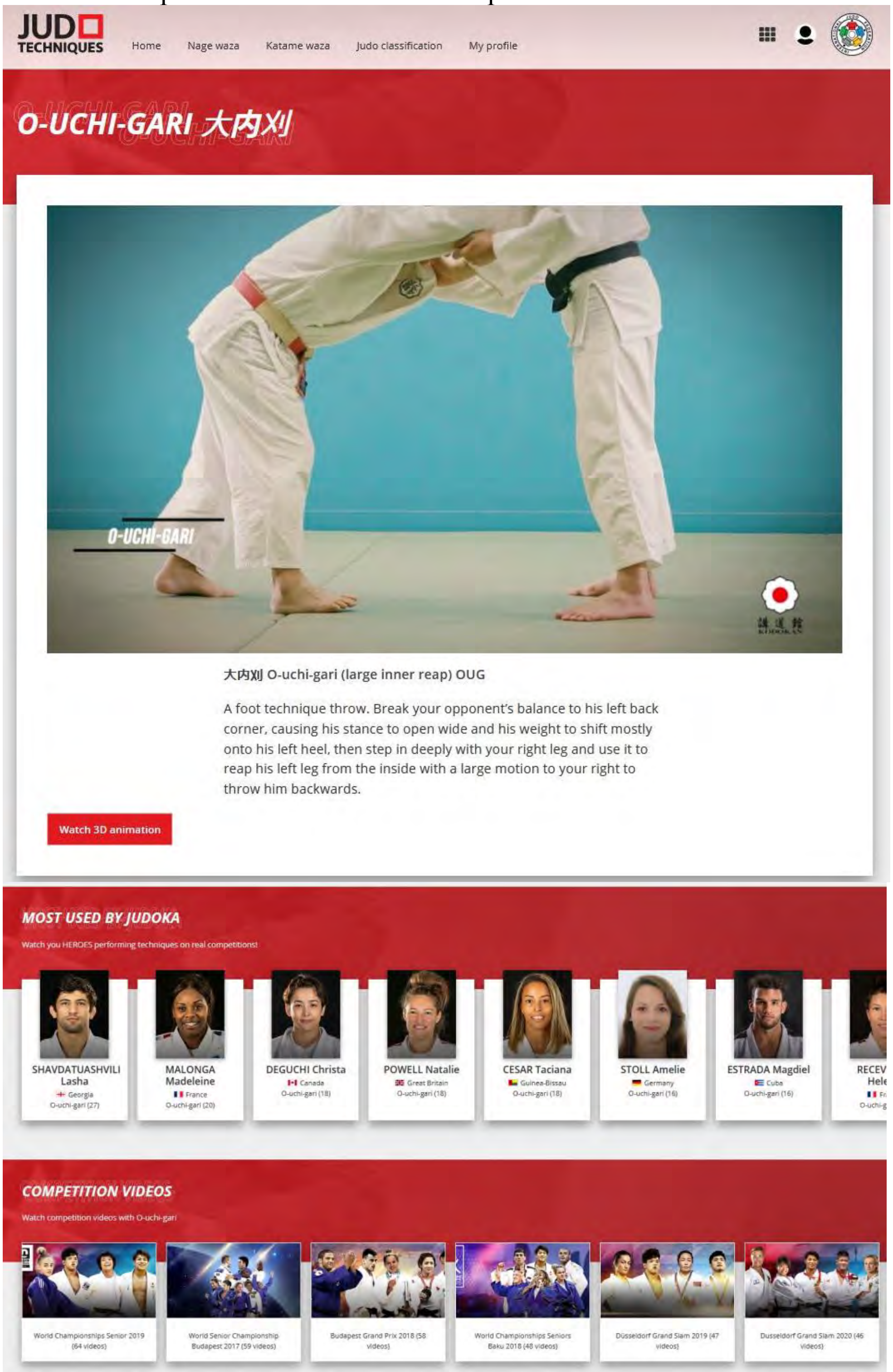
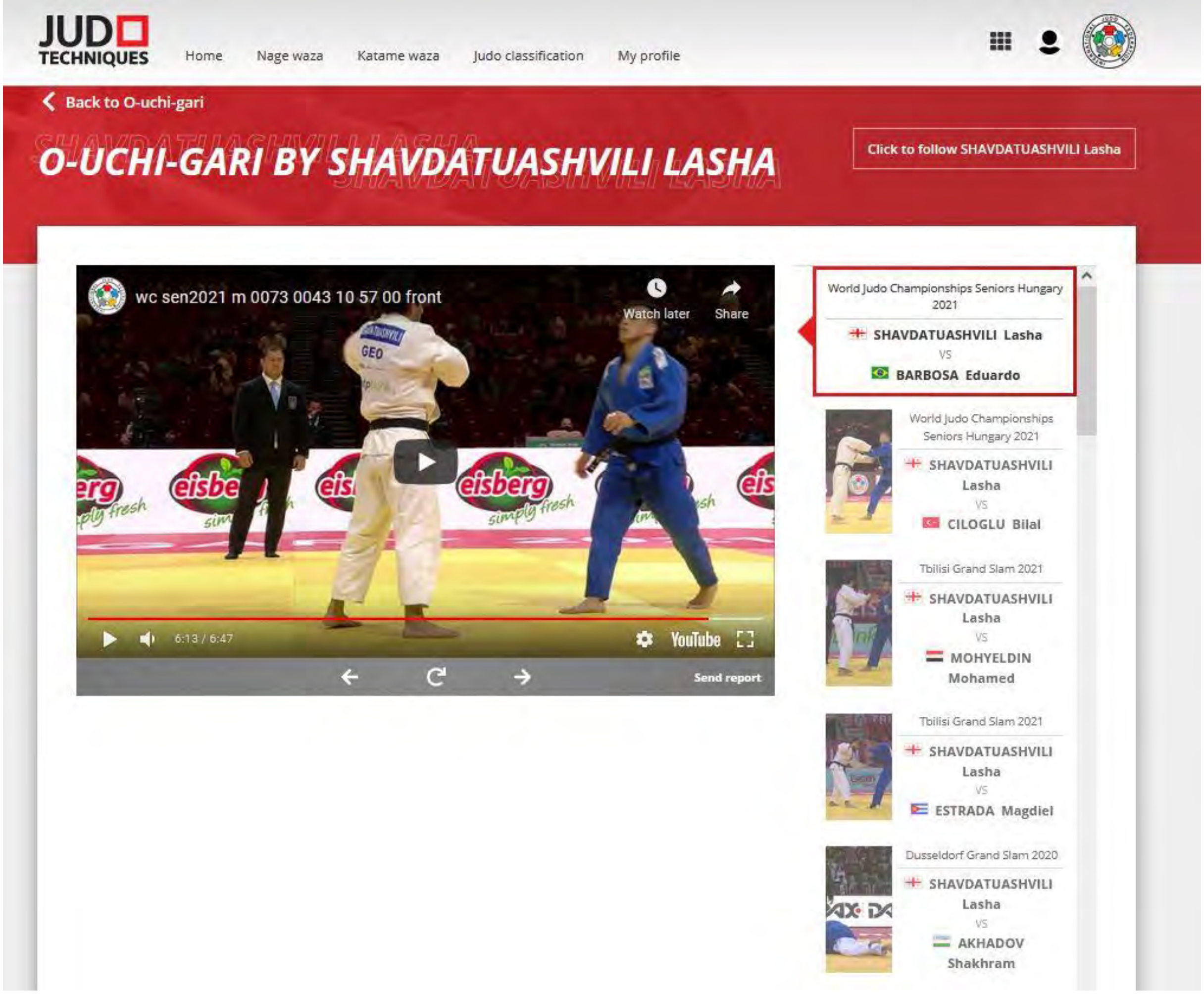


Fig.9.4.v   IJF Site 4 "JUDO.IJF.ORG" Technical Educational Site



F

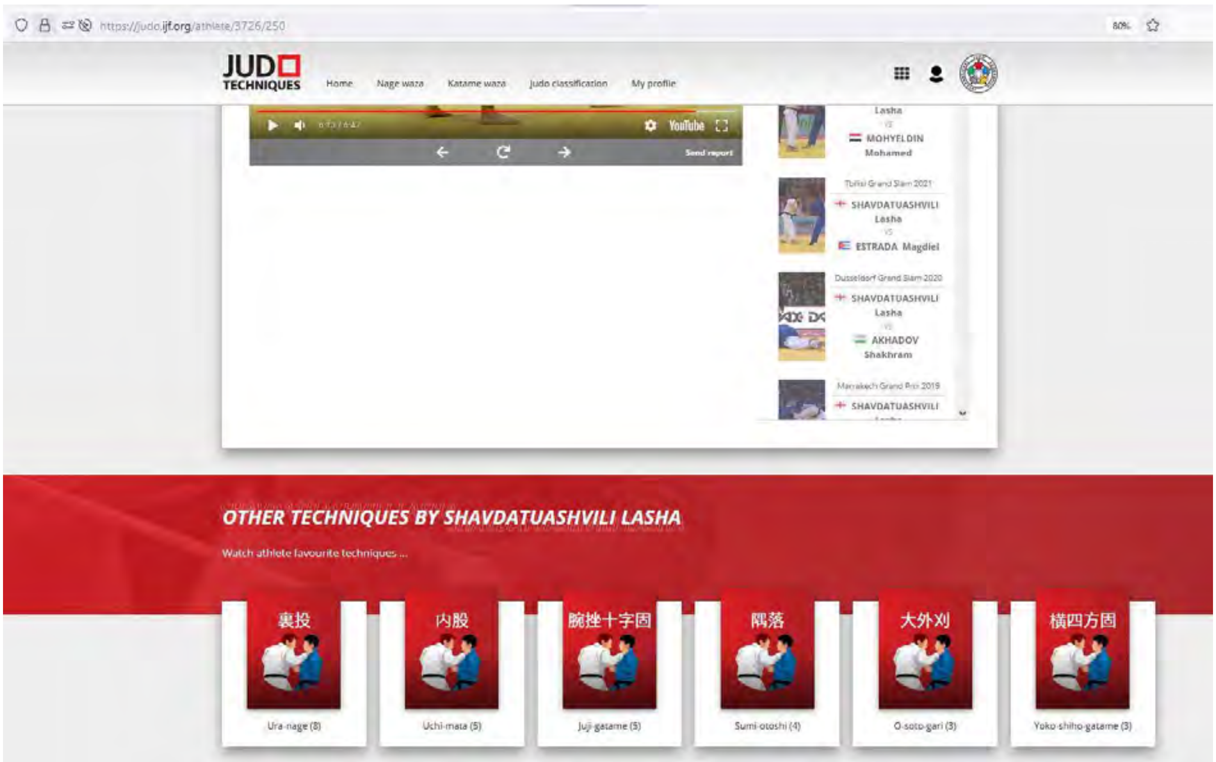


Fig.9.4.ξ IJF Site 4 Example of Athlete complete technical Scouting

RESERVED IJF STATISTICAL DATA SITEπ

IJF administrators have access to two sites that enable us to gather statistical data:

- https://www.ijf.org/backend/statistics
- https://www.ijf.org/backend/tag_search?

Statistics gathered on this site is presented to IJF commissions so they can make informed decisions about the future of Judo sport.

https://www.ijf.org/backend/statistics

The page is closed for the public, and only IJF administrators have access. The main purpose is to analyse data and enable to follow the trends.

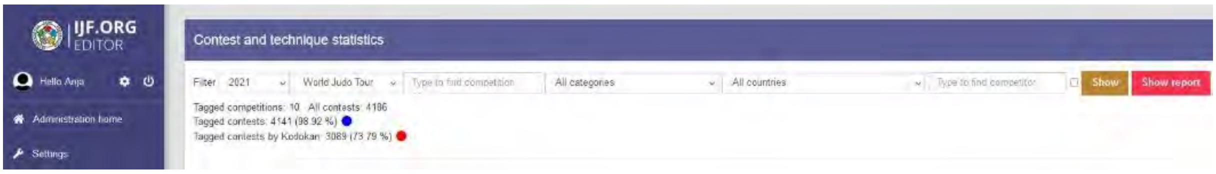


Fig.9.4 o IJF Reserved Site

The site enables us to analyse the data for:

- Certain competition
- Certain level of competition
- Different age group
- Certain period

Based on the tags defined in Tagger, the program automatically gathers the following statistics:

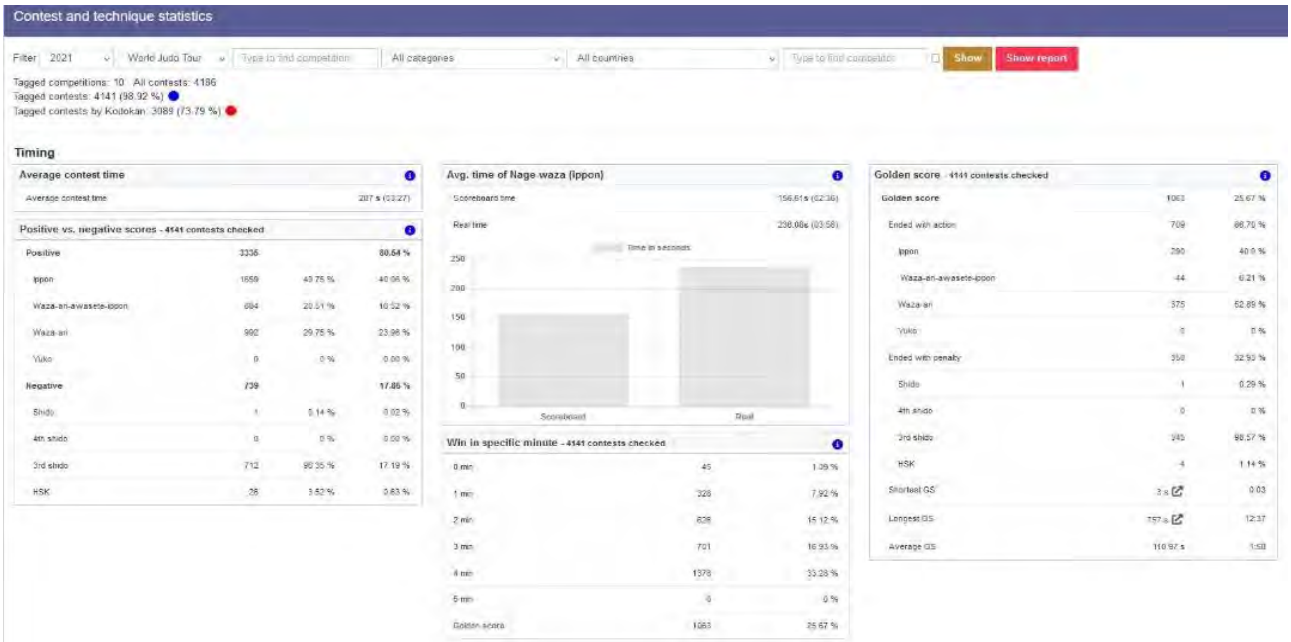


Fig.9.4.π IJF Reserved Site Example of Statistics

Time of the contest:

- Average time of the contest
- Average time to score ippon (scoreboard, real)
- In which minute the contest has finished
- Time of golden score (shortest, longest, average)

Scores:

- The number and percentage of the contest won with a positive score (ippon, waza-ari awasete-ippon, waza-ari)
- The number and percentage of the contest won by negative score (3rd shido, hansoku-make)
- The same statistics for the golden score

Techniques

Nage-waza vs katame-waza ippons - total 1082 (100%)		
Nage-waza ippons	721	66.64 %
Katame-waza ippons	361	33.36 %

Leg grab		
Hansoku-make/Hold-Trouser-Leg	0	0 %
Shido/Hold-Trouser-Leg	152	

Nage-waza ippons - total 730 nage-waza ippons (64.83%)		
Uchi-mata	101	13.84 %
O-uchi-gari	69	9.45 %
Seoi-nage	60	8.22 %
Sumi-otoshi	45	6.16 %
Ko-soto-gake	45	6.16 %
O-soto-gari	40	5.48 %
Ippon-seoi-nage	30	4.11 %
Tani-otoshi	26	3.56 %
Ura-nage	23	3.15 %
Tai-otoshi	22	3.01 %

More

Nage-waza scores - total 2528 nage-waza scores		
Uchi-mata	257	10.17 %
Sumi-otoshi	217	8.58 %
Seoi-nage	208	8.23 %
O-uchi-gari	187	7.4 %
Ippon-seoi-nage	107	4.23 %
Ko-uchi-gari	99	3.92 %
Ko-soto-gake	94	3.72 %
O-soto-gari	89	3.52 %
Sode-tsurikomi-goshi	82	3.24 %
Ko-soto-gari	82	3.24 %

More

Katame-waza ippons - total 364 katame-waza ippons (32.33%)		
Yoko-shiho-gatame	86	23.63 %
Juji-gatame	80	21.98 %
Okuri-eri-jime	53	14.56 %
Kuzure-kami-shiho-gatame	37	10.16 %
Kuzure-kesa-gatame	18	4.95 %
Kesa-gatame	15	4.12 %
Tate-shiho-gatame	13	3.57 %
Sankaku-jime	12	3.3 %
Kata-gatame	11	3.02 %
Kami-shiho-gatame	9	2.47 %

Katame-waza scores - total 561 katame-waza scores		
Yoko-shiho-gatame	163	29.06 %
Juji-gatame	80	14.26 %
Kuzure-kami-shiho-gatame	54	9.63 %
Okuri-eri-jime	53	9.45 %
Kuzure-kesa-gatame	52	9.27 %
Kesa-gatame	32	5.7 %
Tate-shiho-gatame	28	4.99 %
Ushiro-kesa-gatame	18	3.21 %
Kami-shiho-gatame	16	2.85 %
Kata-gatame	15	2.67 %

Fig.9.4.ρ IJF Reserved Site Example of Statistics

Also, the techniques used in the competitions are analyzed:

- How many ippons were scored with nage waza and how many with katame waza
- How many ippon was scored with a certain technique
- How many waza-aris were scored with a certain technique

Winning penalties (direct HSK) - total 32 winning penalties (direct hsk) (2.84%)		
Illegal-Joint-Lock	6	18.75 %
Waki-gatame	6	18.75 %
Head-Dive	5	15.63 %
Bridge	4	12.5 %
Kani-Basami	2	6.25 %
Unsportsmanlike-Conduct	2	6.25 %
Bye	2	6.25 %
Report bad Video	2	6.25 %
Report bad data	1	3.13 %
Reap-Supporting-Leg	1	3.13 %

More

Penalties - total 7227 penalties		
Non-Combativity	2905	40.2 %
False-Attack	1232	17.05 %
Avoid-Grip	1078	14.92 %
Outside-Contest-Area	475	6.57 %
Defensive-Posture	408	5.65 %
Hold-Same-Side	208	2.88 %
Hold-Trouser-Leg	196	2.71 %
Fingers-In-Sleeve	121	1.67 %
Hold-Sleeve-Ends	115	1.59 %
Pistol-Grip	101	1.4 %

More

Fig.9.4.φ IJF Reserved Site Example of Statistics

We can also analyse negative scores – penalties and determine what was the major reason for:

- Shido and
- Hansoku-make

https://www.ijf.org/backend/tag_search?

This site is also available only to IJF administrators. It enables us to search for certain tags so we can review them and search for the examples we want to demonstrate.

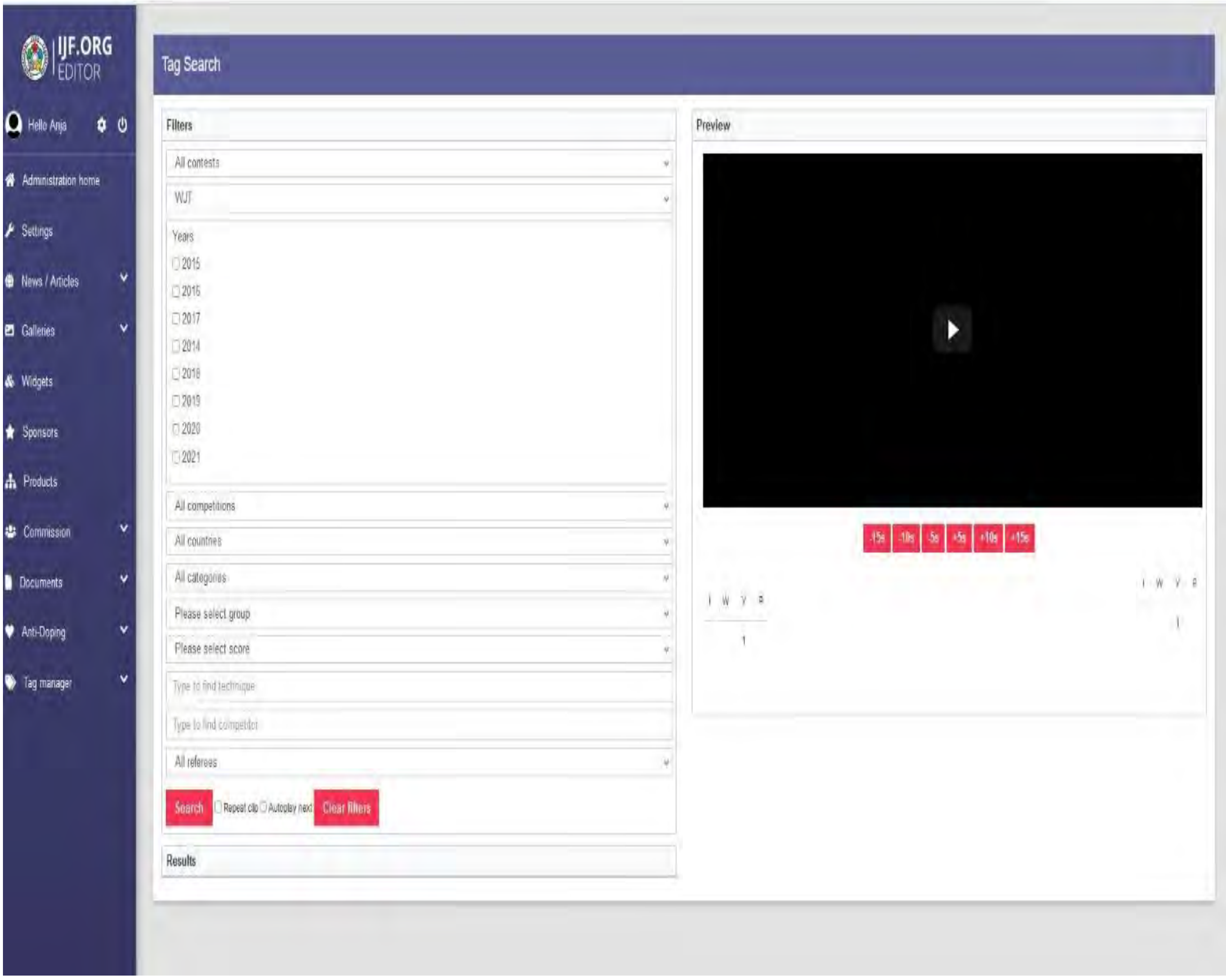


Fig.9.4.χ IJF Reserved Site   Example of the working area

Today 2021 it is possible to find online web services that give information at different levels about match analysis around the world. Two interesting examples are the ***Judo Data System*** and ***Athletes Analyzer***

JudoData Sistem

Judo Data analyzes all competitions valid for the Qualification Olympic IJF World Tour organized under the aegis of the International Judo Federation (No Continental Championships because, for example, there are no videos of the African Championships and often not even of the Pan-American ones). The analysis of every single meeting takes place in two phases.
The first is Notational Analysis, during which ***Events*** are recorded semi-automatically and already enriched with basic data.
The second phase is that of the detailed technical description of what was recorded.
All data generated and presented on ***www.judodata.com*** are related to the relevant portion of the video.

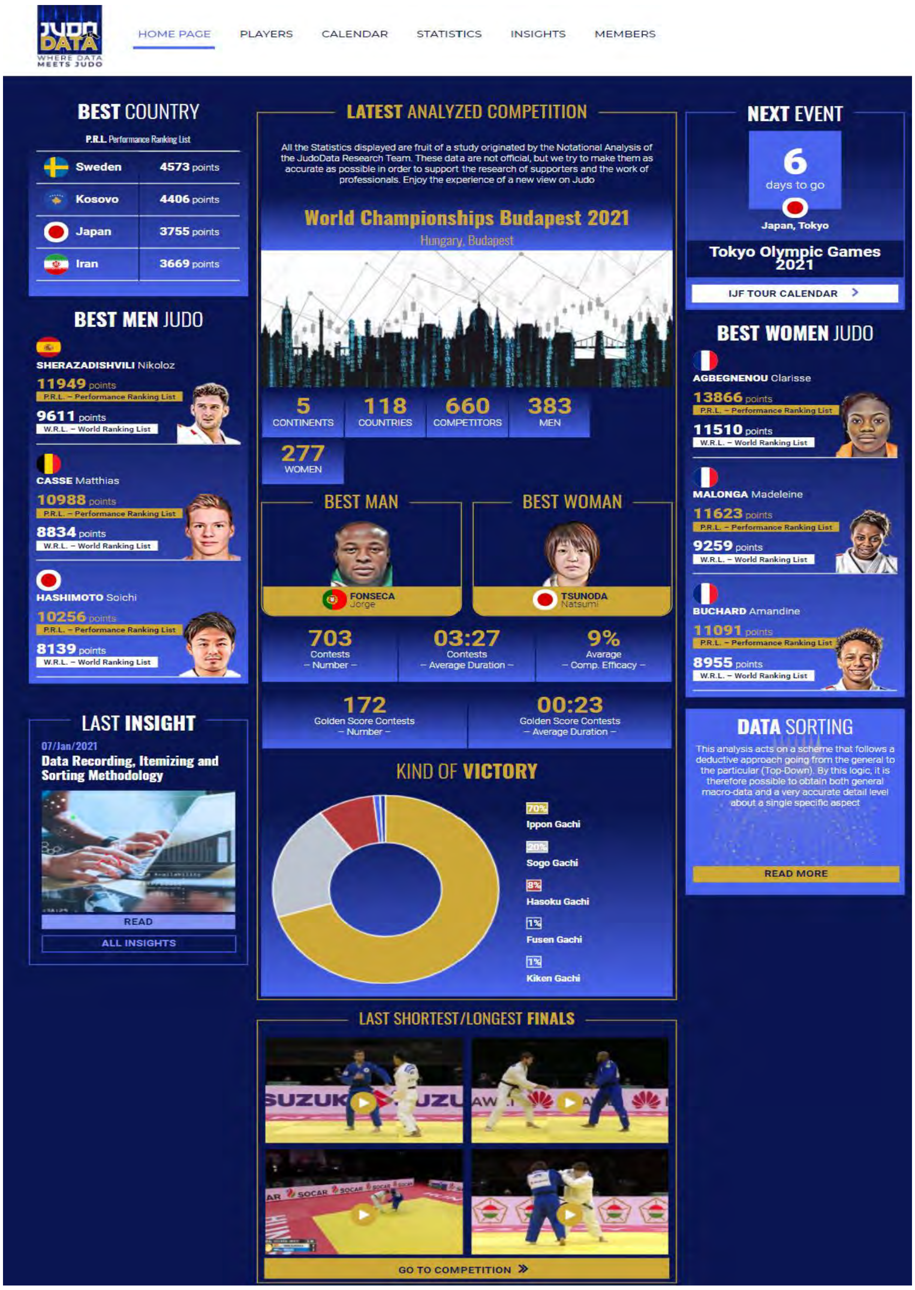


Fig.9.4.r. Judo data, home page

On the basis of the subscription level that you subscribe to, it is possible to filter and view the specific videos relating to what is requested (example: All the Uchi Mata that have produced a result and performed with the Classic grip on the Left (Hidari Kumi Kata).

The registered ***Events*** and some of their characteristics are:

Event - Features

- * ***Active Phases*** (Hajime-Matte) *: Duration; Approach to Kumikata; Referee
- * ***Passive Phases*** (Matte-Hajime) *: Duration; Video review; Referee
- * ***Tachi Waza Attacks*** *: Torì; Laterality Tori; Kumikata Tori; Uke; Uke laterality; Technique; Technical family; Referee
- * ***Ne Waza Attacks*** *: Torì; Torì Work Position; Uke; Opening Action; Technique (if any); Technical family; Referee
- * ***Sanctions*** *: "Uke"; Sanction Type; Reason for Sanction; Referee
- * ***Meeting Outcome*** *: Winner; Loser; Type of outcome; Referee.

From the calculation of the collected data, different indices of performance that make up the ***Performance Points*** of each Athlete in every single race.
These points are added to those of the official World Ranking List and generate the ***Performance Ranking List***, a list that takes into account not only the ranking position in the various tournaments but also the technical performance of each Athlete.
JudoData is aimed at a heterogeneous and varied public, being able to be simply consulted by enthusiasts and fans, or used by reporters to provide more detailed information, but moreover, it aims to become a tool for professionals who intend to maximize the work of Match Analysis through an extremely powerful and flexible visualization and search system.

Athlete Analyzer Judo

The first version of Athlete Analyzer Judo was released in 2015 and has been under constant development since then. Athlete Analyzer is software consisting of a web system combined with apps for iPhone and Android.
The purpose of the Athlete Analyzer is to provide a complete system for the long term development of judoka from club level up to Olympic team members. As we say – they are used by Olympians, made for everyone. Athlete Analyzer is easy enough to use for athletes from 14 years and powerful enough to support senior athletes on the highest level.
Athlete Analyzer consists of two main parts; Video Analysis and Training Management. There're extensive features to enhance collaboration between coaches and athletes within teams and also between coaches on different levels. Many of our athlete users are members of a club, a regional team and the national team. All coaches around each athlete use Athlete Analyzer to help the athletes to develop and reach their highest potential. ***Video Analysis***
Video analysis is a natural part of all athlete development. Athlete Analyzer facilitated this in a four-part process described below.

Video Upload
Many of our younger users use their smartphones to record their matches. After the competition, they upload their match videos to Athlete Analyzer. If the matches are broadcasted or stored on YouTube by the competition organizer, they can also link their matches directly from YouTube.

Video tagging
Usually, the athlete tags their own match videos. Athlete Analyzer comes with predefined structured tags, which makes it very easy and quick to tag match situations like scores and penalties.

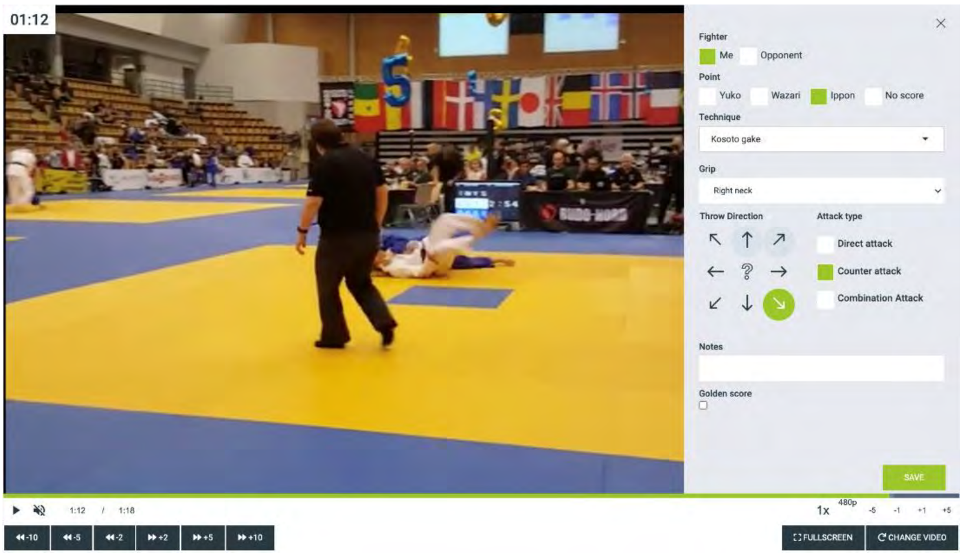


Fig.9.4s Athlete Analyzer Penalties and scores

On the highest level, it might be a coach or a video analyst who do the tagging, but we do not recommend that. There are many benefits to letting the athletes be responsible for the tagging. Two of them are:

- The athletes watch and reflect on their own matches in a structured way.
- The athletes take ownership of their own data, which allow for more objective discussions between the athlete and the coach(es).

An extra benefit is that the coach gets everything served and can use their time to focus on the analysis instead of the tagging. It makes it possible to help more athletes in less time.

Short term analysis

When a new match has been tagged by an athlete, all coaches connected to that athlete will receive a notification. The coaches watch the match and write comments and make illustrations on top of the video. Each comment is also a bookmark to the situation in the video, which improves communication and understanding, minimizing misunderstandings. This is extra useful if the athlete has both club coaches and national coaches. The short-term analysis is mainly used to find problems or opportunities to work on in the short term.

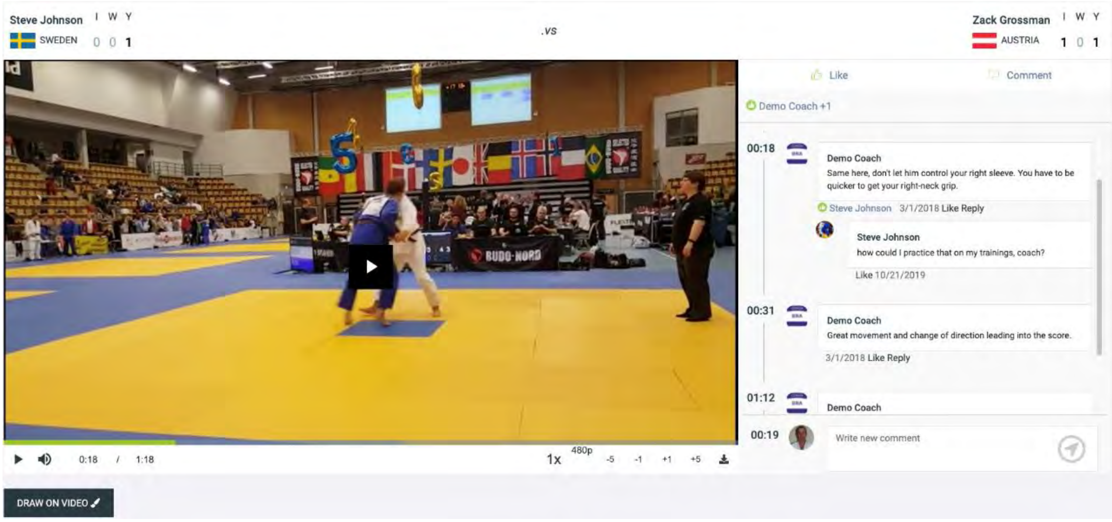


Fig.9.4.t Athlete Analyzer short term study

Long term analysis, statistical data

A strong focus through the whole development of Athlete Analyzer has been to make the statistical data easy to understand and actionable. We want athletes from pre-cadets to seniors and their coaches, regardless of level, to get detailed insights into their strengths and weaknesses.

Athlete Analyzer visualizes patterns in various graphs which can be clicked on to filter down on what needs to be analyzed further.

The statistical data is divided into three different Analysis perspectives; Techniques, Penalties and Matches. It is, for example, easy to see which techniques that have a high rate of usage but has a low score efficiency. The data is bookmarked to the videos, which makes it very quick and easy to study each technique in detail.

It's possible to combine the filters so the user can, for instance, discover which techniques are the largest threat at the last match minutes and so forth. The possibilities to make new insights are nearly endless.

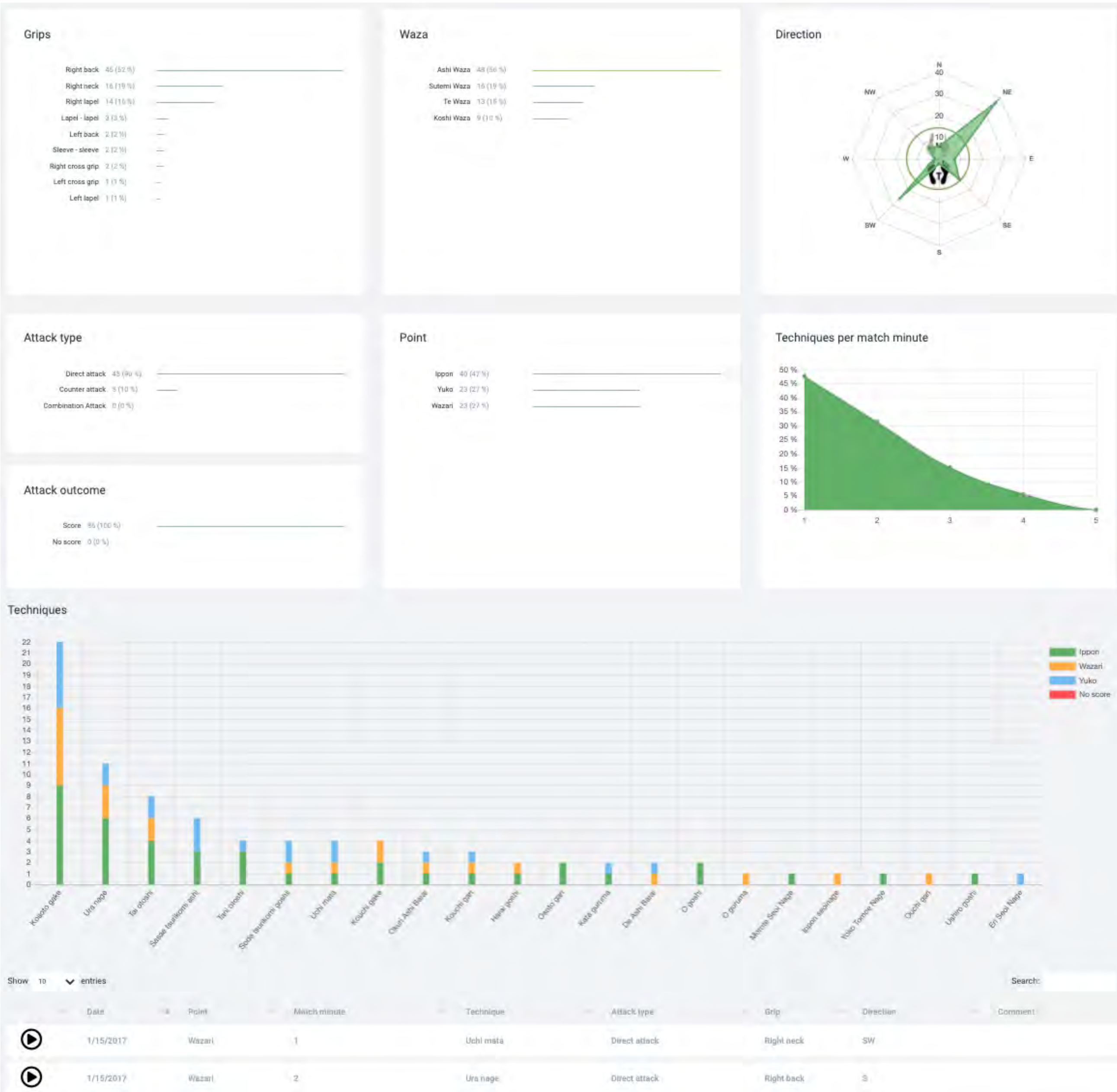


Fig.9.4.u Athlete Analyzer data statistical treatment

Playlists
This is a very used feature to simplify the collaboration between the athlete and the athlete's coaches.
Common use case:
The national coach is performing a long-term analysis and discover some areas to improve during the next training period. The coach can easily add some of the bookmarked video clips to a playlist and then share them with the athlete and the athlete's coaches. This makes the collaboration between the national coaches and the club coaches very effective. All coaches around the athlete, and of course the athlete, know in detail what to work on in their further development. ***Training management***
The training management in Athlete Analyzer is developed with a strong focus on the collaboration between coaches and their athletes and ease of use.

Training planning
The training management process starts with the training plan. The coach creates a training plan by adding appropriate workouts to a calendar. It is possible to use premade training blocks or create new blocks for later reuse. We recommend planning 4-6 weeks ahead before sharing the plan with the athletes. It's also possible to add other events like competitions and training camps in the plan, usually with a longer planning horizon than the detailed workouts.
Training plans can also be shared with other coaches, which makes it possible to collaborate using the same plan. This is often used in teams where coaches have different responsibilities, for example, judo training or strength & conditioning. Another common scenario is the collaboration between the national coaching staff and club coaches. The national coach can share a general plan with the club coach, who can adjust it to fit the specific needs in the club and then share it with the athletes. Since the national coach staff might have very high competence, this means that this knowledge is transferred down to the club level.
When the training plan is ready enough to share, the coach shares it with the athletes. The plan can then be ongoingly edited, which updates all athletes' calendars in real-time.

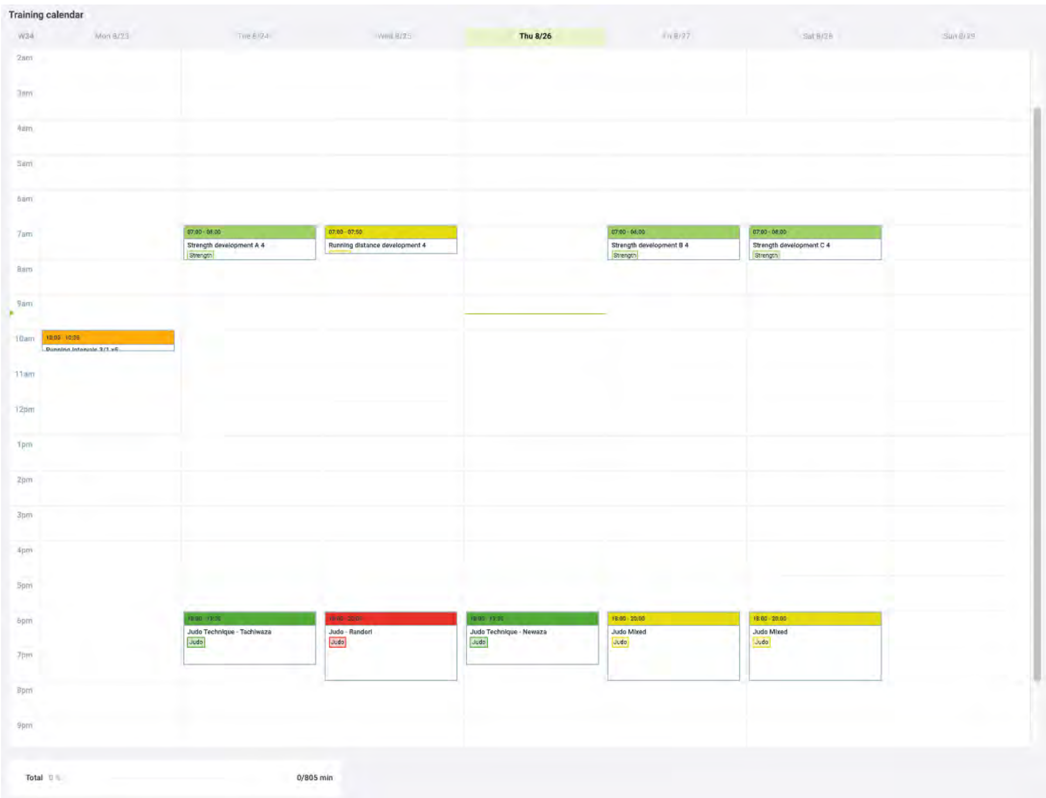
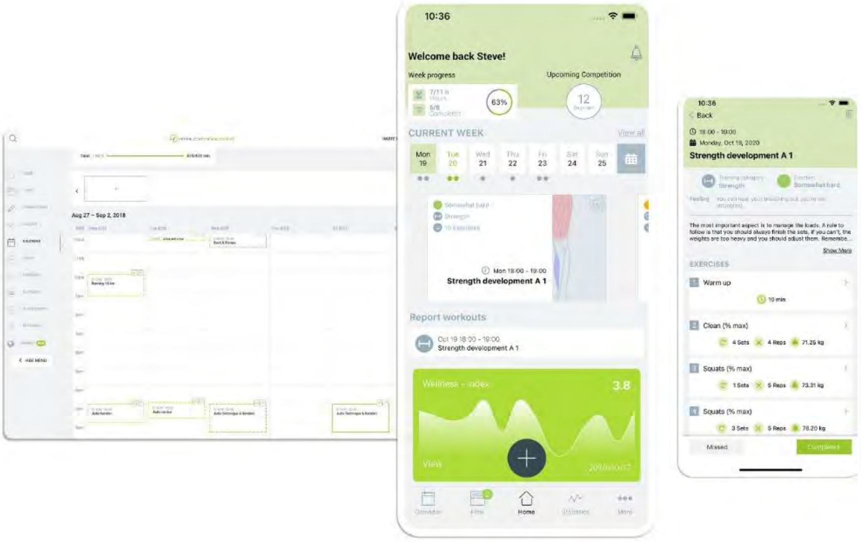


Fig.9.4.v Athlete Ans analyzer training workouts exempla

Training diary
After the coach has shared the plan, the athlete can see what to train every day. The plan with the workouts is accessible both in the apps for iPhone and Android but also in the web app (see picture). Whenever the coach makes a change in the plan, it updates the athletes' calendars. There's no need to send updated plans in any way.



The athlete can see every exercise in the workout and simply mark the workout as done after completion. The athlete also needs to rate the RPE in order to calculate an individual training load. One very appreciated feature is that the coach can plan the weight load in percentages for weight lifting exercise. Athlete Analyzer automatically calculates the planned weight based on each athlete's individual one repetition maximum (1-RM). The system also adjusts the athletes' 1-RM values based on which weights the athletes report that they have used. This enables the planning of strength training for athletes with different physical capabilities with only one training plan.
Athlete Analyzer comes with integrations to well-known HR watches/HR bands like Polar and Garmin. If the athlete wears one of their gadgets, the data gets imported to Athlete Analyzer automatically. This is very useful to analyze cardio sessions in detail.

Training analysis
All training data can be analyzed in various ways. Some basic charts are regarding the training load and the categories/minutes trained.

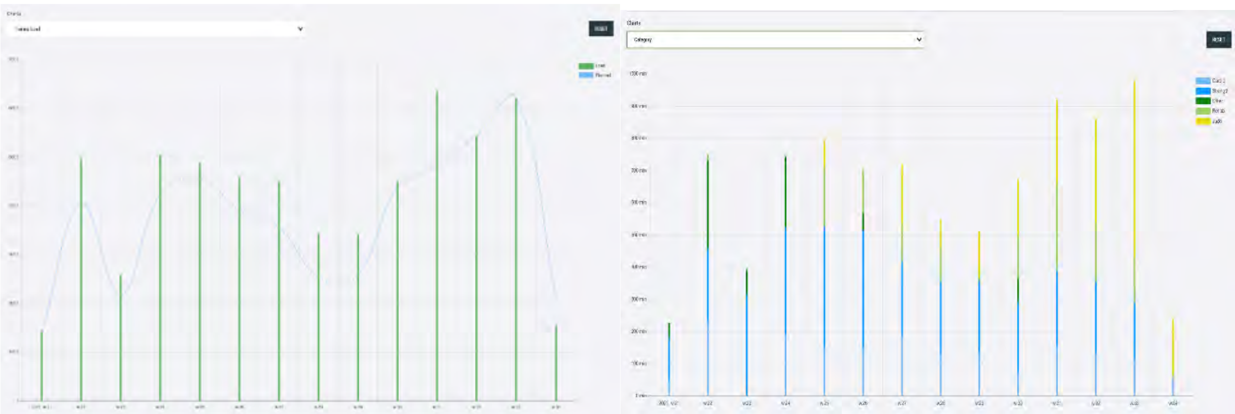


Fig.9.4.x,y Athlete Analyzer Training data

Athlete Analyzer also offers more advanced training analysis like training insights and injury risk. Training insights uses the training load to calculate Fitness, Fatigue and Performance levels according to the TSB formula. It's also possible to use this graph to adjust the training ahead to create optimal tapering before important competitions. The dotted lines show the athlete's levels with their current training plan.

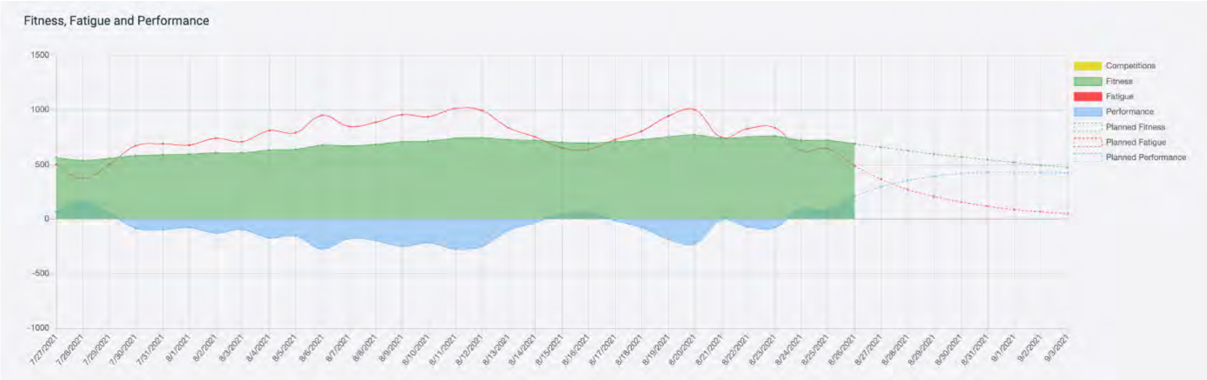


Fig.9.4.w Athlete Analyzer Training data

The system calculates the acute: chronic workload ratio, which makes it possible to monitor the athlete's current injury risk and prevent overtraining.

Fig.9.4.z Athlete Analyzer Training data

Summary and additional features

Athlete Analyzer comes with a comprehensive set of tools to cover all the needs of a judo team. The video analysis section shows the strengths and weaknesses of each judoka in the team. The training planner and training diary make it possible to plan and execute what's most important for each judoka in the team.

The strong focus on collaboration in the system enables collaboration between all team staff members. It also makes it possible to collaborate between different levels, such as national, regional, and club levels.

Additional appreciated features to those described are, for instance, wellness reporting and automatic sleep logging from Polar and Garmin. This creates a solid knowledge and understanding about each judoka in the team and how they respond to the often hard training required to reach success in judo. One other very useful feature is “Flow”. Flow is a kind of social platform within Athlete Analyzer where all activity from the athletes automatically shows up. It makes it very convenient for the coaches to give feedback on the athletes’ efforts, whether it is a competition or a workout. As we all know, feedback from us coaches is an important key to reach good compliance to training plans and keep motivation high among our athletes.

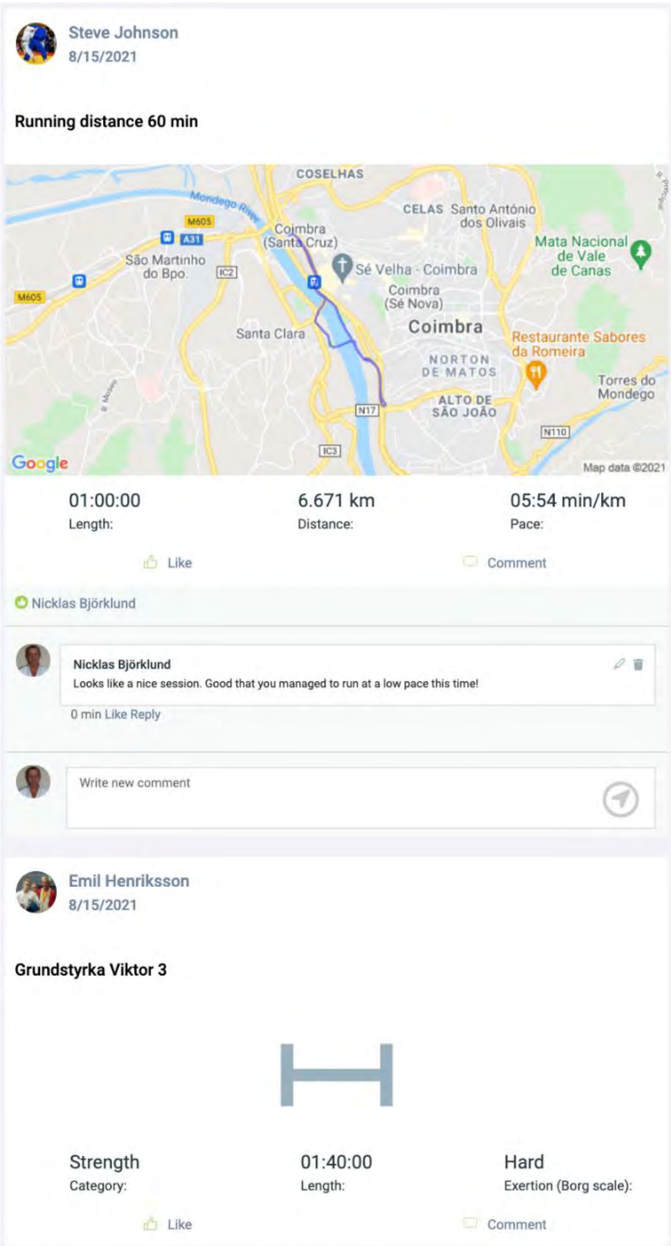


Fig.9.4.a,a Athlete Analyzer “ Flow” exempla

9.5 Prevision Area: Input for Forecasting

Our goal is to develop a pattern utilizing mathematical tools to obtain helpful information about high-level Judo competitions in these paragraphs. In the first part of this paragraph, we will face the capability to get strategic input from the athletes' pattern trajectories on the tatami during competition.
In the second one, we deal with the problems: it is possible to evaluate the probability of a win in a contest or tournament? And it is possible to forecast something useful for coaching?

High mathematics for strategic evaluation

The motion patterns of a couple of athletes' systems are a useful, practical tool with hidden information inside.
The shifting patterns study could be a source of valuable strategic data. However, the price for extract the hidden information is a non-trivial mathematical analysis of these unique time series.
In fact, for what concern the tracking trajectories one of the authors demonstrated 20 years ago, that the shifting paths of a couple of athletes COM projection must be considered belonging to the class of Brownian motions. In the fractional Brownian motion (fBm) approach, initially presented by Mandelbrot and van Ness in 1968, any time series can be considered a combination of deterministic and stochastic mechanisms.
The concept developed through fBm is, indeed, a generalization of Einstein's work. This work showed that a stochastic process is characterized by a linear relationship between mean square displacements $< x^2 >$ and increasing time intervals t, in the formula:

$$\langle x^2 \rangle = 2D\Delta t$$

The general principle of the fBm framework is that the aspect of a trajectory is expressed as a function of time. This can be calculated by a nonfinite integer or fractional space dimension, hence providing a quantitative measurement of evenness in the trajectory.
It is possible to write in mathematical form:

$$D_t^{\alpha}\left[X(t)\right] - \frac{X(0)}{\Gamma(1-\alpha)} t^{-\alpha} = \xi(t)$$

The first term is a fractional derivative. The second is connected to the initial condition of the process. The third is always the random force acting on the COM.

The fractional Brownian motion has the following covariance :

$$\langle x(t_1)x(t_2) \rangle = D_H \left[t_1^{2H} + t_2^{2H} - \left| t_1 - t_2 \right|^{2H} \right] = \Gamma(1-2H) \frac{\cos \pi H}{2\pi H} \left[t_1^{2H} + t_2^{2H} - \left| t_1 - t_2 \right|^{2H} \right]$$

In this case, it is essential to know the mean square displacement of the p

$$\left\langle \left[X(t) - X(t) \right]^2 \right\rangle = \frac{\langle \xi^2 \rangle}{(2\alpha - 1)\Gamma(\alpha)^2} t^{2\alpha - 1} \propto t^{2H}$$

By this expression, it is possible to understand that we are in the presence of different diffusion processes identified by the Hurst parameter.

In particular, this parameter is time- independent. It describes the fractional Brownian motion with anti-correlated samples for $0<H<1/2$ and correlated samples for $½<H<1$.
If H is = to ½, we can speak of pure Brownian motion.
It is also essential that an fBm is connected to a Fractal based Poisson point process. This unique feature will be handy and utilized in the next paragraph to find the suitable theoretical basis to evaluate victory probability and short-term forecasting of a Judo match.
Davidsen & Schuster [37] draws attention to a plausible but straightforward method for generating fractal-based point processes from ordinary Brownian motion.
Their construct resembles a conventional integrate-and• reset process. However, it differs in that the threshold, rather than the integration rate, is a stochastic process.
This kind of behaviour occurs in the body's neurophysiology. For example, ion-channel current fluctuations give rise to random threshold fluctuations. In the model considered by Davidsen & Schuster, the rate remains fixed, and the threshold process is taken to be ordinary Brownian motion. When the integrated state variable reaches the threshold, an output event is generated. The state variable is reset to a fixed value, as with a conventional integrated and reset process. It is also essential to see the autocorrelation coefficient of fBm that, as well known, depends only on the time increment and not by the time function.
The autocorrelation coefficient for all sorts of fBm depends only on the ratio τ/t where τ=t'-t.

$$\rho(\tau-t)=\frac{1}{2}\left(\left|\frac{t}{\tau}\right|^{H}+\left|\frac{\tau}{t}\right|^{H}-\left|\sqrt{\left|\frac{t}{\tau}\right|}-\mathrm{s}ng\left(\frac{\tau}{t}\right)\sqrt{\left|\frac{\tau}{t}\right|}\right|^{2H}\right)$$

.

For the particular case τ = -t we have :

$$\rho(\tau,t)=\rho(-t,t)=1-2^{2H-1}$$

We also remember that only for H=1/2 (Regular Brownian Motion), the autocorrelation coefficient for t and -t is independent. Whereas fBm (t) and fBm(-t) are connected depending on the previous history. [38]. Athlete's Tracks (***Dromograms***) are the evolution in time of a couple of Athletes COM projection on the tatami area.
Generally, in the old Match Analysis, each technical action and throw was considered belonging to a class of the Markovian System. This means that it depends on the previous instant only, without correlation with the past movements. However, a more advanced mathematical approach let able to overcome this conceptual limitation and mathematical simplification.
As we have seen before, an essential feature of fBm modelling for each fighter is the long-term correlations between past and future increments.
This means that the system is not Markovian and then more similar to the actual situation.
It is interesting to note that the human paths produced by strategic thinking are very similar to track produced by inanimate elements.
The scaling regimes can assess this.

In this way, a fighting path can show, if correctly analyzed, when the fighter has a specific fighting strategy or not (kind of random motion) during competition.

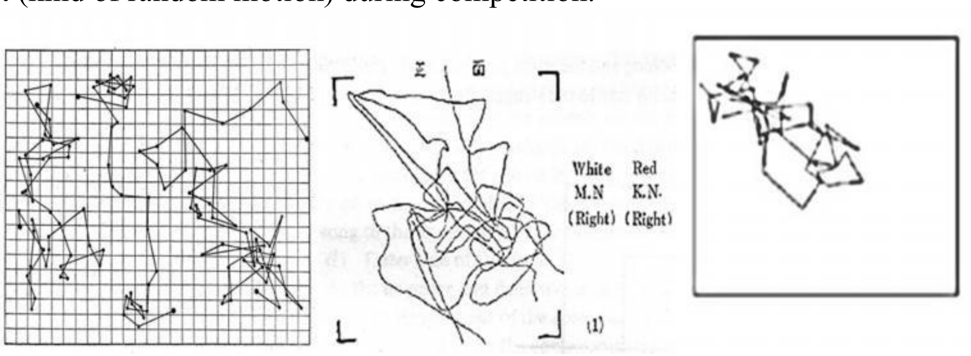


Fig. 9.5.a.b.c. Three trajectories were obtained by tracing a small grain of putty at intervals of 30 sec. Very similar to human shifting path CM projection on the tatami in competition. And Shifting path Computer simulation by fBm.

For example, a median value of 0.5 for *H* indicates no correlation, suggesting that the trajectory displayed a random distribution (Brownian motion).

On the other hand, if *H* differs from 0.5, a positive ($0.5 > H$) or negative ($H < 0.5$) correlation with his fighting way can be inferred, indicating that a given part of the initiative is under control. Depending on how *H* is positioned, concerning the median value 0.5, it can be inferred that the subject more or less controls the trajectory (and the fight evolution in time): the closer the regimes are to 0.5, the larger the contribution of stochastic processes (random attacks without strategy) — in addition, depending on whether *H* is greater or less than the 0.5 thresholds, persistent (attacking) or antipersistent (defending) behaviour can be revealed, respectively. In other words, if the CM projection at a particular time is displaced towards a given direction, the larger probability is that it drifts away in this direction (persistent attacking behaviour). Or, on the contrary, it retraces its steps in the opposite direction (antipersistent defensive behaviour). Thus, the trajectory contains more information than the mean squared displacement. In particular, one can measure the waiting time distribution from stalling events in trajectories.

For pronounced antipersistent processes, immobilization events should be observed. i.e., for particular periods, neither coordinate should show significant variation (athlete stops the shifting action). Due to the scale-free nature of fBm antipersistent, these stops should span multiple time scales. If such events occur, they are indicative of the nature of the process. The absence of such features in shorter time series cannot necessarily rule out the fBm dynamics, particularly for H closer to one (ballistic motion). Distinct stops are relatively rare events and possibly require a very long time of fighting.

Equality between these two probabilities ($H= ½$) indicates no defined strategy in fighting, like simple random motion or stochastic process.

This information obtained by a pure "mathematical lecture" of trajectories; can be enhanced by adding other scientific fighting information to the previous advanced mathematical lecture. Like Grips form, Competition Invariants, Action Invariants, Attack practical many-sided surface, Direction of displacement, Time and position of gripping action, Throws "loci", Length or Amount of displacement, Medium Speed, and Surface Area Utilization and so on.

With this added information, it is possible to obtain much useful strategic information structured as a tree and treat this tree of information with practical Data Mining algorithms to categorise potentially effective strategic connections among shifting trajectories and other Biomechanical fighting information.

$a = \frac{\beta}{m} + \frac{1}{\tau}$, $c = \frac{v_a}{\tau} + \frac{P}{m} - \frac{A}{m} e^{-|x|/b}$. We assume the *time step is a random variable* Δt_{rand} belonging to Gaussian statistics with a mean time step Δt_m and a variance $\sigma_{\Delta t}$.
Thus, we have considered the following expression for the selected time *random variable*:

$$\Delta t_{rand} = \Delta t_m + n_{\Delta t} \cdot \sigma_{\Delta t} \cdot G\_norm \tag{8}$$

Where $n_{\Delta t}$ indicates the total range of variability ($n_{\Delta t} = 2$ for all the following numerical simulations). Then a *normal* "G_norm" gaussian distributed stochastic variable ($\mu = 0$ and $\sigma = 1$) can be provided by the *Box and Muller* (1958) algorithm:

$$G\_norm = \sqrt{[-2 \cdot \ln(Y1_{rand})} \cdot \cos(2\pi \cdot Y2_{rand}) \tag{9}$$

Where $Y1_{rand}$ and $Y2_{rand}$ are two *independent* uniformly distributed random variables. That means that the intrinsic routine, related to the selected Compilator (RAND in Fortran 97), to generate random variables should be called. This subroutine *must be called twice* to obtain the two independent (pseudo-random) variables.
As a first step, a simple uniform statistic is assumed for a random rotation around the centre.
Thus, it was not implemented a more realistic dynamics introducing an *angular moment equation*.
The *random oscillation* towards the centre is simulated as harmonic motion.
Future improvements will regard some reasonable assumptions to build an "objective function". The main criteria will be to select a function correlated to the *player's strategy* around which, in a necessarily *randomly* Information, ordered by importance or effectiveness, is helpful for coaching and athletes. This is one example of the more advanced information obtainable by this underestimated practical tool: Athletes' shifting patterns.
Our analysis started from the microscopic approach to COM motion in the space, that is, fBm. From that derives the connection to the fBm described by the perpendicular of Athlete COM. So it is easy to induce that the Athletes Couple COM perpendicular motion is again an fBm at the microscopic level of fluctuation. But it was also proved that scaling at the lowest level, and the movement is always Brownian.
In support of this connected reasoning, an exciting theoretical demonstration was presented independently in a new paper. We now address a physical Langevin-based theory (Newton connected, remembering that it is a formal derivation of a Langevin equation from classical mechanics). He explained the emergence and the pervasiveness of the 'fractional motions' like Brownian motion, Levy motion, fractional Brownian motion and fractional Levy motion.
A general form of "micro-level" Langevin dynamics, with infinite degrees of freedom, is presented in the article. When we scale from the micro-level to the macro-level, the many degrees of freedom are summarized in only two characteristic exponents. The Noah and the Joseph exponent and the aforementioned fractional motions emerge universally. The previous two exponents categorize the fractional motions and determine their statistical and topological properties.
This functional theory establishes a unified 'Langevin bedrock' to fractional motions that, as we know, are the basic description of Judo shifting paths.

Mathematics for probability and short-term forecasting

From the theoretical point of view, now another question, it is possible in practical principle to have the winning probability for an athlete or forecast the result of his competitions?

It is tough to answer such questions, but the answer is yes from a mathematical perspective. We have specific mathematical tools to do it!
In effect, the solution of the answer is easy if we hypothesize that the attack pattern or occurrence follows the Poisson distribution.
As already demonstrated, athletes' couple motion is described by an fBm of COM's projection. It is also well known that the fBm is connected to specific Fractal-based Poisson point processes when phenomena occur at discrete times (or places) with similar individual events.

A point process is a mathematical construction representing these events as points in space and stochastic when associated with random phenomena like Judo throwing attack or judo gait steps, etc. For a stochastic point process, the statistics of this set of points provide information about the underlying structure of the phenomenon under study.
A fractal stochastic point process results when these statistics exhibit power-law scaling, indicating that the represented phenomenon contains clusters of points overall time or length scales [42].
When these discrete point processes follow the Poisson distribution, we can speak about Fractal based Poisson Point Processes
The Poisson process is an acceptable representation of several physical phenomena in judo, e.g., the attack waves or pattern, the order of feet steps, the random success of the attack, and random attack failures.
Simply put, the Poisson process could be an excellent mathematical descriptive model of **completely random** attack patterns.
The problem is focalized on the effectiveness of the mathematical model proposed, able to utilize the Match Analysis data collected. This model could be improved by modulating the parameters with opportune weights fitting the Match Analysis experimental data for each athlete. In effect, the model must provide the technical capabilities of athletes to shows the victory probabilities.
Or Example:
What is the probability of success (whatever positive result) at the third minute in the competition of one hypothetical athlete with four tokui waza two right and two left and three technical weaknesses, one right and two left and fitness 5/8 after eight actual attacks?
The Poisson attacks' counting process N(t) is Poisson distributed with attack mean λ at time t, and the probability of attack success satisfies the following equation: $P\left[N(t)=n\right]=\frac{(\lambda t)^n}{n!}e^{-\lambda t}$

with n=0,1,2,3,4…. Number of attaks
Where λt is the mean attack rate at time t that could be connected to the athletes' judo technical capability in contest time, in such way: $\lambda=(TA-\frac{TF}{(R+L)}+Fitness)\left\lfloor 1-e^{\left(1-\frac{\tau}{t}\right)}\right\rfloor$

TA = Technical attack (number of Tokui Waza);
(R+1,6L) TF =Technical failures (number of weak spots);
(0.5R+0,8L) R= Right Tokui Waza number L= Left Tokui Waza number
Fitness = number of success/numbers of previous contests
t= τ asked the time of the contest ***Answer P = 0.13 or 13%***

A different approach is connected to the short-term forecasting of Judo action. In this case, it is possible to discuss only in terms of Ippon obtained.
The apparent reason is that there is not a so sophisticated and flexible mathematical tool that can differentiate with precision the forecasting among three kinds of results that are inter-connected like

Judo refereeing evaluations (old rules): Yuko, Waza-Ari and Ippon. For these reasons, we consider only Ippon and Waza Ari results that are 90% of Ippon, as the same results.
In the case of short-term forecasting, with all the limits in this field, we must remember that we are in the presence of Fractal based Poisson Point Processes.
The best solution, in our knowledge, will be an ARMA model (Auto Regression and Moving Average) taking the value in the time of different Ippon or waza-ari obtained by the athlete during a tournament (the best will be with the same adversaries). These data typically could be arranged as a random non-stationary time series. Then their autocorrelation could be used to determine whether there is any pattern in it.
Classically in an ARMA model, the time series of attacks to be forecast is expressed as a function of both values; previous values of the series (autoregressive terms) and previous error values from forecasting (the moving average terms).
The final concern will be to choose the correct ARMA dimension to obtain a short-term forecast of ippon data. Again, a modern mathematical approach let able to overcome the conceptual limitation of the old performed Markovian process.
A significant feature of fBm modelling for each fighter shifting path is the long-term correlations between past and future elements. This can be assessed by the effective presence of the scaling regimes. But the scaling rule in shifting path underlines another meaningful connection the phenomenon (gait steps) could be connected to a fractal-based Point process. **Then a shifting course can show when the fighter has a specific fighting strategy or not (random motion) during competition.**
For example, a median value of 0.5 for *H* indicates no correlation, suggesting that the trajectory displayed a random distribution (Brownian motion).
On the other hand, if *H* differs from 0.5, a positive ($0.5 > H$) or negative ($H < 0.5$) correlation with his fighting way can be inferred, indicating that a given part of the initiative is under control. Furthermore, depending on how *H* is positioned, to the median value of 0.5, it can be inferred that the subject more or less controls the trajectory (and the fight evolution in time). The closer the regimes are to 0.5, the larger the contribution of stochastic processes (random attacks without strategy). In addition, they are depending on whether *H* is greater or less than the 0.5 thresholds, persistent (attacking) or antipersistent (defending) behaviours can be revealed if H is greater than1. For example, the athletes' tendency to take some stops is already shown in a previous paper.
Obviously, this information obtained by a pure "mathematical lecture" of trajectories; can be enhanced by adding to the previous advanced mathematical lecture other Biomechanical fighting information like Grips form, Competition Invariants, Action Invariants, Attack functional polygonal surface, Direction of displacement, Time and position of gripping action, Throws "loci", Length or Amount of displacement, Medium Speed, and Surface Area Utilization and so on.
With this added information, it is possible to obtain many practical strategic details. Structured as a tree and treat this tree of knowledge with opportune Data Mining algorithms to categorise potentially effective strategic connection among shifting trajectories and other Biomechanical fighting information.
More deductions can be inferred, based on the suitable mathematical model, by the Match Analysis. Describing more judo aspects (like generation of shifting path, gait steps or pace, attack wave, etc.) by a Fractal based Poisson point process or simply by a Poisson Point process, it is possible to obtain information about the order of magnitude of the probabilistic evaluation of the attack success at a limited time in the competition. Or the tentative short term forecasting of a victory in a match like the probability to take Ippon utilizing ARMA methodologies. This information, ordered by importance, effectiveness, and obtainability, is helpful for coaching and athletes to build a proper competition strategy.

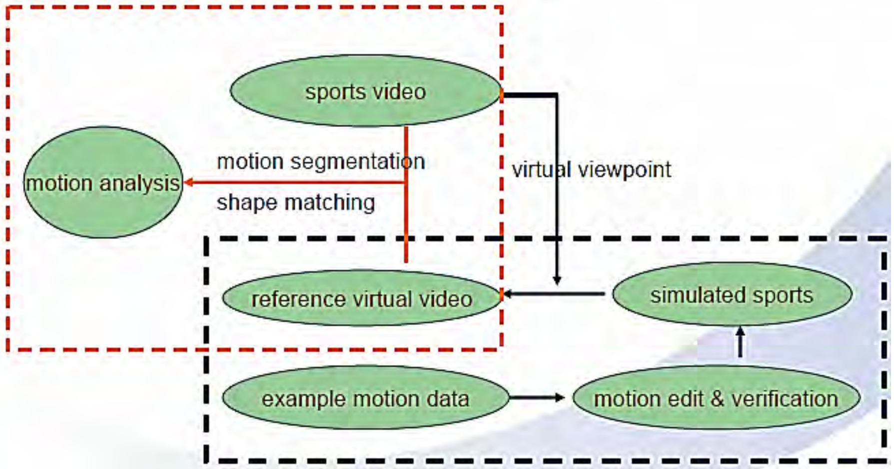
9.6 JUDO: The Next Generation (virtual training)
Virtual Reality VR augmented reality AR and Phone APPs.

New Training Way

Coaches at all levels face the difficult task of creating challenging training sessions for their Athletes regularly. One particular means of improving player learning is by aiding athletes' understanding of the tasks they must carry out. Indeed, clear and precise instructions are an essential component of any learning process. In this field works on virtual reality to particular motor skills, aiming to develop techniques which can improve performance, are helpful to coaches that are interested in examining whether training in the iconic environment can help trainees to detect the mistakes that they are doing when performing specific tasks

Virtual Reality

Taking this approach even further is ***virtual reality*** (Bideau and co-workers., 2004; Del Percio and co-workers. 2007). This may be defined as the simulation of a real or imagined environment that can be experienced visually in three dimensions: sound, tactile, and other forms of feedback.
The High-Tec training methods are widely used in China for the Olympics as an example for video superimposing. In the following diagram, we can see the overall Chinese approach.



Diag. 9.6.a Chinese virtual training system

This approach has previously been used in American football as a training mechanism by simulating the environment of elite competition through material such as cyber eyeglasses, data-generating gloves and simulators. This environment will allow players to experience and relive all the sensations (e.g. crowd noises, wind, rain) they usually feel in real competition and provide visual and motion cues on performance. In the next, there is shown the cave system from the University of Michigan.

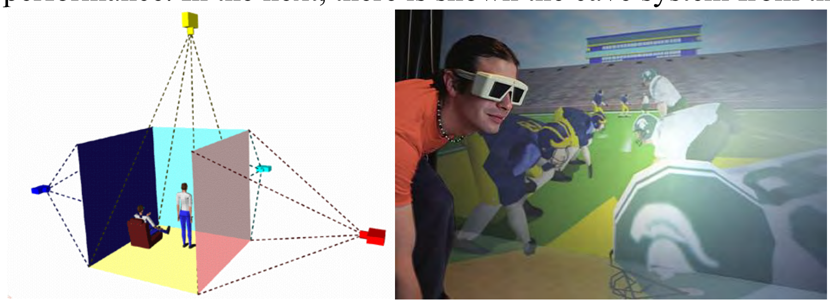


Fig.9.6.a US Virtual training tools

The Virtual Football Trainer is a sophisticated and highly interactive software package that integrates the following functions:

- Modelling and editing a play on a laptop in two dimensions
- Automatic creation of the three-dimensional play animation
- Controlling the 3D play animation in the CAVE
- Distributing the 3D play animation over the Web

From Japan came the wrestling arm; the prototype system of a 5-DOF force display system with four air cylinders and a force sensor is developed for the affect display and interaction of virtual humans based on human nonverbal behaviour and physiological measurement in arm wrestling. By using the system, the relations between force display and physiological index of the peripheral skin temperature of fingers associated with circulation dynamics in response to forced actions are examined

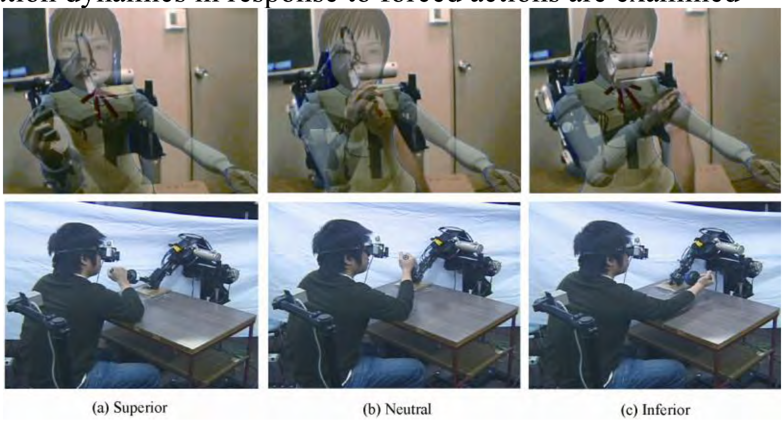


Fig.9.6.b.c.d.e.f.g, Japan virtual reality training with a robot.

Virtual reality aims to speed up learning time and the achievement of optimal performance. The system will also use relevant information on playing performance, such as fitness and tactics, to maximise the effect. For example, the computer can recreate match actions such as pickups attacks. The athlete's performance can then be analysed during each activity, and virtual reality is then used to improve specific techniques. Players wearing a computer-linked virtual reality suit will be helped and guided through the exact movements required, again using an expert model.

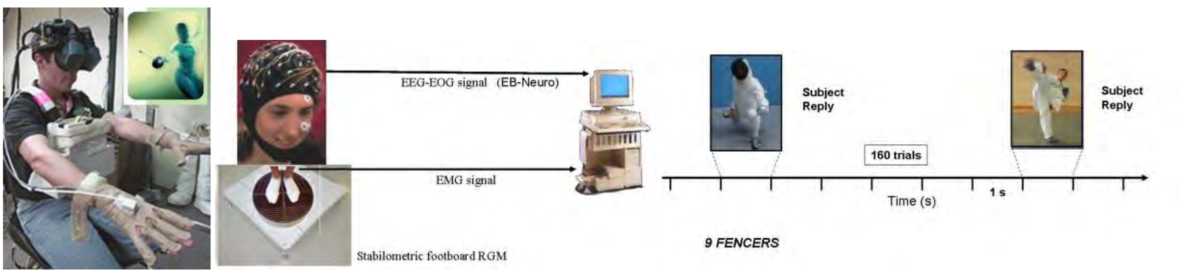


Figure 9.6.h – Virtual Reality Fencing and Karate– NeuroLab CONI, Italy, 2008

AR Augmented Reality

Augmented reality is a technology that allows to simulate and improve the technique, for example, of the judo throw using what and how the competitor, in reality, performs it.
It also allows the imposition of a given physical structure of the computer-generated sequences of movements.
The imposition of these two images on each other (overlapping in the image of the actual and computer image) is called 'imaging' of reality.
Another operative definition of Augmented reality is possible to find in Mauro Cesar Gurgel de Alencar Carvalho and coworkers "Augmented reality applied to Ushiro ukemi visualization" 2007.

An AR system supplements the real world with virtual (computer-generated) objects that appear to coexist in the same real world. While many researchers broaden the definition of AR beyond this vision, we define an AR system to have the following properties:
combines real and virtual objects in a natural environment; runs interactively and in real-time; and registers (aligns) real and virtual objects with each other

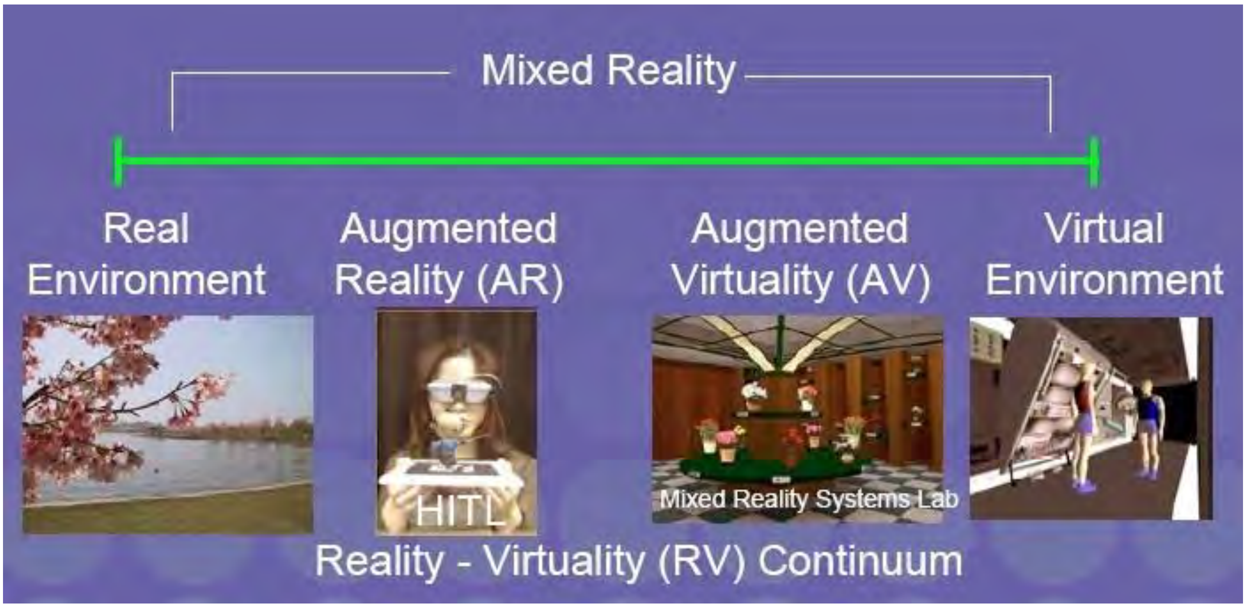


Fig.9.6.i Representation of Augmented Reality

The consequence of imaging in this technology is conducting mental training using "sighted glasses". These glasses show the examined competitors how they should do the throw in the best way. This technology was also applied to train kata and technical teaching and improve throwing techniques: Vojciech and coworkers 2015.
But Augmented reality could also be utilized as French Federation to recall the fundamental values conveyed by judo and spotlight the sportspeople taking part in the competition. See the following URL: http://www.allucyne.com/en/customer-project/judo-kodokan-4

APPs Judo Phone Application

During this period of the Covid 19 epidemic, many telephone APPs related to Judo and the possibility of keeping the memory of training, knowledge and even match analysis have flourished or have been improved.

Movesensei Virtual Learning Environment For Judo

Movesensei is a virtual learning environment for Judo throws. It is available on mobile devices in Android and Apple Play stores for free. Being interactive, Movesensei allows people to study details and phases of the throws independently. There were multiple reasons for developing a modern tool like Movesensei for Judo, e.g. to support Judo as a sport to improve and especially help people new in the sport to have a long life in Judo. Judo is a highly demanding sports activity where reaction must be done fast, and execution of the throws must be effective. This requires a clear vision of the movements that have been practised into skills.

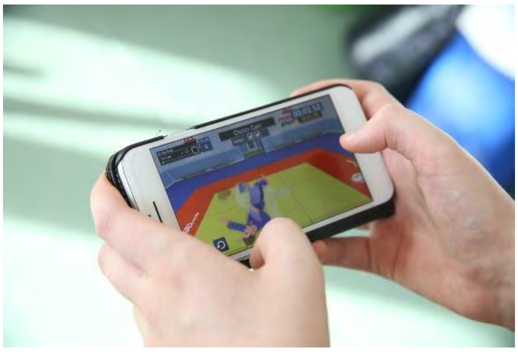


Fig. 9.6.j. Movesensei is a virtual learning environment for learning judo throws, and it runs on mobile

Judo has maintained traditions well all over the world, which is making the judo community united. This is a benefit, but it will make starting the sport more challenging with vocabulary and many new things to learn. With Movesensei, it is possible to learn the names of the movements and directions of the throws. Then on the tatami, it is possible to train physical skills for the movements. In *Figure 2,* ukemi is presented. Ukemi falls are important for safe landing and base of health and long training career in Judo.

Fig.9.6.k., Ukemi for different directions is done first before throws

The main principles in Judo are maximum efficiency and minimum effort. Methodology for constructing the throws in Movesensei is based on a Biomechanical re-assessment by Professor Attilio Sacripanti. Biomechanics is the most general and comprehensive classification for treating the techniques and therefore is the most suitable for Movesensei purposes. It is the perfect way to demonstrate functional phases of the throw, and it is possible also to give some measures for the forces during the throws.
All the throws are expressed by two forces *F1* and *F2,* that are affecting from opposite sides of the uke. With these movements, it is possible to control rotational movements, which are causing uke to fall down and land into his back. Forces describe the forces during the throwing phase, i.e. kake in Japanese. The

Kake phase was selected because that it is a moment during the throw where energy is consumed the most. Biomechanics reassessment is useful for teaching purposes since it expresses well that movements from the whole body are needed for completing the throw. So even in leg or hip, or hand techniques, whole-body rotations are used to complete the throw effectively. In *Figure 3,* sample throws are shown with Throw analyses. Throw analyses are calculated after the throw based on the user's height and weight. Based on these quantitative figures, it is possible to get an idea between the throws and see how well principles in judo are executed. Currently, separation is done between two forces. Later, they can be further divided into Lever- and Couple type throws.

Fig.9.6.l.m., Throw analyses after completing the throws are presented

Although Movesensei is still in its early days, it can be used as a supplementary learning material for serving the judo community. It gives teachers one extra way to activate and engage groups between lessons. Students can see information on the throws they have contributed themselves.
As an example of using Movesensei for supplement training, the teacher tells the group that next week we practice O-soto-Gari in the training sessions.
Students learn osotogari during time off the tatami. They can discuss on principles and directions of forces during the throw. It is possible to compare needed energy for the throw and compare how much relative energy are needed for completing the throws.
After this, physical skills are developed during training.
Future development for the Movesensei will include more dynamic situations and interactivity. There will be scenarios for action-reaction, in which principles of judo throws become even clearer and more interesting. Additional throwing techniques will be introduced. As an interesting part, throw-analysis will be continued further. With proper throw analysis functions, it is possible to tune any of the throwing phase parameters independently, and the range can change from maximum efficiency to maximum safety. Based on the information gathered from the virtual environment, it is possible to formulate ideas and strategies on judo before physical skills develop. This can keep people longer in the sport and help them reach their goals.
Movesensei will make the Judo community around the world more united and active. It helps this great sport to expand, and the impact of judo principles executed more effectively.

Judo & Match Analysis

Judo throwing related database

Judo and Match Analysis is an Italian App produced by Decasport. it that is able to collect information about tournaments in a specific database in which you can record the technique applied, its directions, weight and etc.:
Archive of the techniques performed and suffered in the competition,
History of matches played in the "Tournaments" section only for techniques selected, for example utilizing the button "Eff", etc.

Fig.9.6.n., The cover image of Match Analysis App,

This App could be very useful to study personal development or adversary scouting offline in order to prepare himself for the next tournament,
One till now evident limitation of this App is, the Italian language utilized, till now there is not an English working edition

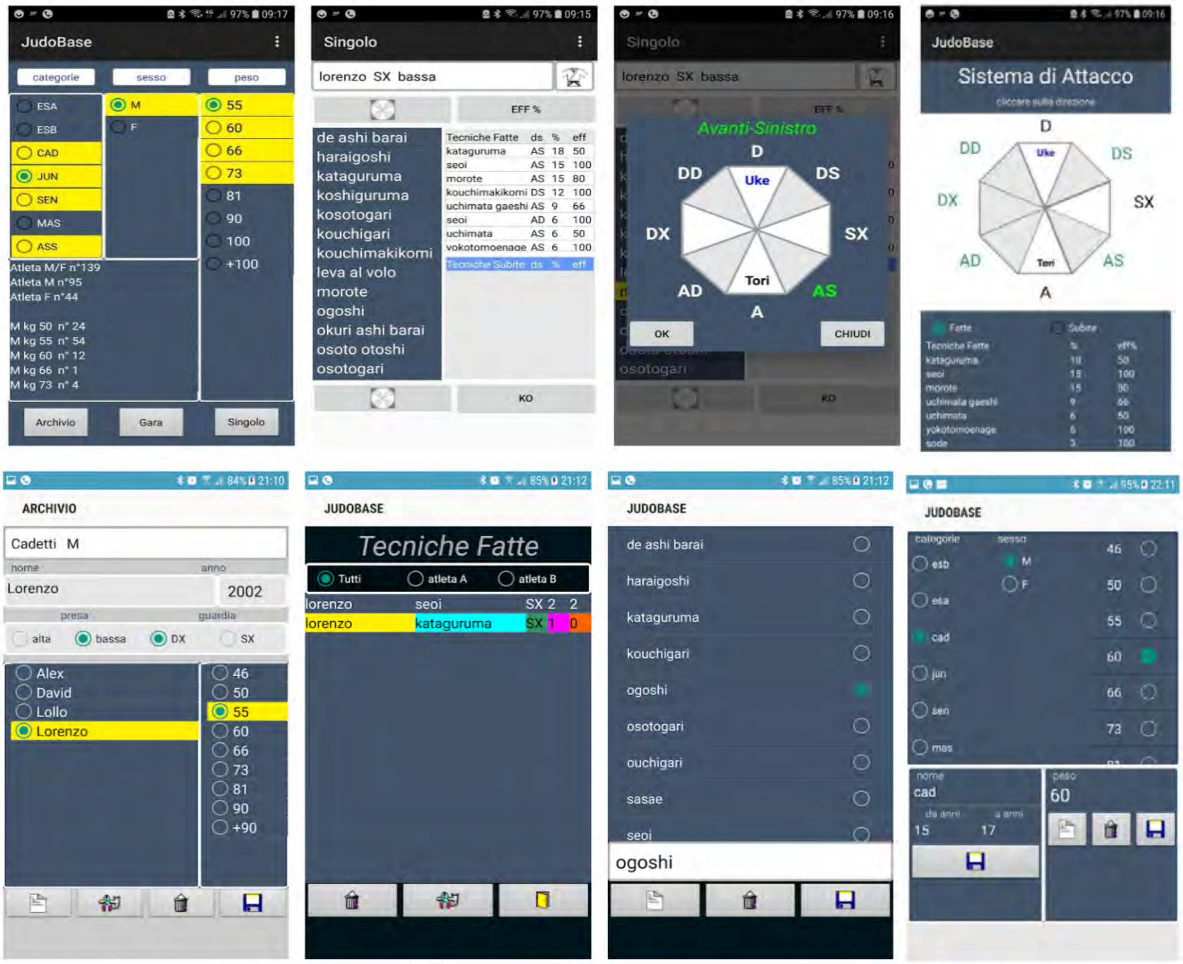


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Fig.9.6.o.p.q.r.s.t.u.v., Some screen-shots of this App


ALG
KOR

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Chapter 6 - Biomechanics of Groundwork Techniques

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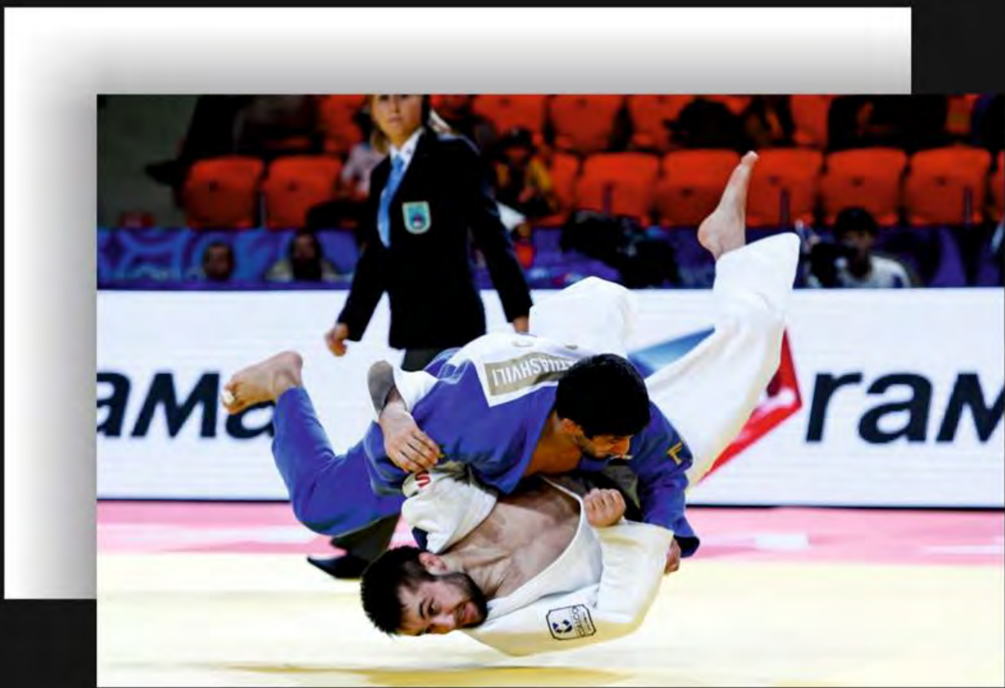


Appendices

Judo beyond Legend

Man and Judo Scientific Complexities

Man and Judo Scientific Complexities

Non-linear complex systems are difficult to analyze. But non-linear models and nonlinear data processing methods are much more appropriate to study man and complex sports like judo.

The "linear thinking" ignores the fact that the human body is a complex nonlinear system with static and dynamic fractals responses.

All sportspeople, from coaches to athletes, face challenging problems (many of them nonlinear). They overcome them with significant energy expenditure but waste time, with the old but practical "trials and mistakes" method".

Most of these problems would be more easily solved by the correct information obtained by appropriate analysis methods.

Even the European Parliament has emphasized the importance of nonlinear dynamics and deterministic chaos in biomedical researches. Then most of these results can be utilized by Biomechanics in sports analysis and even better in complex sports like judo.

In this part of the book, we present six very advanced appendices that show how difficult and complex is the Biomechanics of the beautiful world of judo. In the light of advanced knowledge, for six main reasons:

1. the complex nonlinear structure of the human body
2. very complex motion pattern in competition
3. infinite different positional situations not repeatable in time
4. Optimization of judo components and displacements
5. Complex experimental models to find the appropriate information or data from judo
6. Complex experimental and theoretical demonstration that some judo throws are safe for Athletes if rightly applied.

All the six appendixes show the objective complexity under the linear approximation; our world is a complex system. The Human body is the most complex system globally. Judo is a difficult sport among sports, the most complex sport in our daily lives.

About the previous six aspects of the "Judo" problem, the first appendix shows how difficult is the study of the situation, motion and interaction (Throw) in competition.

The second one shows us how nonlinear and fractal principles are often present in the human body from inside to outside up to sports motion.

In the third appendix, we face the problem with the athletes' motion from the starting standing still position shift on the mat. The Fractional Brownian motion, performed in every competition phase, is connected to the classical standard measurements of Newtonian Dynamics.

The fourth one is also very complex because it focalizes on the optimization problem of judo. This means throwing techniques to build one target function and maximising or minimising it, for displacements means applying optimization concept on a stochastic system.

The fifth and the sixth appendices faced the problem of safety in judo for children and for Tori, an issue very often undervalued, for the multi-disciplinary complexity of research design in this area.

We tried to solve these problems, but the problematic mathematical approach and complex experimental layout made it entirely understandable with a postgraduate formation. However, we try in the conclusions of each appendix to resume the main result obtained, when possible, in an easy way.

Appendix I
A Physical Complex System

Advanced Biomechanical theory of judo competition

Contest dynamic: Advanced Biomechanical Theory of Judo Competition

Advanced Biomechanical Theory of judo competition

I Introduction

Contest dynamics as a mathematical theory, therefore applicable to all contest sports, is the main topic of this paper. After the physical definition of "Athlete" and "Couple of Athlete" systems and after singling out the interaction fundamental parameter, we analyse the classes of possible potentials describing the interaction. In the end, we specify the physical bases of mutual interaction between athletes and the trajectories of flight motion.
All the matter will be connected to measurable quantities or parameters useful for researchers and trainers.

II "Athlete" and "couple of athletes" systems: definition and physical

The physical characterization of the environment of the contest quickly leads to the individualization of working forces on Athletes systems:
1) Gravity force, 2) the push/pull forces, 3) constrain reactions of the mat, transferred by friction.
Suppose we define the "Athlete" subsystem as a "biomechanical athlete". Namely, a geometric variable solid of cylindrical symmetry takes different positions and performs only definite rotations by the articular joints. In that case, we can easily define the global system that concerns the competition analysis: the "Couple of Athletes" system. This system is described as a jointed system of cylindrical symmetry built by the semi-rigid junction of two biomechanical athletes. This system will have only two "energy levels" with specific degrees of freedom.
A) A couple of Athletes closed system
The two biomechanical athletes have fixed and semi-flexible contact points, " the grips".
In this way, the two athletes are blended in only one system in stable equilibrium; this system moves by the third principle of dynamics. The ground reaction forces will be, in this case, the resultant of overall push/pull forces produced by both athletes.
B) "Couple of Athletes" open system.
The two biomechanical athletes have no fixed contact point. Therefore, to keep their condition of unstable equilibrium, they will be at best like a simple inverted pendulum model (Pedotti 1980) (4), while friction will be made motion possible by the third principle of Dynamics.
Having defined the Couple of Athletes open and closed systems and its components, i.e. the Athletes, the biomechanical analysis of contest dynamics, we will study in terms of system motion and mutual interaction, which according to the principle of the overlap of effects wd be able to be seen separately to obtain a more straightforward and more understandable solution.
The mechanics of competition cannot be analysed with the deterministic tools of Newton's mechanics. (not repeatable "situations" which happen "randomly" with a small probability of repetition on a vast number of contests) In effect, it would be more beneficial to study the problem according to statistical mechanics to obtain verifiable experimental results.

III Mutual distance as the main parameter of contest dynamics

The study of "Couple of Athletes" open system quickly shows us the main parameter which allows us to classify the mutual position of bodies usefully.
The relative distance between the two Athletes, the attack strategy and the execution of techniques are directly dependent on this parameter.
It is helpful to classify three kinds of distances that need three different biomechanical approaches.
1) Long distance (Karate, taekwondo, kickboxing, etc.).
It is the distance from which the unarmed Athlete will perform a successful kick attack.
It is the main distance in Karate contests
2) Average distance (Boxing).

It is the distance from which it is possible to box
3) Short distance (Judo, Wrestling, Lucha Canaria, leonesa, Coresh, Sumo, etc.).
It is the distance from which it is possible to grip or grasp the adversary. In this condition, the Athlete changes his position from unstable to stable. Grips are the primary tools to transfer the energy to the adversary both in opposition and in helping the throwing techniques.

IV Reference systems and interaction: definition and classification

After defining the physical strategy and the main interaction parameter and specifying the boundary conditions connected to system dynamics, the next step is defining " the reference systems" to describe motion and interaction.
The first reference system will be put in the gym (a Cartesian reference system solid with the gymnasium walls). It is in a reasonable approximation: the inertial reference system or the laboratory reference system.
The second reference system, valid for the simplified study of mutual interaction, will be put in the movable barycentre of "Couple of Athletes" open or closed system. This reference system will be called, " Centre of mass reference system".
In all contest sports: interaction can be seen, in the function of mutual distance, as a continuous shortening and lengthening of this parameter, during contest time, plus a few physical specific mechanisms to win each sport.
These mechanisms for the Couple of Athletes closed system can be classified, for contest sports, in two categories:
The winning Mechanisms able to throw down the adversary are based on two physical principles.
1) Application of a couple of forces; 2) Application of a physical lever
So, interaction happens before finding a contact point and applying the pull sufficient to throw down the adversary. In the second mechanism, the physical lever with a stopping point, the use of unbalance is necessary.

V Possible classes of potentials: a general study

In each contest sport, interaction is founded on two separate phases, a common one (shortening of mutual distance) and a specific one (applying permitted ways to seek advantage: strokes or throwing mechanisms). The standard part is comparable to a classic "two-body problem in the central field.“
From mechanics, we remember:
a) Instead of studying the motion of two athletes, it is possible to analyse the equivalent more straightforward movement, in the centre of the mass reference system, of only one sham athlete gifted with a "reduced" body mass $\frac{m_1 m_2}{m_1 + m_2}$
b) In the centre of the mass reference system, motion can be described by a two-dimensional trajectory on the ground (mat) making use of the coordinates: r e θ.
c) Instead of solving the integral of motion by differential equations, it is better to use for the solution the Lagrangian of the system that is potential and kinetic energy.
It is better to study the most straightforward motion with constant angular momentum to single out the general class among many potentials that will describe the common part of the interaction.
In this case, the bi-dimensional trajectory can be treated as one-dimensional because $\theta = \frac{l}{mr^2}$ and the interaction force F(r) will be a function of the distance between sham athlete and Centre of the mass of Couple of Athletes system, that is of the sham potential $V' = V(r) + \frac{1}{mr^2}$ with $V(r) = -Kr^{-\alpha}$ and the ά parameter a will take integral values 0,1,2,3, ...
The sham potential V'(r) will belong to one of the subsequent classes of attractive potentials Fig.(1).

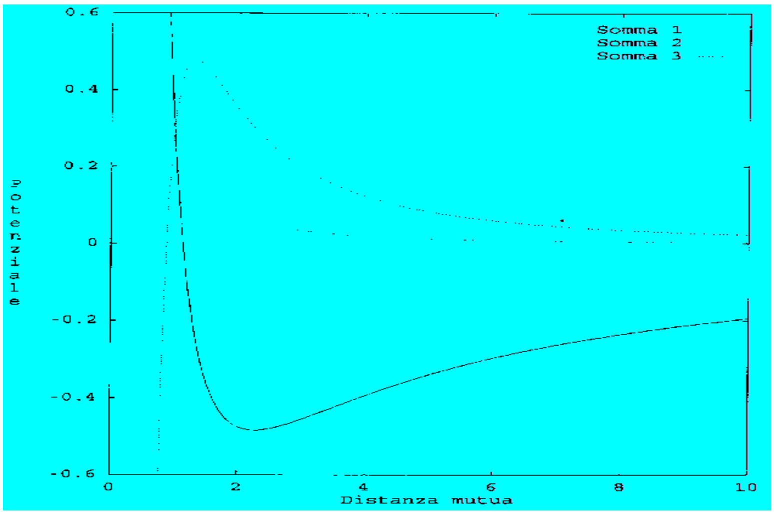


Fig 1 attractive sham potentials

This example clearly shows that only attractive-repulsive potentials as V'(r_1) will be helpful to describe the standard part of interaction during the contest.

VI Potential and interaction in the centre of the mass reference system

The general potential which will describe the exchange will have the available exponential form:

$V' = r^{-a} + r^{-2a}$ From previous considerations, it is possible to declare that the curve's family can explain the standard part of interaction shown in a generalised Morse's potential:

$V = D\left(e^{-2a(r-ro)} - 2e^{-a(r-ro)}\right)$ V' is a particular expansion of this expression.

The specification of a general form of interaction potential can give us much useful information:

1) r_o is the equilibrium distance (grip distance in wrestling).

2) D is the mechanical potential energy in the equilibrium point equal to mean mechanical energy valued in terms of oxygen consumption as ηO_2.

3) It is possible to evaluate the constant of expanding the potential near the minimum point. We get, in this case, the connection with the harmonic term of expansion $Da^2(r-r_o)^2 = E_c$ or

$$a = \frac{1}{L}\sqrt{\frac{E_c}{D}}$$

To know the potential, let us go back to the Algebraic expression of force

$$F = ma = 2aD\left(e^{-ar} - e^{-2ar}\right)$$

Singling out the standard part of the interaction as a " two-body problem in the central field" allows us to utilize an essential result of classica1 physics about the mean-time value of a few variables (Virial's Theorem). Both for motion and interaction, it guarantees that, if the generalized force F is a sum of friction and central forces, the mean kinetic energy of the system in time is independent of friction forces:

$$\overline{T} = -1/2\frac{\partial V}{\partial r}r \approx \frac{\eta}{e}\overline{O}_2 - \overline{V} = \eta_1\overline{O}_2 - \overline{V}$$

Where η_1 is the global efficiency of the contest, at every time smaller than η.

The conservation of mean mechanical energy in time, based on Virial's Theorem, allows us to obtain the expression of shifting velocity (2).

$$\dot{r} = \sqrt{\frac{2}{m}\left[\frac{\eta_1 O_2}{\tau}\frac{r^2\theta^2}{d} - D\left(e^{-ar} - 2e^{-2ar}\right)\right]}$$

The limit for r→ O of this expression allows us to calculate the attack velocity at the instant of impact (r=O), which can be expressed (3) concerning attacking oxygen consumption: $\lim_{r\to 0}\dot{r} = \sqrt{\frac{2D}{m}} = \sqrt{\frac{2\eta O_2}{m}}$

VII Potential and interaction in the centre of the mass reference system

A) "Couple of Athletes" closed system.

This system achieves "random" shifting by changing couple velocity direction in push/pull forces produced by Athletes to generate specific "situations" to apply winning techniques.

In this case, "random" means that statistically, there is not a preferential shifting direction.

The motion can be accomplished by friction between soles and ground on the base of the III° principle of Dynamics; the general equation describing the situation is the II° Newton's Law ma= F . In the generalized force, F will appear both frictions and push/pull contribution.

The friction component is proportional to the velocity $F_a = -\mu v$. Therefore, the changes in velocity and direction produced by push/pulls are created by the resultant force developed by the two Athletes themselves.

Concerning the whole contest time, they are acting impulses in very short intervals of time. Consequently, the single variation can be described by Dirac's of the impulse u from the elementary force, where u means the mechanical momentum variation Δv m.

The resultant will be the algebraic sum of the push/pull forces (8). The random changes in direction will be evaluated as the variation (± 1) j of the elementary force.

The whole force is: $\phi(t) = u\sum_j \delta(t - tj)(\pm 1)_j = F'$

Then the generalized force is $F = F_a + F'$, and the general equation of the motion has the well-known structure of Langevin's Equation:

$$\dot{v} = -\frac{\mu}{m}v + \frac{u}{m}\sum_j (\pm 1)_j \delta(t - t_j) = F_a + F'$$

Because the push/pd resultant is "random", it is impossible to forecast the trajectory in only one contest. However, the statistical analysis of many matches will be able to have information about the system behaviour.

1) Because the direction changes have the same probability, that is, over many contests, there is not a preferred direction, then the mean value of F' in a random sequence of directions will be zero
$< F' > = 0$

2) The mean over time and directions of two push/pull forces products give us information about force variation in time (8):

$$\langle F'(t)F'(t')\rangle = \frac{u^2}{m^2}\langle (\pm 1)_j (\pm 1)_j \delta(t - t_j)\delta(t' - t_j)\rangle = \frac{u^2}{m^2 t_o}\delta(t - t'_j)$$

Checking these conditions allows us to see quickly that the motion of the Athletes can be described in terms of statistical mechanics as Brownian motion over an unlimited surface.

The motion equation can be solved (with constant variation methods). The solution states that the system velocity is directly proportional to push/pull impulse u and inversely proportional to the total mass m. Thus, the biggest Athletes move, statistically, at less velocity. $v(t) \propto \frac{u}{m}$

In these cases, it is correct to evaluate only the mean values of the quantities. For example, the correlation function $\langle v(t)v(t')\rangle$ gives us the delay time of measurable velocity variation (8)

The solution is $\langle v(t)v(t')\rangle = \frac{m}{2\mu}C\left[e^{-\frac{\mu}{m}(t-t')} - e^{-\frac{\mu}{m}(t+t')}\right]$ if we think of a steady-state (t+ t')>> (t-t') the result is $\langle v(t)v(t')\rangle = \frac{m}{2\mu} C e^{-\frac{\mu}{m}(t-t')}$, and the delay time is $t^* = \frac{m}{\mu}$ directly proportional to the Athletes' mass (8). Suppose we put zero as the starting speed. In that case, it is possible to evaluate the kinetic energy mean value of more contests (8): $\frac{m}{2}\langle v^2\rangle = \frac{m^2}{4\mu} C\left(1 - e^{-\frac{2\mu}{m}t}\right)$ for $t \to \infty$. This expression speedily tends to zero, and then it is possible to write the steady-state relationship

$$\frac{m}{2}\langle v^2\rangle = \frac{m^2}{4\mu} C$$

The C constant can be evaluated by a modified Einstein's method for the classic Brownian motion. Therefore if we think that the Athlete bio-system shows one of the lowest working efficiency or $\frac{L}{O_2} = \eta \ll 1$, then (8) it is possible to write $\frac{m}{2}\langle v^2\rangle = \frac{m^2}{4\mu} C = \eta O_2$ or $C = \frac{4\mu}{m^2}\eta O_2$

From this equation, it is possible to get (8) the square momentum is directly proportional to friction and overall oxygen consumption $u^2 = 4\mu t_0 \eta O_2$. At the same time, the correlation velocity function takes (8) the value $\langle v(t)v(t')\rangle = \frac{2}{m}\eta O_2 e^{-\frac{\mu}{m}(t-t')}$ from which the speedy fluctuation is inversely proportional to mass m, directly proportional to oxygen consumption and friction independence.

It is possible to state that friction acts on forces and energy but not on the velocities.

It is also possible to see the evolution of momentum correlation function in the formula:

$$\langle u(t)u(t')\rangle = 2m\eta O_2 e^{-\frac{\mu}{m}(t-t')}$$

This relation shows us fascinating information. The fluctuation of momentum and velocities has a time memory as large as retard time t* = m/μ.

This is the interval time after which the coupling system heavily changes the momentum or the velocity from the previous ones. It is possible to see the delay time changes with the Athletes mass. For the heavyweights, for example, it will be more challenging to have high-speed changes (very different pace motion).

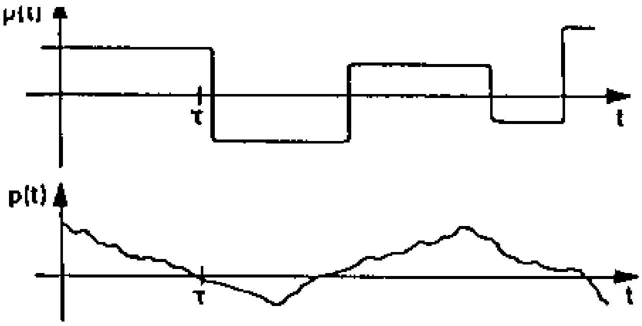
But the delayed time is also inversely proportional to the friction coefficient. If we consider a mat with zero friction, the delayed time becomes infinite. This means that the heavyweights can't change their position at all. This is direct proof of the friction necessity in fight motion.

It is important to remember that the correlation function singles out only mean u(t). It is possible to find momentum functions u(t) very different in each detail but with the exact momentum correlation at another time. Figure 2 shows us two limit situations:

a) lightweight athletes with very few, but very strong, interactions during the fight, with retard times proportional to: $\Delta\frac{m}{\mu} \approx \frac{m}{\mu}$.

b) Heavyweight athletes with continuous push-pull interactions with retard time $\Delta\frac{m}{\mu} \ll \frac{m}{\mu}$.

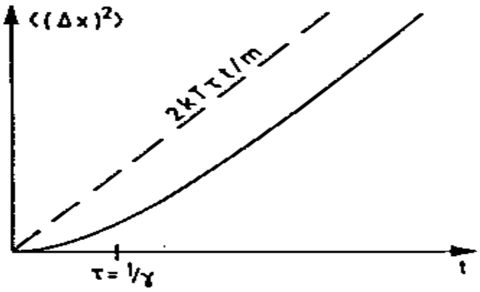
In these two relations $\Delta\frac{m}{\mu}$ is the so-called collision time, the mean distance between two push-pull statistically independent, which is different from the single push-pull time δt.



From the experimental point of view, finding a couple of athletes' positions on the mat is more straightforward than its momentum. After momentum correlation function integration, between 0 and t, remembering that u=mv, it is possible to obtain a fascinating result about the statistic time evolution of Athletes couple, the centre of mass, in the limits both for short times and very long respect to the retard time:

$$\left\langle [x(t)-x(0)]^2 \right\rangle = (2\eta O_2)\cdot \begin{cases} t^2 \to 0 \le t \ll \dfrac{m}{\mu} \\ \dfrac{2t}{\mu} \to t \gg \dfrac{m}{\mu} \end{cases}$$

As it is easier to see that the mean square shift in time of couple centre of mass is always a function of energy, but in one case, it depends on the square time. In the other one, it is a linear function of time. However, in this case, it is also friction inversely proportional in the following figure 3. We can see the time evolution of a couple centre of mass shifting.



If we study the bidimensional shifting paths on the mat (Tatami) of couple centre of mass because the motion as we see to belongs to the class of Brownian motion, it will be valid the following relation: $r\theta = \sqrt{dt} \Rightarrow \dfrac{d}{r^2\theta^2} = \dfrac{1}{t} - or - \left(f = \dfrac{d}{4\pi^2 r} \right)$ it is possible to understand the biomechanical meaning of this frequency in the limits: r→∞ ; r→0

The contact frequency or attack frequency is possible to write as oxygen function by the relation: $f = \dfrac{1}{2\pi^2 r}\sqrt{\dfrac{2\eta O_2}{m}} = \dfrac{f_i}{2\pi^2 r}$.

Krylov developed the modelling of two hard spheres improved by Sinai to the system of two colliding discs. Both these systems have been demonstrated that are chaotic.

In this demonstration, a mixing parameter K=λ/r>1 in our approximation takes the meaning: λ= free mean path between two interactions; r= Athletes inter-range.

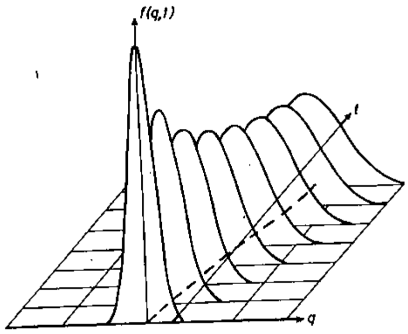
Then if this relation is fulfilled, the motion of the Athletes' couple centre of mass becomes chaotic.

Suppose the Couple of Athletes system moves by Brownian motion. In that case, it will be possible to find, if not the real path, the trajectory most probable. If f(q,t)dq is the probability of finding a couple of Athletes in the position q in the interval dq at time t; it is possible to demonstrate that this probability satisfies the Fokker-Plank equation, which describes the variation of probability of Couple of Athletes presence on the Tatami, during the time of competition.

$$\frac{\partial f(q,t)}{\partial t} = -\frac{\partial}{\partial q}\left(Kf(q,t)\right) + \frac{1}{2} D \frac{\partial^2}{\partial q^2} f(q,t)$$

Where K= - μq is the push-pull coefficient; and D is the diffusion coefficient.
Now remembering the Einstein relationship, the diffusion coefficient D can be correlated with the time evolution of the centre of mass of Athletes couples.
Both in the limit of the brief time interval or very long time interval, delayed time, or the square mean shift on the mat connected to the energy. By remembering the previous relations, it is possible to write: for short times $\langle x^2 \rangle \equiv \langle q^2 \rangle = 2Dt = 2\eta O_2 t^2$ and for very long times: $\langle x^2 \rangle \equiv \langle q^2 \rangle = 2Dt = 4\eta O_2 \frac{t}{\mu}$

Then the diffusion coefficient for very long times is proportional to the double of energy consumption and inversely proportional to the friction coefficient, for short times is proportional both to the energy consumption and to the time (this means that it is not constant in time).
The function f(q,t) gives us the most probable shifting path in time, singled out by the maximum probability points of the same function during its time evolution.



Considering the well-known work of Smoluchovski on the Brownian Motion, the " Physical that produces the random evolution of the contest allows us to obtain the basic probability of this Markovian process.
Then for dual sports, it is possible to obtain from the transition probability Q the solutions of Conditional Probability. Which give at the infinite time limit the chance to find an athlete between x and x + dx at time t. In the mathematical form, we can write:

$$Q(k,m) = \frac{1}{2}\delta(m,k-1) + \frac{1}{2}\delta(m,k+1)$$ That gives us the solution

$$P(n|m,s) = \frac{s!}{\left(\frac{v+s}{2}\right)!\left(\frac{v-s}{2}\right)!}\left(\frac{1}{2}\right)^s$$

The experimental proof of this model can be found in some Japanese works, on the world championship of 1971.

VIII Experimental check (verification- validation)

The results about shifting trajectories study for Couple of Athletes system during the contest, analysed by statistical mechanics techniques concerning "random" situations not repeatable in time, with a definite probability frequency, could appear only a theoretical exercise if they were not verified and validated with experimental results. The following illustration shows "dromograms" from judo (1) championships in Japan in 1971. There is no preferential direction in push/pull forces over time. (Fig. 5)

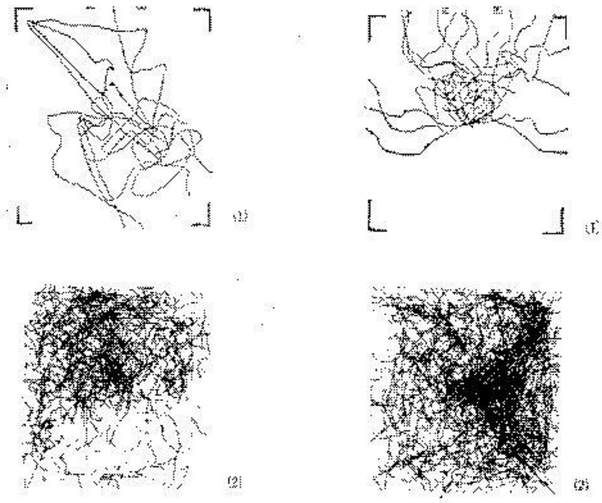


Fig 2 (1, 2, 7, 12) judo contest motion patterns in 1971 Japan championships.

IX Physical principles and interaction trajectories

"Couple of Athlete" closed system.

The interaction second face was solved by the author in the years 1985-1987 and led to the corollaries, about the use of forces in space (static conditions), with the analysis of flight paths and symmetries (dynamic conditions) and with the identification of the basic physical principles of throwing techniques. Using Galileo's principle of relativity, it will be possible to extend the validity of the known results from static to dynamic conditions of the contest.

1) A couple of forces techniques

For this class of techniques, we will apply the principle of simultaneous actions. Then, body motion in space can be simplified in the summation of a flat motion in a sagittal or frontal plane, plus an eventually simplified motion in space.

So, the first motion, produced by applying a principal couple of forces, is a flat rotary motion independent of gravity force.

In terms of variational analysis, the first motion flight path is obtained by the "extremals" of the general function. $I = \int_{x1}^{x2} y^r \left(1 + y'^2\right)^{1/2} dx$ For example, for r=-1 with solutions x=a- b sinθ e y = c – b cosθ, in this case, the "extremal" is the circular arc of radius b and centre B (a, c).

The general equation will describe the first motion (with θz=s)

$$\frac{2}{3} Ml^2 \ddot{\theta} = Ml \frac{d^2 s}{dt^2} \quad \text{or} \quad (z - \frac{2}{3} l)\ddot{\theta} + 2\dot{z}\dot{\theta} + \ddot{z}\theta = 0$$

The second trajectory (applied in another group of the same class of techniques) is the summation of motions produced by gravity force plus a secondary couple of forces. These forces act in a perpendicular plane to the gravitational field.

The second flight path is, with good approximation, the parabola arc with vertex V coincident with the rotation centre B of a principal couple of forces Fig 3,4,5

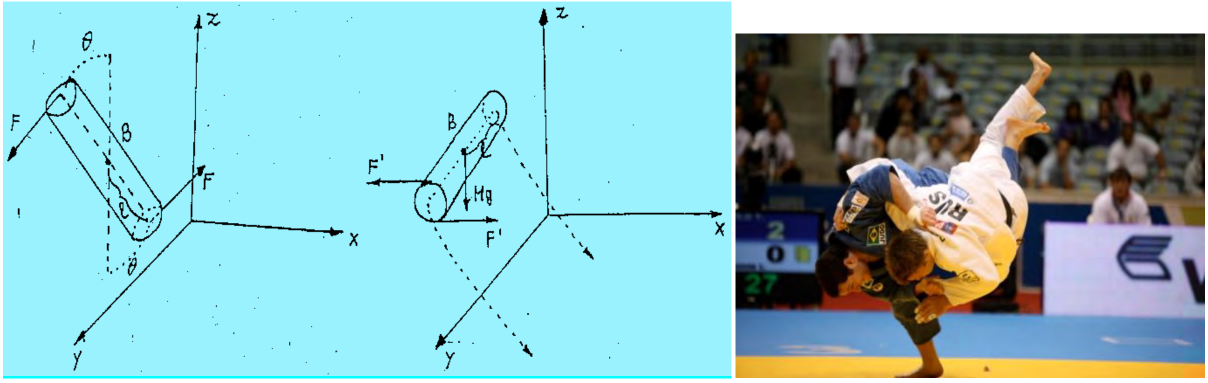


Fig 3,4,5 Technique of a couple of forces –Uchi Mata

2) Techniques of the physical lever.

Considering the biomechanical athlete as a rigid cylinder, applying the stopping point (fulcrum), then the starting impulse must be regarded as necessary and sufficient to perform the unbalance, that is to shift the barycentre perpendicular out from the support base, while it sets to the adversary's body a rotational momentum under the condition $\frac{1}{2}I_z\omega^2{}_z \;\square\; 2Mgl$

So, the athlete can be assimilated to a symmetric heavy top, falling in the gravitational field. Because the starting impulse is acting during a short time-lapse. The trajectory, in a force field, is given by the solution of the variational principle :

$$\delta\int_{q1}^{q2}\sum{}_j p_j dq_j - \delta\int_{t1}^{t2} H(p,q)dt$$

In our case, the external field is conservative. Then it is possible to apply the principle of minimum action, that is: $\Delta\int_{t1}^{t2}\sum_j p_j q_j dt = \Delta\int_{t1}^{t2}\tau dt = \tau\Delta\int_{t1}^{t2} dt = \Delta(t_2 - t_1)$

The body will go along the path of the least transit time.

The Jacobi form of the principle of minimum action gives us other information:

$$\Delta\int_{t2}^{t2}\tau dt = \Delta\int_{\rho 2}^{\rho 2}\sqrt{H - V(\rho)}d\rho = 0$$

The ρ parameter measures the length of the path. It makes sure the body will go along a geodetic of a certain symmetry. In this case, it is possible to show that it is going along a spiral arc, geodetic of cylindrical symmetry. Fig 6,7

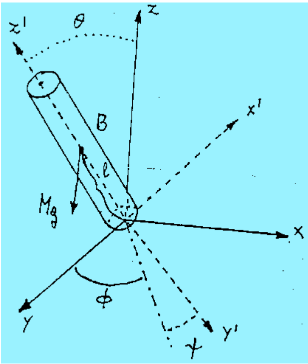


Fig 6,7 Technique of lever Tai Otosh

In fact, the kinetic and potential energy will be:

$\tau = t_0$ V=Mgl W=0

$\tau = t$ V= Mgl cosθ W=$\frac{I_1}{2}(\dot{\phi}^2 sin^2\theta + \dot{\theta}^2) + \frac{I_3}{2}(\dot{\phi}\cos\theta + \dot{\psi})^2$

$\tau = t_f$ V=0 W=$\frac{I_1}{2}\dot{\phi}^2 + \frac{I_3}{2}\dot{\psi}^2$

Where it is possible to write $I_1 = I_2 = \frac{2}{3}Ml^2$ e $I_3 = \frac{1}{2}Mr^2$

On the other hand, the angular functions will be:

$\dot{\phi} = \frac{b - \cos\theta}{sin^2\theta}$ and $\dot{\psi} = \frac{I_1}{I_3}a - \cos\theta(\frac{b - \cos\theta}{sin^2\theta})$

If $\omega_z = \cos t.$ it is possible to write

$$\frac{\partial W}{\partial \dot{\psi}} = I_3(\dot{\phi}\cos\theta + \dot{\psi}) = I_3\omega_z = I_3 a$$

if the angular momentum is, L=$I\frac{d\Omega}{dt}$ the equations of motion will be:

$$I_1\ddot{\theta} + (I_3 - I_1)\dot{\phi}^2 sin\theta\cos\theta + I_3\dot{\phi}\dot{\psi}sin\theta = Mglsin\theta$$

$$I_1(\ddot{\phi}sin\theta + \dot{\phi}\dot{\theta}\cos\theta) + (I_1 - I_3)\dot{\theta}\dot{\phi}\cos\theta - I_3\dot{\theta}\dot{\psi} = 0$$

$$I_3(\ddot{\phi}\cos\theta - \dot{\theta}\dot{\phi}sin\theta + \ddot{\psi}) = 0$$

If we remember that both energy and angular velocity (ω_z) are constant of motion, then it will be:

$$E = T + V = \cos t \Rightarrow E' = E - \frac{1}{2}I_3\omega_z^2 = \frac{I_1}{2}(\dot{\theta}^2 + \dot{\phi}^2 sin^2\theta) + Mgl\cos\theta = \cos t.$$

With s=cosθ and remembering the values of $\dot{\phi}$ e $\dot{\psi}$ the function will give the body's flight path:

$$\rho = \int_{s(0)}^{s(l)} \frac{ds}{\sqrt{(1-s^2)(\alpha-\beta s)-(b-as)^2}}$$ which derive from the equation:

$$\dot{\theta}^2 sin^2\theta = sin^2\theta(\alpha-\beta\cos\theta)-(b-a\cos\theta)^2$$

With $\alpha = \frac{2E'}{I_1}$ and $\beta = \frac{2Mgl}{I_1}$

The Initial conditions θ =0 and $\dot{\theta} = \dot{\phi} = 0$ give us the solution **E'= Mgl = cost.**

Then the flight path between $\theta_0 = 0$ e $\theta_1 = \frac{\pi}{2}$ is a geodetic arc of cylindrical symmetry.

From the classical mechanics, we remember that for a helicoidal motion simultaneously, both these solutions are true:

$$vT = h - and - \varpi T = 2\pi$$

Then the Helix pitch is: $h = 2\pi \frac{v}{\varpi}$

If we go to the limit, it is possible to understand why the increase of the rotational component is equivalent to the Athletes lowering. Because shortening of the helix pitch means to reduce the flight path of the adversary, reducing in the same time his defensive capability to turn acrobatically on the abdomen. (12,13).

X Probabilistic analysis of the interaction

"Couple of Athlete" closed system.

In studying the specific interaction for the Couple of Athletes closed system, the attack mechanics guarantees only two solutions. Either: to be successful or not, faced to a defence which is effective or not.

Then comes the question of what probability of success has defence and attack, and how can the probabilistic analysis connect them.

A powerful direct attack without "shams" or "combinations" is independent in the first approximation. That means we have a series of Bernoulli tries.

By applying the binomial distribution to the attack, the probability of having two successes, whatever results excluded Ippons, every ten tries over the eight possibilities of attacks in five directions is:

$$A = \frac{10!}{2!(10-2)!}\left(\frac{1}{40}\right)^2\left(1-\frac{1}{40}\right)^{10-2} = 0.028$$

While the defence probability of having two successes (excluded Ippon), every ten tries over the six kinds of defence around himself (2π) are:

$$D = \frac{10!}{2!(10-2)!}\left(\frac{1}{12\pi}\right)^2\left(1-\frac{1}{12\pi}\right)^{10-2} = 0.025$$

The mathematical probability of 2 successes every ten-strong direct attacks is 2.8 %, while two every ten defence is 2.5 %.

So, in this case, the probabilistic analysis shows us that in Couple of Athletes closed system, the result for a robust direct attack would be just a bit easier than defence.

XI Conclusion

The biomechanical analysis of contest sports competitions has given us some significant results:

a) the motion of Couple of Athletes system is a Brownian motion;

b) interaction between athletes can be subdivided into two steps: the first is common to all contest sports (shortening of mutual distance); the second step is peculiar to each sport.

Ex. long-distance sports: direct blows to sensible or conventional body points; very short distance sport: tools for throwing the adversaries by two physical principles ;

c) the kinetic energy of the athlete depends on oxygen consumption and the athlete's efficiency;

d) The capability of changing velocity does not depend on friction; it is inversely proportional to the mass and directly dependent on oxygen consumption and efficiency;

e) the variation time of velocity is dependent on the mass and inversely proportional to friction;

f) the attack speed at contact is given by square root of double of oxygen consumption multiplied by efficiency divided by body or limb mass;

g) the measure of the variation of push/pull force is related to the extent of the friction in direct proportion to oxygen consumption;

h) the flight path of the thrown athlete is geodetic of three specified symmetry or their linear composition;

i) the couples of forces techniques are independent of friction; it is possible to use them whatever the shifting velocity is;

j)the physical lever techniques depend on friction; that means it is possible to use them only for stopping the adversary;

k)the techniques of a couple of forces are energetically the best;

l) among the techniques of the physical lever, the maximum arm is energetically the best;

m) attack frequency is directly proportional to impact velocity and indirectly to mutual distance;

n) attack frequency is directly proportional to kinetic energy for time and inversely to mass and square of the distance;

o) the direct attack blow has a success probability of 66% compared to defence.

XII References

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Appendix II
Non-Linearity in Human Body

Movement and Man at the end of the random walk

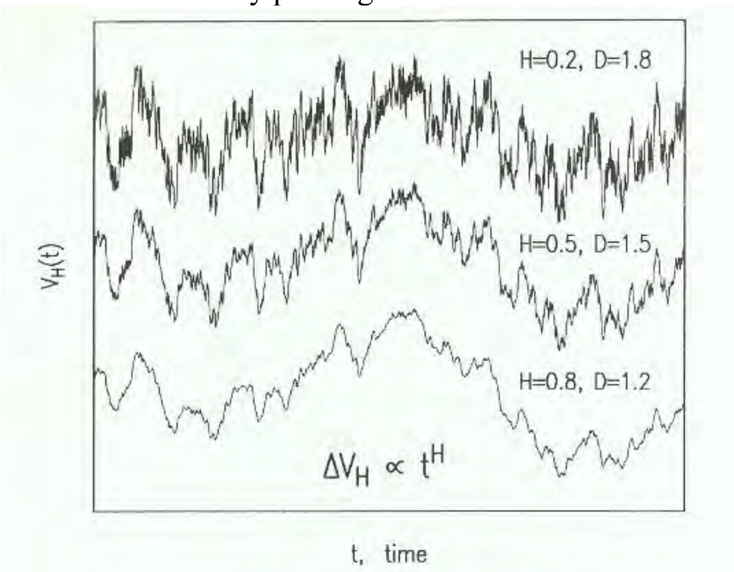
Movement and man at the end of the Random Walks

Movement and Man at the end of Random Walks

1 Introduction

Fractals in Human Body Physiology

Starting from the Mandelbrot work (1977), the fractal is most often associated with irregular geometric objects that display self-similarity.
This property holds on all scales in an idealised model, but this is not all truth in the real world.
In the human body, several complex anatomic structures display fractal-like geometry. In our particular language, we will call them "Static", related to the irregular geometric definite form of the design.
Many of these self-similar structures serve at least one fundamental physiologic function: rapid and efficient transport over complex spatially distributed systems or organs.
Fractal geometry also appears to underlie critical aspects of mechanical heart functions and brain structure.
In the human body, a variety of other organs systems contain fractal-like structures that ease information dissemination (nervous system) or nutrient absorption (bowel). All that shows the ubiquity of "Static" fractals in the human body.
The fractal concept can be found, in the human body, not only as "static" like in the irregular geometric structures but also in that which we will call in our special agreement "Kinematics" form of fractals.
They are connected to the body's complex processes that generate irregular fluctuations across multiple time scales
We can understand better this behaviour by plotting their fluctuations at different time resolutions.



2 Inside the Body

2.1 Fractal Dimension: Self Similarity and Self-affinity

Since the fractals occupy an intermediate position between the standard geometric subject with integer dimensions, they can be conveniently characterized by their fractal dimension
Then an important parameter describing fractal geometrical structures is the fractal dimension which generalizes the usual integer-valued topological dimension., for each structure, it was empirically found that the total length L varies as a power of the length scale l

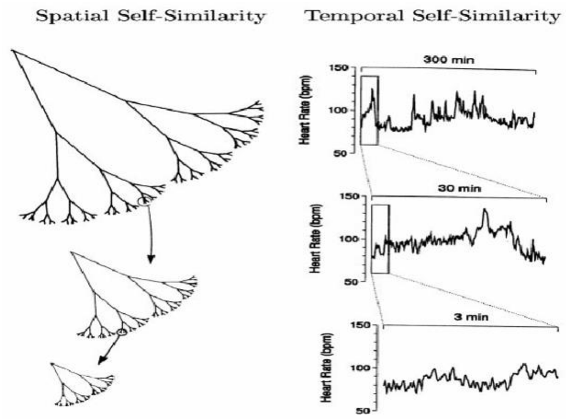
$$L(l) \propto l^{1-D} \quad (1)$$

The parameter D is called the fractal dimension of the curve. Another way to write the equation (1) is

$$L(l) \propto N(l) \cdot l \Rightarrow N(l) \propto l^{-D} \quad (2)$$

Where N(l) is the minimum number of boxes with side l needed to cover the fractal curve.

There are several generalizations of the fractal dimension, but it is possible to find them in every fractal book. However, data are usually a sequence of real numbers (time series). In this case, we may have no information about the detail of the problem that we call Kinematics.
It is assuming that an unknown deterministic dynamic determines the time series. However, under general conditions, it is still possible to reconstruct its phase space and analyze the system "Kinematics".This is the foundation of the non-linear time series analysis. In effect, we can obtain from the dynamical equation of the system an apparent random time series that reveals the simple structure of the dynamics when embedded in R^2.
Fractal dimensions, as seen, can be introduced in various distinct ways, each emphasizing a different geometric aspect of the pattern.
An essential property of a fractal is its self-similar nature. Therefore, if we magnify some fragment of such pattern (both static geometrical or kinematics temporal), we would see the same structure reproduced on a new scale. Moreover, if the miniature copy may be distorted in another way, for example, somewhat skewed, in this case, we call this quasi-self-similarity, self- affinity. A favourite example of self-similarity in many textbooks is the trajectory of the Brownian Motion of a particle. Although this trajectory is exceptionally irregular, it displays some remarkable invariance. If we take a small region containing part of the trajectory and enlarge it, the result would look very similar to the whole original trajectory. The following figure shows two examples of self-similarity, the first geometric the second time-related.



2.2 Fractal as Geometrical Self Organization
We speak of the self – organization or, more precisely, self-organized behaviour if every part of the complex system acts in a well-defined way on the given internal order or configuration.
To show in a rigorous mathematical term the self-organization, it is possible on the track of Haken, Liupanov and others to develop a very general theory applicable to a large class of different systems, comprising sociological systems and physical, chemical, and biological systems.
If the internal organizing force is obeying the equations of motion, in the general case of chemical systems, we show that the solution is not linear if q_1 is a function of the concentration of the chemical and the "effect" are q_2, it is possible to write for a self-organized chemical system:

$$\begin{cases} \dot{q}_1 = -\gamma_1 q_1 - a q_1 q_2 \\ \dot{q}_2 = -\gamma_2 q_2 - b q_1^2 \end{cases} \qquad 3)$$

$$q_2(t) \approx \frac{b}{\gamma_2} q_1^2$$

$$\dot{q}_1 = -\gamma_1 q_1 - \frac{ab}{\gamma^2} q_1^3 \qquad 4)$$

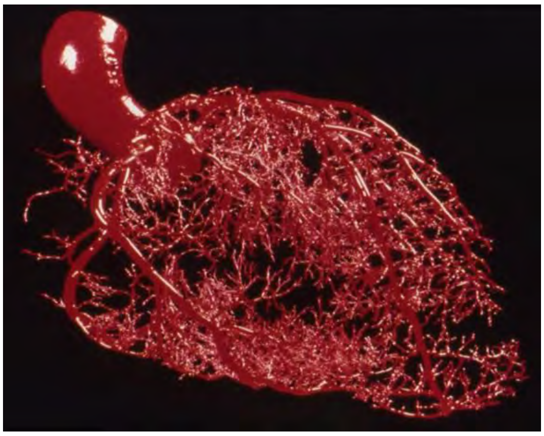
These equations (3) show in a straightforward way that the self-similar structures in the human body could get by nonlinear (Brownian) self-organized chemical reactions (4).
If the system possesses a macroscopically infinitesimal time scale so that during any DT on that scale, all the reaction channels fire many more times than once, yet none of the propensity functions changes appreciably, we can approximate the discrete Markov process by a continuous Markov process defined by the Chemical Langevin (SDE) Equation

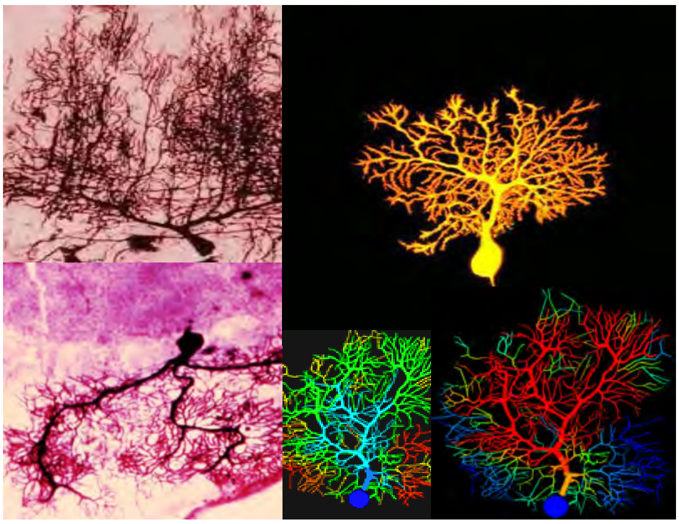
$$X_i(t+dt) = X_i(t) + \sum_{j=1}^{n} v_j a_j X(t) dt + \sum_{j=1}^{n} v_j a_j^{\frac{1}{2}} X(t) N_j(t) (dt)^{\frac{1}{2}} \quad (5)$$

where $N_1 \ldots\ldots N_m$ is M temporally uncorrelated, statistically independent standard variables with mean 0 and variance 1
In the specific structures of the human body like coronary artery tree or Purkjne cells in the cerebellum of the human heart, this Fractal geometrical Self-Organization comes more easily from the corresponding Fokker Plank equation (5):

$$\dot{f}(q_u,q_s) = \left\{ \frac{\partial}{\partial q_u}\left(\gamma_u q_u + a q_u q_s\right) + \frac{\partial}{\partial q_s}\left(\gamma_s q_s - b q_u^2\right) \right\} f(q_u,q_s) + + \frac{1}{2}\left(K_u \frac{\partial^2}{\partial q_u^2} + K_s \frac{\partial^2}{\partial q_s^2} \right) f(q_u,q_s) \quad (6)$$

A Fokker Planck equation is easier to obtain in several cases like chemical reaction dynamics than the corresponding Langevin equation.
This short speech clearly shows that Random Walk or continuous limit the Brownian motion are at the basis of the fractal in human physiology.
There are two well-known examples of physiological self-organization, the coronary artery tree and the Purkinje cells in the cerebellum, shown in the following figures:





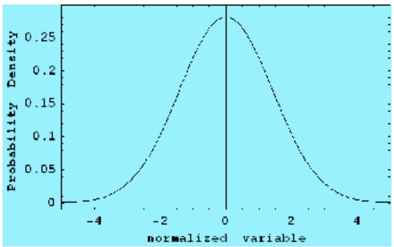
2.3 Gauss and Pareto Inverse Power Law

Chance in physics is connected to the concept of probability. Many processes in real life are random, and their dynamic evolution is complicated to understand from a deterministic point of view.
Probability theory was born to explain the outcome of games. One of the simplest games is tossing a coin where one can find a head or tail.
Usually, the number of proofs is determined and finite (binomial distribution) but more known is the limiting case to the infinite proof number; GaGauss performed this analysis
The indefinite form, we, today, can define the world of Gauss as " simple" as a scientific world view. In this (linear) theory, the output is proportional to the input. Algebra is additive. The presence of simple rules yields a simple result of the problem. These results are stable, the phenomenon is predictable, their result stable, and the final distribution Gaussian.
In the mathematical form, the system evolution is defined by the following equation:

$$\frac{dX}{dt} = \mu X + \xi(t) \qquad (7)$$

In this Langevin equation, we can see that the fluctuation is simply additive. The bell curve that defines the Gauss distribution is the well known simple inverse curve of the normal distribution:

$$P(x) \propto e^{-\left\lfloor \frac{\mu}{D} x^2 \right\rfloor} \qquad (8)$$

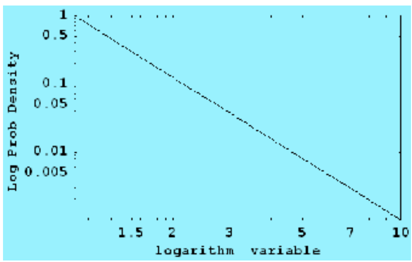


But a more complex scientific vision is connected to a not well known great Italian scientist, except outside the social and economic world, Pareto.
By his law, it is possible to describe a more complex scientific vision of the world. This world is non-linear, in which small changes may produce a divergence in the solutions.
It is a multiplicative world in which simple rules yield complex results. The processes are unstable, the predictability is limited, and the description of the phenomena is both qualitative and quantitative. The Pareto distribution is also an inverse power law distribution.
In mathematical form, the system evolution is defined by the following eq

$$\frac{dX}{dt} = \mu X + \xi(t) X \qquad (9)$$

In this more complex world, fluctuation is multiplicative, and the Pareto inverse power law distribution satisfies the following form:

$$P(x) \propto \frac{1}{|x|^{1+\frac{\mu}{D}}} \qquad (10)$$



2.4 Random Walk and its limits

If we consider a stochastic process is going on time, for example, the motion of a particle which is randomly hopping backwards and forward; this example is known in the scientific world as "Random Walk".

Suppose we would see the probability that after n hopping, the particle is in a position m. In that case, it could be common to connect this probability in discrete mathematical form and to write:

$$P(m;n+l)=w(m,m-l)P(m-l;n)+w(m,m+l)P(m+l;n) \quad (11)$$

This discrete probability equation has two significant limits in its continuum form.

The limit of the random walk with infinitesimal, independent steps is called Brownian Motion.

The first form is the limit that explains more carefully the dynamic of a single particle in time, and its mathematical form is known as Langevin Equation from the French Scientist that proposes it in 1905

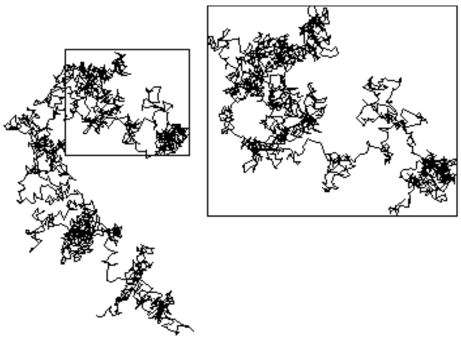
$$\frac{dv(t)}{dt}=-\mu v(t)+\xi(t) \quad (12)$$

The first term after the equal is the dissipation suffered by the particle. The second is the stochastic fluctuation applied to it. If Gaussian type, this dissipation will be zero in mean over time.

The second form is the limit that considers more the global probabilistic aspect of the random process analyzed in phase space. Its mathematical form is known as Fokker Planck Equation from the two German scientists who proposed it in 1930.

$$\frac{\partial P(v,t)}{\partial t}=-\frac{\partial}{\partial v}\left[-\mu v P(v,t)\right]+\frac{\partial^2}{\partial v^2}DP(v,t) \quad (13)$$

The following figure (showing in it also the self-similarity property of this random process) shows one example of a two-dimensional Random Walk or Brownian Motion of a particle. As before described, it is viewed in two different conceptual ways by the two previous limit equations.



2.5 Continuum limit of fractional random walks

An exciting way to approach complex systems also derives from a unique view of Random walks. It is based on incorporating this complexity in it, introducing memory in the random walks through fractional differences. This generalization has the same significant limits previously introduced.
Suppose we see more carefully at the dynamic aspect of the process. In that case, it is possible to write a generalized fractional Langevin equation and to introduce the Fractional Brownian Motion.
In mathematical form, it is possible to write:

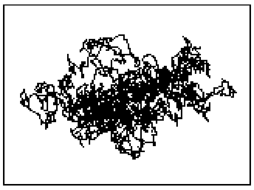
$$D_t^\alpha [X(t)] - \frac{X(0)}{\Gamma(1-\alpha)} t^{-\alpha} = \xi(t) \qquad (14)$$

The first term is a fractional derivative. The second is connected to the initial condition of the process. The third is always the random force acting on the particle.
In this case, it is important to know the mean square displacement of the particle :

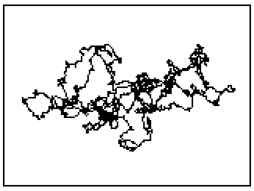
$$\left\langle [X(t) - X(0)]^2 \right\rangle = \frac{\left\langle \xi^2 \right\rangle}{(2\alpha-1)\Gamma(\alpha)^2} t^{2\alpha-1} \propto t^{2H} \qquad (15)$$

From this expression, we can understand that we are in the presence of an anomalous diffusion process, identified by the H parameter, usually called the Hurst parameter. In particular, this parameter is time-independent. It describes the fractional Brownian motion with anti-correlated samples for $0<H<1/2$ and correlated samples for $½<H<1$ if H is = to ½ we can speak of Brownian Motion. If, in general, H could be a function of time. In recent times this significant extension is called multi-fractional Brownian motion.
This important generalization comes from certain situations occurring either in the field of turbulence (Frisch 1999) or from Biomechanics (Collins and De Luca 1994). There is a need for a more flexible model necessary both: to control the dependence structure locally and allow the path regularly to vary with time.

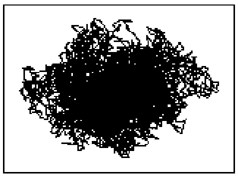
Pure Brownian motion: next step is uncorrelated with the previous step H=0.5



Anti-Persistent Fractional Brownian motion: each step is negatively correlated with the previous step H<0.5



Persistent Fractional Brownian motion: each step is positively correlated with the previous step H> 0.5

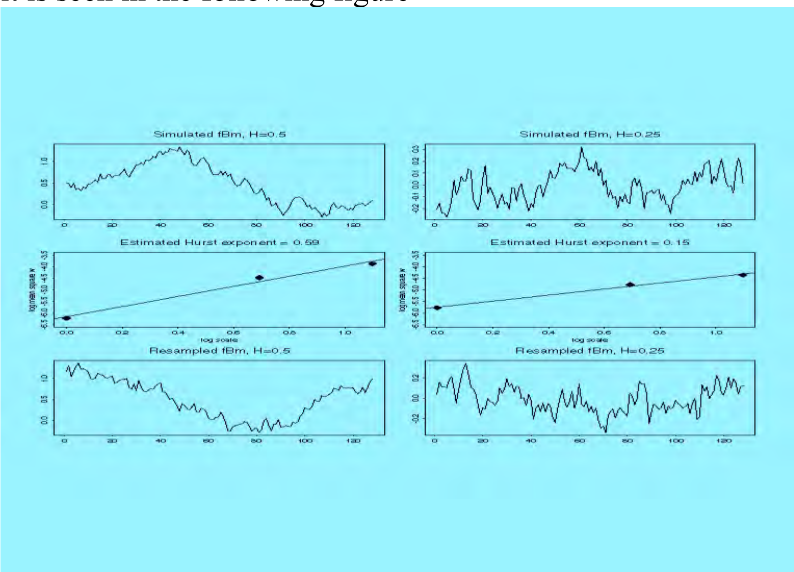


2.6 Time series: some examples of internal body answers.
Many organs inside the human body could be controlled or analyzed by instrumentation which grips electric time-series signals as answers of the specific organ.
For example, Brain imaging data may generally show fractal characteristics - self-similarity, 1/f-like spectral properties (like Pareto inverse power law).
Normally Self-similar or scale-invariant time series like EEG, ECG, have 1/f-like power spectrums with these accepted classification

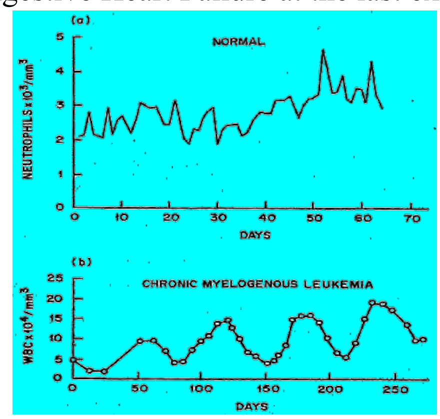
- if a = 0, noise is *white*
- if a = 2, noise is *brown* (random walk)
- if a = 3, noise is *black* (Nile floods)
- if 0 < a < 2, noise is *pink* (J. S. Bach)

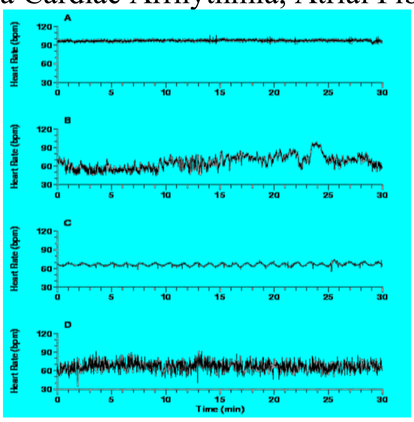
$$P_f \approx \left| f^{-\alpha} \right| \qquad (16)$$

Fractional Brownian Motion has covariance parameterised by Hurst exponent 0 < H < 1
The Hurst exponent, the spectral exponent a, and the fractal (Hausdorf) dimension FD, are related: 2H+1 = a or 2-H = FD for example, classical Brownian motion has a = 2, H = 0.5 and FD = 1.5 as quickly it is seen in the following figure

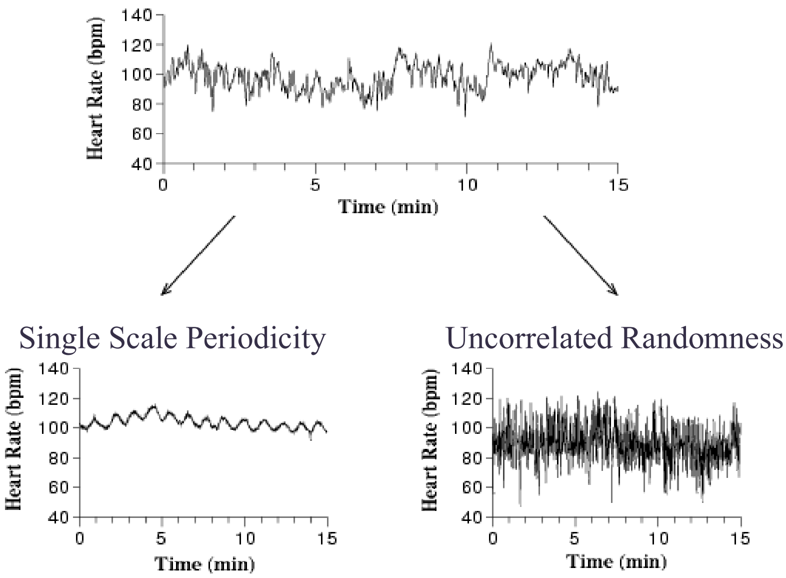


Wavelets are the natural basis for the analysis and synthesis of fractal processes in the human body. They are used in brain image analysis, but the same method could be applied to heart analysis.
In the first two figures, we can see an example of diseases in white blood cells and circulatory dynamics.
In the next four, respectively, it is possible to see:
One example of Severe Congestive Heart Failure, on the signal of a Healthy Heart, again a Severe Congestive Heart Failure at the last example is the signal of a Cardiac Arrhythmia, Atrial Fibrillation

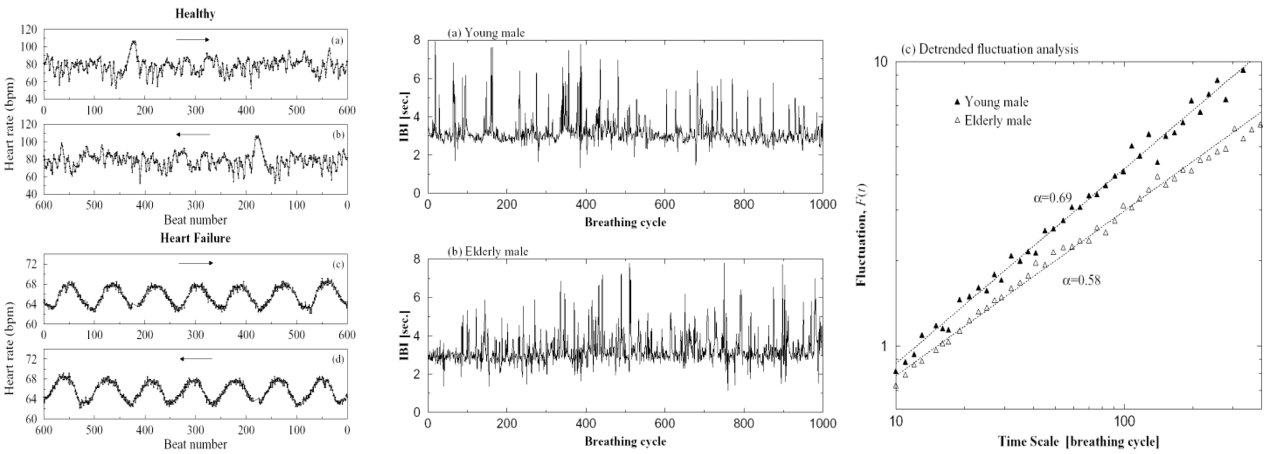




Another attractive property of these signals is that Fractal Complexity degrades with Disease.
In the following example, it is possible to see the degradation of a signal from complexity to a simplified signal index of disease.



Another hypothesis is connected to the time irreversibility of the signal. Time irreversibility is greatest for healthy physiologic dynamics, which have the highest adaptability. Time irreversibility decreases with ageing and disease in the first heart rate in the following Human Respiration: Loss of Long-Range (Fractal) Correlations with Age



2.7 Myosin (II) Brownian Ratchet and the Muscular Contraction

Now it is experimentally well known that the model of Brownian Ratchet give us a good explanation of the non-processive motor, the Myosin II, using the thermal fluctuation and also the energy stored in the ATP structure, can move long the Actin filament

Two models are the Huxley and Simmons power stroke (lever arm) model and the Brownian ratchet.

The problem is to compute the actual Myosin translation to evaluate the correctness of the model.

The translation caused by the pivoting of the lever arm would be about 5 nm. New technologies for manipulating a single actin filament allow testing the lever arm model, but the displacement varied considerably. Some reports have shown myosin displacement of about 5nm, consistent with the lever arm model.

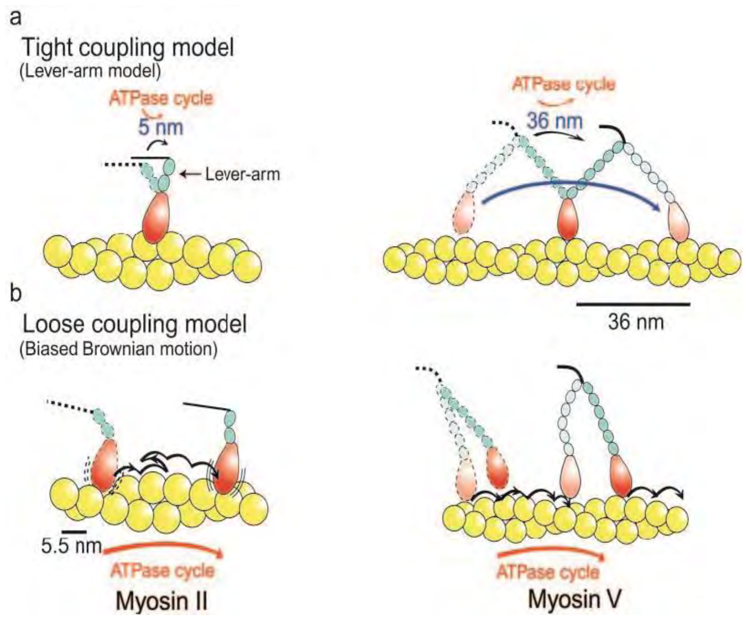
However, others have shown that if myosin is oriented correctly relative to the actin filament axis as in muscle, the value increases to 10-15 nm out of model predictions.

For the ratchet model, one problem is that the scale of the motion is smaller than the Brownian motion of microneedles because the average amplitude is between 30-40 nm.

Recently Yanagida et others 2000, has shown, manipulating a single myosin head and measuring the displacements with a scanning probe. This assay allowed the measurement of individual displacements of a single myosin head with high resolution. The data showed that a myosin (II) head moved along an actin filament with single mechanical steps of 5.5 nm. Groups of two to five rapid steps in succession often can produce displacements of 11 to 30 nm.

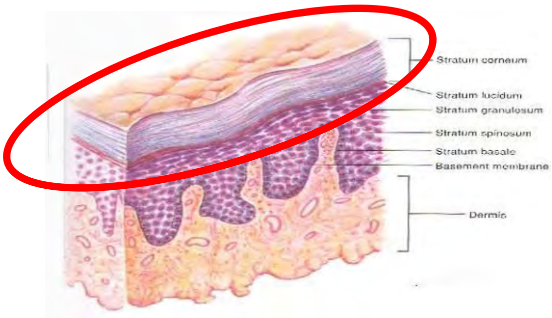
Similar substeps observed are constant in size with the repeat actin monomers (5.5 nm), independent of force. Because some subsets are backward, it is more likely that a Myosin head may step along the Actin monomer repeat by biased Brownian Motion.

In the following figure, we can see for the Myosin II and V, both the models:

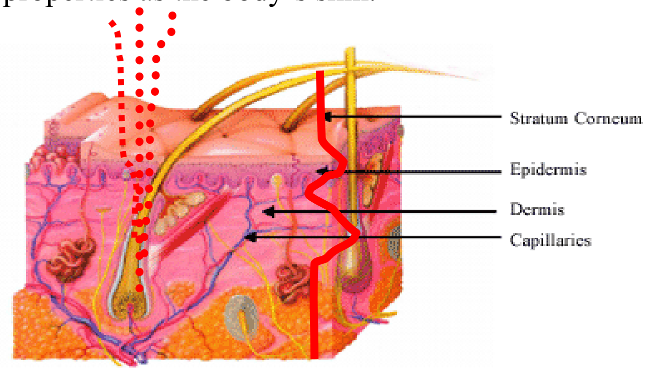


2.8 On the Boundary

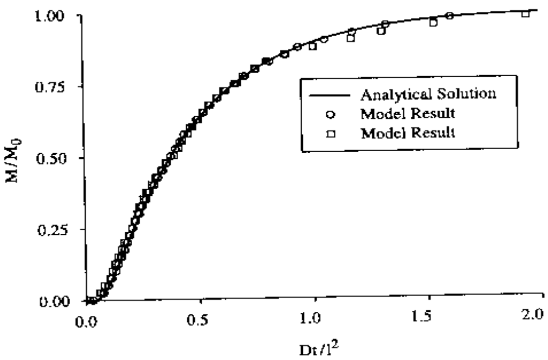
This year, an exciting model as Random Walk Model of the Human Skin Permeation was presented by Frash in 2002. In this model, the skin usually made by different heterogeneous materials in the other layer, was introduced first as a homogeneous membrane: made by the same material



Typically Effective path length can be defined as the thickness of a homogeneous membrane having identical permeation properties as the skin. Effective diffusion is the dispersion of a homogeneous membrane having similar permeation properties as the body's skin.



The following figure shows the exciting results of this random walk model of the human skin
Random walk simulations for mass penetration through SC with logKcor_lip=0
Dcor/Dlip = 1.0/0.01



3 Outside the Body

As it is shown, geometric fractals and temporal fractals are widely common inside the human body. But if we remember that, also at the microscopic level, Brownian motion is ubiquitous like DNA, molecular motors for the seven myosin family, axon transmission command, etc. This means that the basis of the muscular contraction is Brownian. By Scalextric muscles, we can go outside the human body to find other exciting presence of the Brownian motion. Astonishingly, there are many different random processes or situations in which the Brownian motion normal, fractal, and multifractals are present. The following paragraphs there are showing some interesting examples.

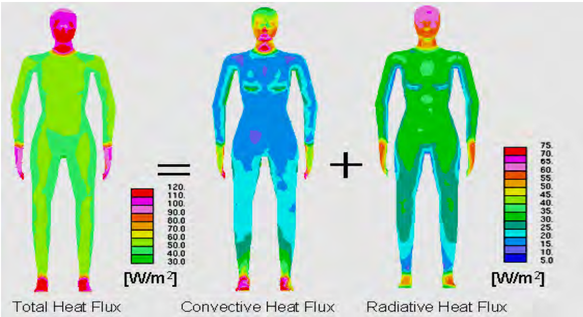
3.1 Fluctuation of surface body temperature.

Suppose the surface body temperature fluctuation is analyzed, for example, by a thermo-camera. In that case, we can see that the equation describes this topological situation in a steady-state condition, in which the ζ (t) is the random fluctuation of the incident absorbed radiation. And ΔT(t) is the surface body difference of temperature depending on the time and the position

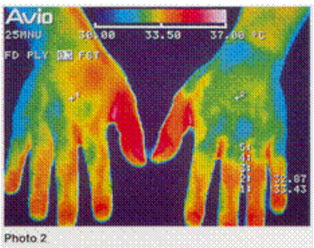
$$c_v \frac{d\Delta T(t)}{dt} + h\Delta T(t) = \zeta(t) \qquad (17) \quad \text{Langevin like equation}$$

$$\left\langle \left(E - \overline{E}\right)^2 \right\rangle = kT^2 c_v \qquad (18) \ \text{Fluctuation in energy}$$

$$\left\langle (\Delta T)^2 \right\rangle = \frac{kT^2}{c_v} \qquad (19). \ \text{Fluctuation in temperature.}$$



The previous equation shows that the surface temperature fluctuation of the human body is Brownian. But the topology of the surface temperature taken by thermo-camera quickly reveals that the superficial temperature is a function of time and position.
In the next frame, the last consideration is obvious

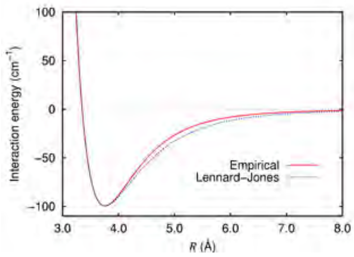


Suppose the body makes a motion or works in a not controlled condition. In that case, the equation considered as a whole could take this form in his free-evolution captured by thermo-camera:

$$c_v \frac{d^2\Delta T(t)}{dt^2} + \left(h + \frac{dc_v}{dt}\right)\frac{d\Delta T(t)}{dt} - \frac{d\zeta(t)}{dt} = 0 \qquad (20)$$

This situation is complex because the specific heat c_v is not constant. However, it is a highly complex function at least of time, space, food, fat, .and body dimensions; some works in this field to identify the actual shape of this function were made by Sacripanti and co-workers about ten years ago (1995-1997). It is a mistake or a first approximation to identify a constant number as specific heat for the human body. In reality, the human body is a complex engine with continuous production and dispersion of energy (the metabolic heat).

In this case, the function $c_{v,}$ better called "body's Thermal Inertia", is not constant but a complex function with the shape as Lennard-Jone$_s$ potential.



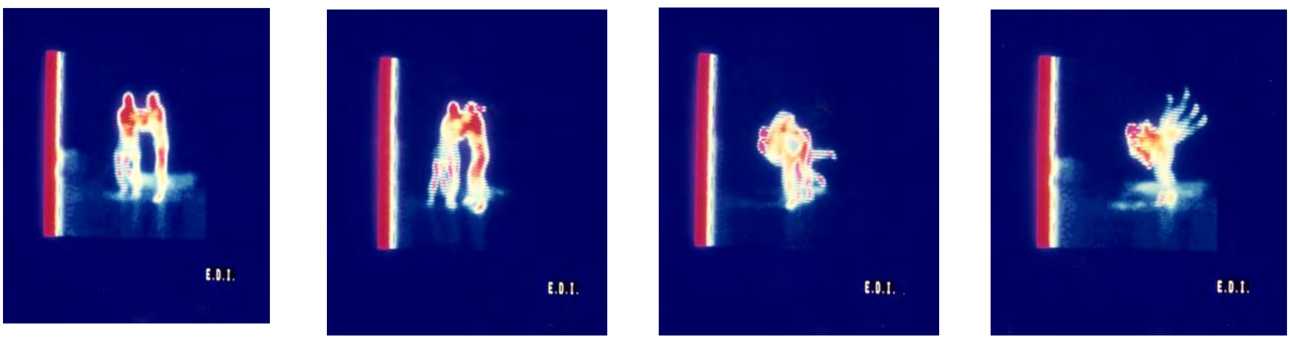
Also, h the thermal coefficient is not constant, but its dependence is very more complex. Because for work like regular activity or sports movement is not controlled thermal condition, it must satisfy the following experimental Sacripanti's relationship:

$$S\sigma\varepsilon\left(\frac{T_s^4-T_a^4}{t-t_0}\right)+0.6n\frac{kS\mathrm{Re}^{0.8}\,\mathrm{Pr}^{0.33}}{l}\frac{T_i-T_a}{t-t_0}+\left\{e^{-\frac{4S}{lh}\frac{T_s-T_b}{T_b-T_a}}\right\}$$

$$\left\{\left[0.132\varepsilon_h\frac{4S^2k\,\mathrm{Re}^{0.8}\,\mathrm{Pr}^{0.33}}{hl^2}\frac{(T_s-T_a)^{1.2}}{T_a^{0.2}(t-t_0)}\right]+\left[0.16(1-\varepsilon_h)\frac{4S^2D\lambda\,\mathrm{Re}^{0.8}\,Sc^{0.33}}{Rl^2h}\left(\frac{M_se_s}{T_s}-\frac{M_ae_a}{T_a}\right)\frac{(T_{vs}-T_{va})^{1.2}}{T_{va}^{0.2}(t-t_0)}\right]\right\}$$

$$\left\{e^{-(0.2\varepsilon^2+0.5\varepsilon-0.7)\frac{\lambda P-\sum}{\lambda P}}-1\right\}=\frac{dO_2}{dt}$$

In the following figures, we can see some thermograms of a judo technique taken by a thermo-camera in the author and co-workers (1989). The thermal emission was connected to the oxygen consumption using the previous Sacripanti's relation.



3.2 Human balance Centre of Pressure (COP) vs Centre of Mass (CM)

In static equilibrium, the CM (centre of Mass) projection and the COP (centre of pressure) would lie on the same plane. On the vertical line, COP would coincide as a proportional model with the projection of the CM on the ground.

Both motions are similar, but the COP motion is always more significant than the CM projection motion. This can be illustrated in Biomechanics using a simple model, the inverted pendulum, Winter 1998, Pedotti 1987 .for the anterior, posterior balance.

The pendulum rotates around the ankle joint. We take as the origin of the Cartesian system if we denote as F the force acting on foot by force plate at the point (-ζ, η), the COP. The system is described in Newtonian approximation by the equations:

$$\begin{aligned} m\ddot{y} &= F_y \\ m\ddot{z} &= F_z - mg \\ I\ddot{\alpha} &= \eta F_z + \zeta F_y - mgL\cos\alpha \end{aligned} \qquad (22)$$

The component F_z is the same force as is obtained from the readings of the force transducers. For a slight deviation around the vertical z-axis, we may replace cosα with y/L. In the first approximation, we may also set Fz= mg. Then the last equation will be:

$$y - \eta \approx \left(\frac{\zeta}{g} + \frac{I}{mgL} \right) \ddot{y} \qquad (23)$$

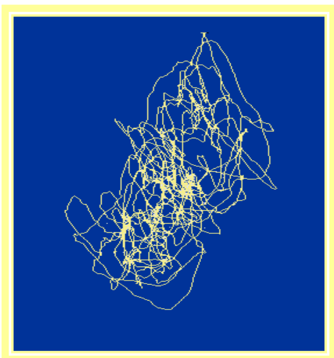
After some easy manipulation and putting the equation in terms of the angle π/2- α= θ we obtain:

$$\ddot{\alpha} - \left(\frac{mgL}{I} \right) \alpha = 0 \qquad (24)$$

This equation, of course, describes an unstable situation; the inverted pendulum topples over. However, this classical procedure does not explain the Random Walks characteristics of quiet standing coordinates of the COP. They can be defined by the equation of Hastings & Sugihara 1993 that combines a random walk with a friction term like a Langevin equation:

$$dx(t) = -rx(t)dt + dB(t) \qquad (25)$$

Here dB is the uncorrelated noise with zero mean



Posturogram- Random Walk of the COP coordinates.

3.3 Multifractals in Human Gait

Walking is a very complex voluntary activity. The typical pattern shown by the stride interval time series suggests particular neuromuscular mechanisms that can be mathematically modelled.

The fractal nature of the stride time series of humans was incorporated into a dynamical model by Hausdorff using a stochastic model. Ashkenazi et others later extended this model to describe the analysis of the gait dynamics during ageing.

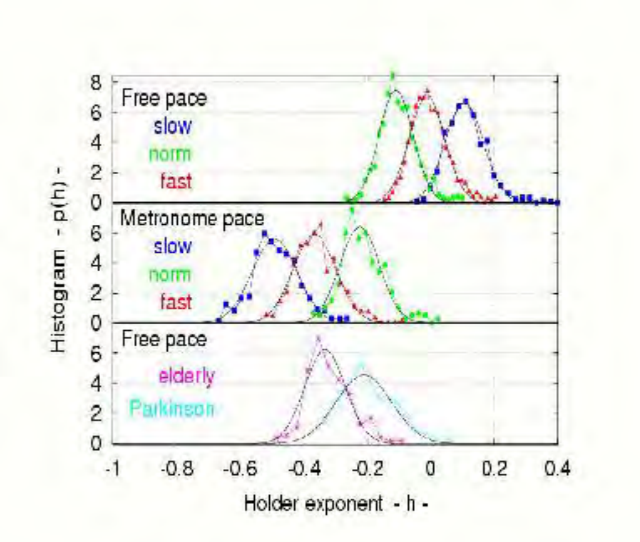
The model was essentially a random walk on a Markov or short-range correlated chain. Each node is neural that fires an action potential with particular intensity when interested by the random walker.

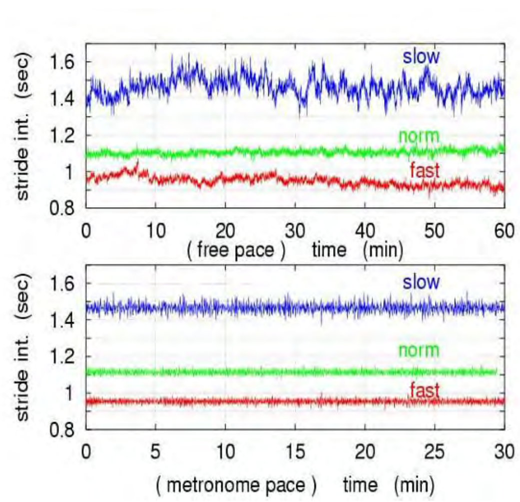
This mechanism generates a fractal process with multifractals aspects. The Holder time-dependent exponent depends parametrically on the range of the random walker's step size.

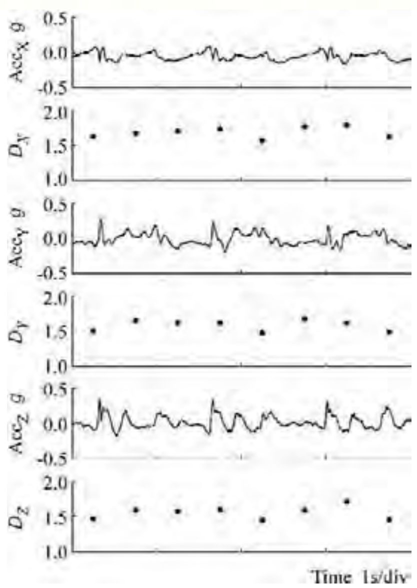
The multifractal gait analysis is also used to study the fractal dynamics of body motion for patients with particular ageing problems or diseases, like Parkinson or post-stroke hemiplegic.

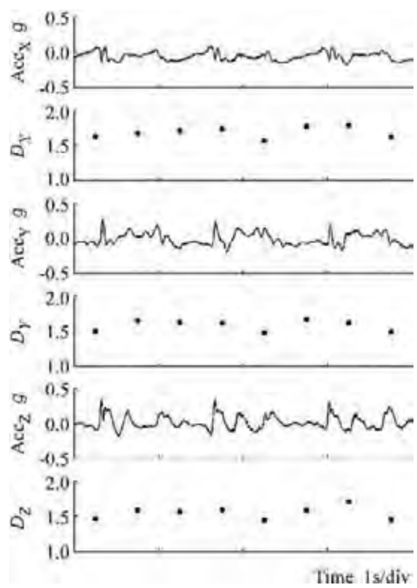
In the following figures, we can see.

- The variation of the time-dependent Holder exponent, with the walker step size for free pace and metronome pace at different speeds.
- The different time series is produced by the free pace and metronome pace at different speeds.
- The relative acceleration signals and the corresponding fractal values in post-stroke and Parkinson patients.







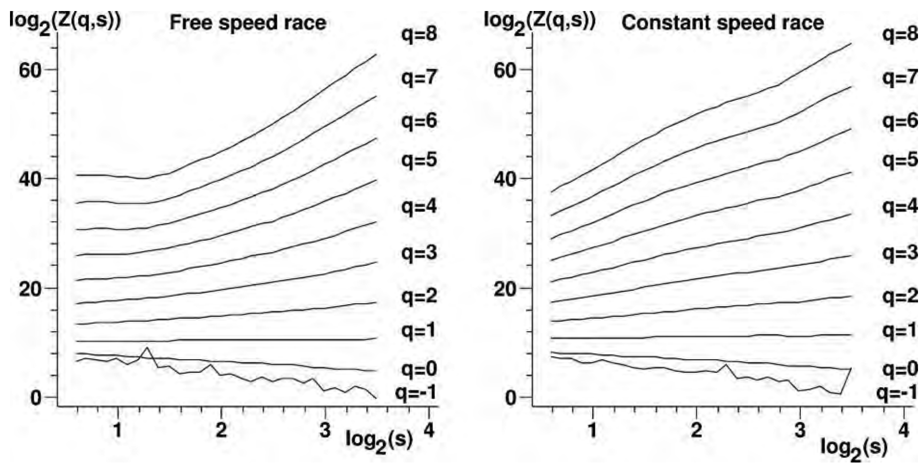


4 From the Usual Movement to Sport Movement

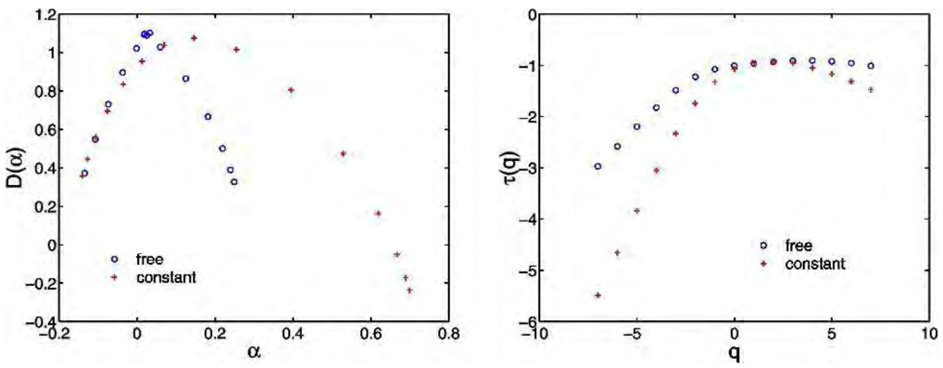
4.1 Multifractals in Running training

The fractal nature of the physiological signals: heart and respiratory frequencies and oxygen uptake in long-distance runs were compared and analyzed by Billat et others 2001-2002-2004.
Today middle- and long-distance running are characterized by speed variability.
The statistics show that if there are considered the last three world records on middle- or long-distance running, it can be observed that velocity varies by 5%.
In races, the variation of the velocity and the choice of the optimal speed involves a complex interplay between physiological and psychological factors.
We use the multifractal analysis in the biomechanics of running for classifying signals which exhibit a rough behaviour.
We quantify this behaviour by calculating the holder exponent using multifractal analysis.
The following equations give the formula of the exponent:

$$H(t_0) = \liminf_{t \to t_0} \frac{\log|f(t) - P_m(t - t_0)|}{\log|t - t_0|} \qquad (26)$$



Free and constant heart rate scaling law behaviour



Heart rate spectrum and scaling exponent

4.2 Situation Sport

In Biomechanics of Sport, it is interesting to classify the sport to study the athletic performance.

There are many potential classifications, for example, in the function of performance energy expenditure. However, one of the more useful ones is the biomechanical classification in the most fundamental movement performed during the performance.
This classification allows to single out the most fundamental complex movement that must be measured by specific scientific discipline as a whole or in step size.
In the alternative, this most basic movement could be the goal of an expert group like Sports Physiologist, Neurologist, Biomechanics, engineering, trainers, technicians.
This classification aims to find the specific observational approach to solve the problem by mechanical or mathematical models, both qualitative or quantitative.
This classification allows us to group all the sports into four prominent families.

Cyclic Sports
All the sports in which the basic movement is repeated continuously in time like gait, running, marathon cycling, swimming, etc.

Cyclic Sports
There are sports in which the basic movement is applied only once in the performance. For example, discus shot put hammer throw, pole vault, high jump, long jump, triple jump, ski jump, javelin throw, etc.

Alternate-Cycling Sport
There are all the sports in which two basic movements are applied alternatively in time, like 110 hurts, 400 hurts, steeplechase, golf.

Situation Sport
There are all the sports with the presence of the adversary.
These sports can be divided into two classes (without and with contact), and each class in two subclasses *dual sports* and *team sports.*
The first dual ones are tennis and ping pong, and as team sports, we can find volleyball and beach volley.
The last dual ones, in which athletes can contact together, are fighting sports: judo, boxing, wrestling, karate, etc., and as a team sport, soccer, basketball, football, water polo, hockey, etc.
The situation sports are sport in which it is impossible to find a repeatable motion pattern for each specific game. For each contest, the motion in it is a random process. There is no fundamental, detailed movement during the action. However, it is possible to find these repeatable movements .only during the interaction among athletes.
The correct way to analyze such macro phenomena is to study them. In two steps: motion and interaction with basic, repeatable movements.
And we can find it astonishing that motion for each class of these sports could be associate with one of the previous Brownian Motions that we show.
Let's consider for each sport the basic motion pattern of a large number of games from the statistical point of view, like the classical Gaussian approach. Then, it appears quickly that the motion belongs to the classes of Brownian Motion.

4.3 Dual sport
We consider a couple of athletes as a single system. The motion of the centre of the mass system is definite by a push-pull random force. That in formulas can be express as:

$$\varphi(t) = u\sum_j \delta(t - t_j) \qquad (27)$$

The system is isolated, no external forces less the random push-pull forces then the motion equation will be a Langevin, an equation (Sacripanti 1992), and it is possible to write:

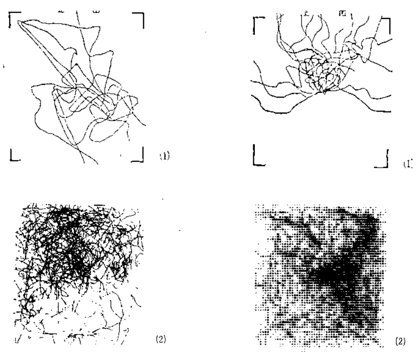
$$F = ma = -\mu v + u\sum_j (\pm 1)_j \delta(t - t_j) = F_a + F' \qquad (28)$$

Considering the well-known work of Smoluchovski on the Brownian Motion, the " Physical that produces the random evolution of the contest allows us to obtain the basic probability of this Markovian process.
Then for dual sports, it is possible to obtain from the transition probability Q the solutions of Conditional Probability. Which give at the infinite time limit the likelihood to find an athlete between x and x + dx at time t. In the mathematical form, we can write:

$$Q(k,m) = \frac{1}{2}\delta(m,k-1) + \frac{1}{2}\delta(m,k+1) \qquad (29)$$ that give us the solution

$$P(n|m,s) = \frac{s!}{\left(\frac{v+s}{2}\right)!\left(\frac{v-s}{2}\right)!}\left(\frac{1}{2}\right)^s \qquad (30)$$

The experimental proof of this model can be founded in some Japanese works, on the world championship of 1971.
In the following figure, we can see the summation of motion patterns of 1,2,7 and 12 contests of judo .it is easy to see that the random fluctuation does not have a preferential direction over time. This means that $\langle F' \rangle = 0$ and the motion of the Centre of Mass systems is Brownian.



$$\langle F' \rangle = 0$$

4.4 Active Brownian Motion
Motion in a team sport is better modelized by the active Brownian motion proposed by Ebeling and Schweitzer, tacking the oxygen uptake from the particles and its consumption from the environment.

A particle with mass *m*, position *r*, velocity *v*, self-propelling force connected to energy storage depot *e*(*t*); velocity-dependent friction γ(*v*), external parabolic potential *U(r)* and noise *F*(*t*) could satisfy the following Langevin like an equation that could be written:
This is the motion system equation for the active Brownian motion

$$m\,\partial_t \boldsymbol{v} = d_2\, e(t)\,\boldsymbol{v} - \gamma(\boldsymbol{v})\,\boldsymbol{v} - \nabla U(\boldsymbol{r}) + F(t)$$
$$\partial_t \boldsymbol{r} = \boldsymbol{v} \qquad (31)$$

From the original work of Ebeling et co-workers, it is possible to take into account the energy depot: space-dependent take-up q(r), the internal dissipation c e(t), and also the conversion of internal energy into kinetic energy d2 e(t) v2 then the relative equation is:

$$\partial_t\, e(t) = q(\boldsymbol{r}) - c\, e(t) - d_2\, e(t)\,\boldsymbol{v}^2 \qquad (32)$$

Energy depot analysis (for *q*(*r*) = *q*0) that are special constant conditions, gives the following result, after some calculation, in terms of friction non-linear coefficient**:**

$$\gamma(\boldsymbol{v}) = \gamma_0 - \frac{d_2\, q_0}{c + d_2\, \boldsymbol{v}^2} \qquad (33)$$

This data can be specialized for human people playing team games, as shown in the following pages.

4.5 Team sport

In the first Sacripanti's model, relative to the dual situation sports, the centre mass of a couple of athlete's systems is a classical Brownian Motion. Which means there is no particular direction in their motion patterns.
In the case of a team sport, the situation is entirely different. There is, in mean, a unique preferential direction in motion pattern, and every single athlete is not in stable equilibrium as a couple of athlete's systems.
In this case, it is necessary to adopt a different model for the motion, like the active Brownian motion proposed by Ebeling and Schweitzer., to consider the oxygen uptake from the environment. In this particular case, it is possible to write for the energy depot variation :

$\frac{dE(t)}{dt} = \dot{V}(t) - \eta(v^2)Kv^2E(t)$ Let's take the hypothesis that the energy E(t) is slowly varying. The previous equation can be simplified based on the following considerations:

$$\frac{dE(t)}{dt} \approx 0$$
$$\dot{V}(t) \cong \overline{V}(t)$$

Then it is possible to obtain the particular value for the energy $E_0(t)$, namely:

$E_0 = \frac{\overline{V}}{\eta K v^2}$ the equation achieves a term kE_0v as shown by Ebeling, the friction coefficient, in this case, will be:

$$\gamma_v = \gamma_0 + E_0 \equiv \gamma_0 - \frac{k\overline{V}}{\eta k v_0^2} = \gamma_0 - \frac{\overline{V}}{\eta v_0^2} \qquad (34)$$

Also, considering the potential interaction against the adversary, collision or avoidance, we can present the second Sacripanti model.
Based on the Ebeling and Schweitzer model and the Helbing equation, the following Langevin type equation proposed in Sacripanti's second model accounts of:

motion, oxygen uptake, kinetic energy from uptake and potential mechanical interaction like collision and avoidance manoeuvres:

$$ma = \left(\gamma_0 - \frac{\overline{V}}{\eta v^2}\right) v(r,t) + \frac{m}{t}\left[v^0 e(t) - v_1\right] + \theta k(r_{1,2} - d_{1,2}) N_{1,2} +$$
$$+ A_{1,2} N_{1,2} e^{\left(\frac{r_{1,2}-d_{1,2}}{B}\right)} \left[\lambda_1 - (1-\lambda_1)\frac{1+\cos\varphi_{1,2}}{2}\right] + u\sum_j (\pm 1)\delta(t-t_j) \qquad (35)$$

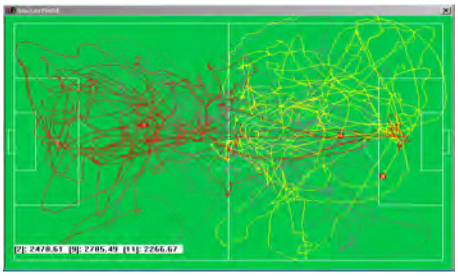
In compact form, it is possible to write

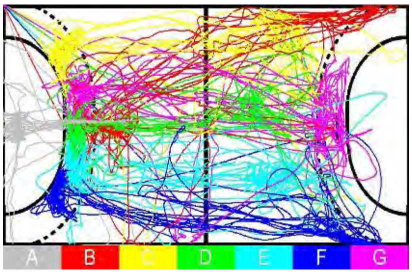
$$ma = -\gamma_v v + F_{acc} + \left[\Sigma F_1 + \Sigma F_2\right] + u\sum_j (\pm 1)\delta(t-t_j) =$$
$$= -\gamma_v v + F_{acc} + \left[\Sigma F_1 + \Sigma F_2\right] + F' \qquad (36)$$

The solution model proposed by Ernest could model the specific preferred direction in motion patterns of the team sports. However, with a particular modification, it is possible to model the basic probability of this Markovian process (the game) in the function of the specific attack strategy utilized.
In effect, for the team sports, it is possible to write the transition probability Q in the function of the attack strategy α.
The α parameter can vary from 1 to 5, with these meanings :
1= lightning attack ; 2= making deep passes; 3= manoeuvring ; 4= attack by horizontal passes; 5= Melina
The solution of the conditional probability P is connected to the limit of mean value in time for finding the athlete between x and x + dx at time t, in formulas:

$$Q(k,m) = \frac{R^\alpha + k}{2R^\alpha}\delta(m,k-1) + \frac{R^\alpha - k}{2R^\alpha}\delta(m,k+1)$$
$$con -1 \le \alpha \le 5 \qquad (37)$$
$$\langle m(s)\rangle_{av} = \sum_m mP(n[m,s) = \left(1 - \frac{1}{R^\alpha}\right)\langle m(s-1)\rangle_{av}$$

In the following four figures, it is possible to see that, despite the preferential direction present in each motion pattern, from the statistical point of view (summation of several motion patterns from several games) and team games, the random fluctuation does not have a preferential direction over the time. This means that $\langle F' \rangle = 0$ and the global motion also, in this case, is Brownian.





$$\langle F' \rangle = 0$$

5 Conclusions

From this article, it is understandable that all the self-organizing complex systems, especially the biological ones, like the human body, are better described by non-linear evolutions equations that show themselves in their static, kinematics and dynamics forms. (fractals).

The only connection among these different aspects is the generalized Brownian Motion in every known formulation: classic, fractional, active, etc.

Its results starting from fractals to multifractals aspects, assure us, in the light of our knowledge, that Brownian dynamics is one of the basic modellings of the mathematical alphabets of Life.

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Appendix III

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How Athletes shift during fights

Competitions' Judo Patterns in Computational biomechanics and fighting strategy indication

How Athletes shift during fights
Competitions' Judo Patterns in Computational biomechanics and fighting strategy indication

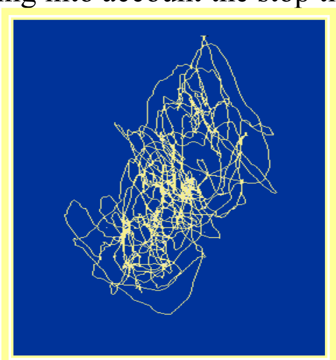
Introduction

In this Appendix, the motion of athletes on the mat as CM (Centre of Mass) loci of a Couple of athlete's systems will be analyzed in his whole complexity.
In this entire book, from time to time non-linear description of complex systems comes into sight to show the limit of the linear approximation.
All three appendixes show the objective complexity under the linear approximation; our world is a complex system; the human body is the most complex system globally. Judo is a complex sport among the situation sports, the most complex sports in our daily life.
Only in these years, scientists can organically approach complex non-linear systems. However, we are at the first meter of a beautiful and long way. These three appendices will show some of the difficulties present in the complex non-linear systems, like a man who plays judo.
At first, the standing still positions (starting position before the fight) will be studied considering the connection between COP (Centre of Pressure) and CM motion.
The mistake usually made by neurophysiologists studying the fBm qualitatively by the ellipse covering the COP curve is analyzed in the light of the geometrical non-linear approximation
Then a model of 2D motion on the mat will be studied as a result of a computational approach.
Finally, we analyze the extrapolation to the three-dimensional natural CM motion and its connection with macroscopic Newton second law that everybody can apply—describing a couple of athletes shifts and their interactions.

The starting position

The starting position isn't a standing still position; several causes can be put forward to explain this particularity.
Firstly, and fundamentally, the vertical erected posture is relatively late from a phylogenetic point of view. It could explain the position of the human pelvis, which is not fully adapted to upright standing.
This anomaly results in a vertical misalignment of the joints and segmental centres of mass, producing horizontal shear forces around the joints to stabilise these segments.
Since a muscular contraction cannot develop a constant level of force over time, the resultant moment of forces around the CM cannot be constant.
It follows that the CM is necessarily and permanently accelerated.
Secondly, in addition to this muscular cause, the large inertia of the upright body also prevents the COP from resulting in comparable CM horizontal displacements. As a result, a horizontal gap between the vertical projection of the CM and the COP is observed.
Consequently, a horizontal acceleration, and thus a horizontal force, variable in amplitude and direction, is communicated to the CM.

As shown in Appendix II, it's possible to describe the COP by Brownian motion and Fractional Brownian Motion. Taking into account the stop time of the COP motion.



Posturogram of the COP

Collins and de Luca were the first to propose in 1993 this method for interpreting COP trajectories.
In the fBm approach, initially presented by Mandelbrot and van Ness in 1968, any time series can be considered a combination of deterministic and stochastic mechanisms.
The concept developed through fBm is, indeed, a generalisation of Einstein's work. This principle showed that a stochastic process is characterised by a linear relationship between mean square displacements < x^2> and increasing time intervals t, in the formula:

$$\left\langle x^2 \right\rangle = 2D\Delta t \qquad (1)$$

The general principle of the fBm framework is that the aspect of a trajectory. This principle expressed as a function of time may be quantified by a nonfinite integer or fractional space dimension, hence providing a quantitative measurement of evenness in the trajectory.
In mathematical form, it is possible to write:

$$D_t^{\alpha}\left[X(t)\right] - \frac{X(0)}{\Gamma(1-\alpha)} t^{-\alpha} = \xi(t) \qquad (2)$$

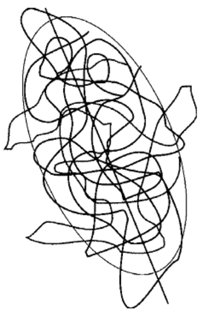
In which the first term is a fractional derivative, the second is connected to the initial condition of the process. The third is always the random force acting on the COP. In this case, it is vital to know the mean square displacement of the point :

$$\left\langle \left[X(t) - X(0)\right]^2 \right\rangle = \frac{\left\langle \xi^2 \right\rangle}{(2\alpha - 1)\Gamma(\alpha)^2} t^{2\alpha-1} \propto t^{2H} \qquad (3)$$

From this expression, it is possible to understand that we are in the presence of an anomalous diffusion process. Identified by the Hurst parameter, in particular, this parameter is time-independent, and it describes the fractional Brownian motion with anti-correlated samples for $0<H<1/2$ and with correlated samples for ½<H<1. If H is = to ½, we can speak of Brownian motion.

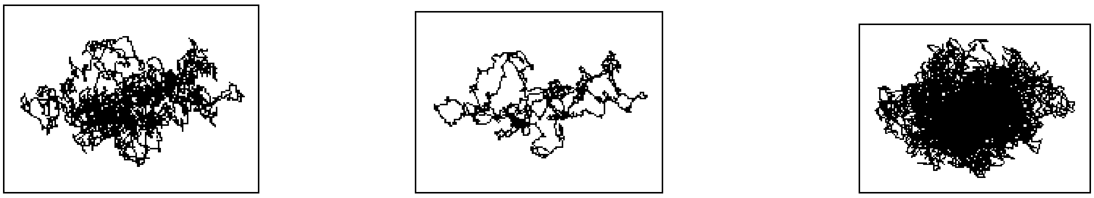
Neurophysiologist's linear approximation mistake

Usually, many parameters linked to the COP displacements in the posturography are typically described by the subjects' postural performance. The COP surface area (90% c onfidence ellipse, see Fig. 1) evaluates the subject's performance. The smaller the surface, the better the performance.
The COP length indicates the net muscular force variation, which allows the evaluation of the postural control. The coordinates of the average position of the COP on the medio/lateral axis or X-axis (X COP mean) and anterior/posterior axis or Y -axis (YCO P mean) indicate the distribution of the plantar pressures.

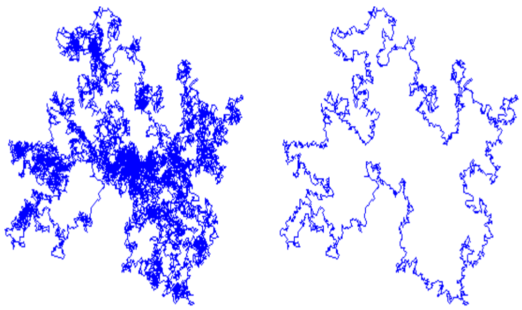


But the mistake is connected to the surface simplified evaluation. In general, the fBm surface could be a function of time; this generalization is called multifractal Brownian motion.
Then based on the Hurst parameter's variation, it is possible to have three types of Brownian motions. As we can see in Appendix II

1. *Pure Brownian motion: next step is uncorrelated with the previous step H=0.5. Brownian diffusion*
2. *Anti-Persistent Fractional Brownian motion: each step is negatively correlated with the previous step H<0.5. Ipo Brownian diffusion*
3. *Persistent Fractional Brownian motion: each step is positively correlated with the previous step H> 0.5 Iper Brownian diffusion*



Then it is possible to have the same surface with three curve densities different inside the confidence ellipse.
The better way to identify the surface area of the COP curve is to evaluate the perimeter. However, the confidence ellipse is a 2D surface, while the boundary of a Brownian motion is a curve of 4/3 D.

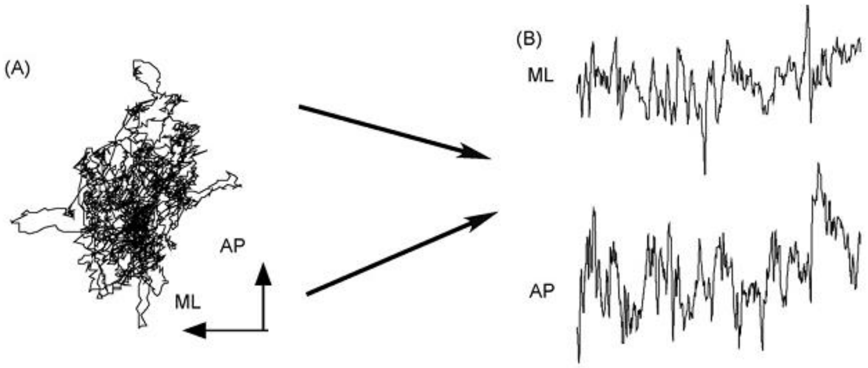


The motion of the Projection of Couple of Athlete' loci

In a couple of athlete systems after stabilized grips, the projection motion of the CM of the couple on the mat belongs to the Brownian motions class.
It is a 2D fBm (See Appendix I) equivalent to the two fBm performed by the projections of CM of each athlete.
The fBm is a complex motion, fractal related, and shows the auto-similarity property.
(See Appendix II).
In that case, the fractional dimension *D*, along with a single axis, is related to the Hurst scaling exponent *H* since *D* =1—*H* for the present case.
Graphically, this scaling regime *H* corresponds to the half slope of the line portions. They constitute a variogram (mean square displacements < x^2> as a function of the increasing time interval) depicted bi-logarithmically.
We call the previous posturogramme for the static condition, variogram for dynamic ones.
The variogram, in that case, is given by the formula

$\left\langle [X(t)-X(0)]^2 \right\rangle \approx t^{2H}$ (4) And requires a log-log plotting:

The following figure, it is showing the decomposition of a 2D fBm fighting path in two 1D fBm



As demonstrated in appendices I and II, the variogram shows the motion paths of CM projection of the Couple system on the mat during one or more fights.
This 2D motion can be reconstructed by an original model in computational biomechanics, specifically produced for this book.
It is important to note that loci motion is an fBm connected to two fBm, each for every fighter.

Athletes Shifting in Computational Biomechanics

Numerical Evaluation.

This evaluation aims to formulate a numerical strategy to evaluate reasonable athletes' paths, linked, in a simplified way as a first step, to the previously discussed theory.
The fundamental assumptions are introduced and described in the following. Table:

a. the two athletes are supposed to be located at the two ends of a bar;
b. the bar can rotate around its middle point, considered as the barycentre of the *athlete's couple*;
c. the length of the bar oscillates in a *harmonic-random* way;
d. the centre of the bar (barycentre of the couple) moves in a *random motion*.

Thus, the motion of the two athletes is simulated by the *random motion* of a "*pulsating*" "*spinning*" *circle*. With a mass equal to the sum of both athletes and whose variable diameter depends on both their arm's length and their shoulder "thickness". In all the following numerical simulations, a total 140 kg weight and a 0.2-0.8 m diameter range are assumed.
From the previous discussion, it follows that the global motion of a single athlete is assumed to be the vectorial composition of three different elementary movements:

- *random motion* of the centre of the "*athletes couple*",
- *random rotation* around the centre;
- *random oscillation* towards the centre.

It is worth observing that all three elementary motions are characterized by *random behaviour*.

The "couple centre" motion is characterized, at each step, by a direction *uniformly randomly chosen* (on 360 grades). Along the selected direction, *displacement* is calculated, supposing a *rectilinear uniformly accelerated* motion. The *time length* of the motion is evaluated, again, by a *random number generation approach*. In more detail, the displacement of the *coupling centre*, along with the already chosen direction, is evaluated through the following equation:

$$m\frac{d\mathbf{v}}{dt} = -\beta\mathbf{v} - m\frac{(\mathbf{v}-\mathbf{v}_a)}{\tau} + \mathbf{P} - \mathbf{A}e^{-|x|/b} + \mathbf{L} \tag{5}$$

The total mass of the athlete's couple is the vector velocity. The relaxation time necessary to reach the "target velocity" $\mathbf{v}_a$, $\mathbf{P}$ a *pushing force*, $\mathbf{A}\exp(-|x|/b)$ is a global term related to borderline distance strategy, while $\mathbf{L}$ is the *random Langevin force*. This kind of force is introduced through the *random choice of the direction* and the *random choice* of the length of the "*couple centre*" displacement before the *following change of direction*. Thus, the deterministic behaviour of this kind of motion is simulated by the solution of the following scalar equation:

$$m\frac{dv}{dt} = -\left(\beta + \frac{m}{\tau}\right)v + \left(\frac{mv_a}{\tau} + P - Ae^{-|x|/b}\right) \tag{6}$$

Whose solution is easy?

$$\Delta s = \frac{c}{a}\Delta t + \left(\frac{v_0}{a} - \frac{c}{a^2}\right)\left(1 - e^{-a\Delta t}\right) \tag{7}$$

Where Δs is the total displacement of the "*couple centre*" displacement during the time step Δt, way, a *tactic* function should be added? The *strategy* depends on the player characteristics.
Some numerical realizations of possible athletes' paths, belonging to a statistical ensemble built up by the previously described approach, have been carried up.
In Fig. 1, it is shown how the athlete's movements are simulated by *moving*, *spinning* and *pulsating* "*athletes couple circles*", shown in the red colour. The athletes are located at the ends of the reported red diameters, while the tracks of one of the two athletes are noted in black lines.

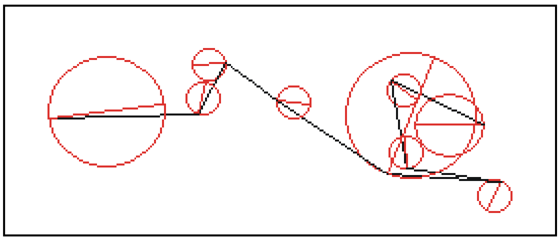


Fig. 1 Movements of the "athletes couple"

In Fig.2, a single game related to a possible realization belonging to a supposed statistical ensemble is reported.

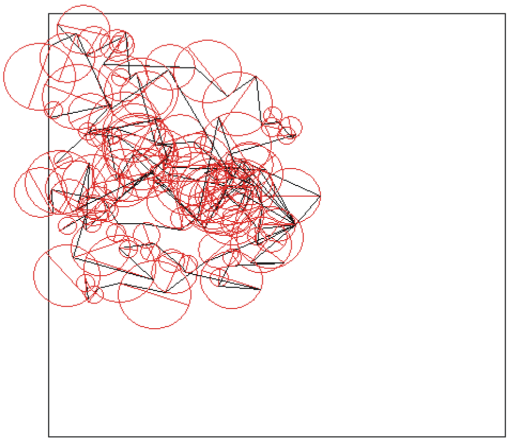


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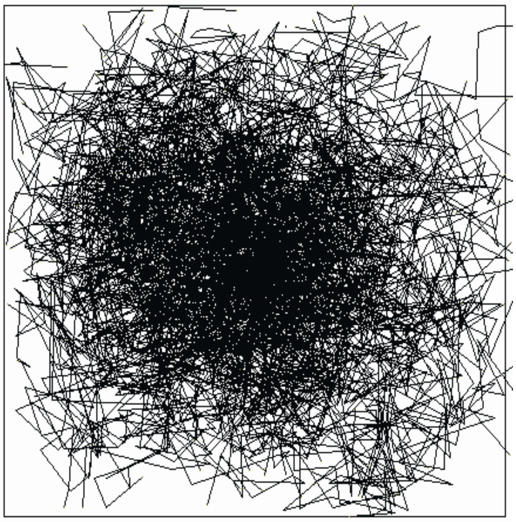
Fig.3 shows a superposition *realization* of the tracks of a single athlete, belonging to the *same statistical ensemble*, regarding *16 different virtual games*. The ensemble is built upon the supposition of complete symmetry.

Fig



In Fig..4a and 4b, two different realizations of the tracks of a single athlete, belonging to the same statistical ensemble, regarding a single game, are reported.
The ensemble is constructed, supposing a smooth asymmetry along the N-W direction.
Fig. 4c shows recorded tracks of an actual single game.
Also, in Fig..5a and 5b, two other different realizations of the tracks of a single athlete, belonging to the same statistical ensemble, regarding a single game, are reported.
This new ensemble was created, superimposing a smooth asymmetry along the S-N direction.
Fig. 5c shows recorded tracks of an actual single game.
Fig. 6a, 6b, 6c; and Fig. 7a, 7b, 7c show superimposition of 7 and 12 single tracks with superimpositions of actual matches.

It is important to note that the changes of some parameters described before allow describing different actual tracks. Another essential point to note is the occurrence of *spatial permanence* of the tracks (Figg. 4a, 4b, 4c in particular). As the tracks depend on random movements, the spatial permanence could be related to the Fractional Brownian-like motion (fBm) of the tracks (actual tracks).

Fig. 4a
N-W asymmetry
one game
a **1°** realization

Fig. 5a
S-N asymmetry
one game
a **1°** realization

Fig. 4b
N-W asymmetry
one game
a **2°** realization

Fig. 5b
S-N asymmetry
one game
a **2°** realization

Fig. 4c
one game
experimental tracks

(1)

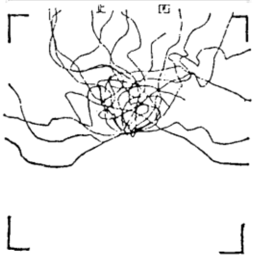


Fig. 5c
one game
experimental tracks

Fig. 6a
7 games
experimental tracks

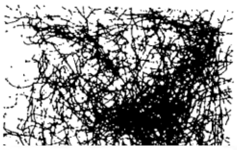
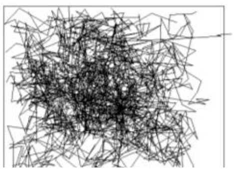
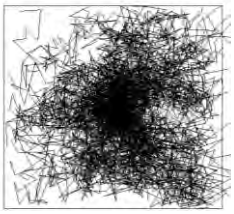


Fig. 7a
12 games
experimental tracks

Fig. 6b
N-W asymmetry
7 games
a **1°** realization



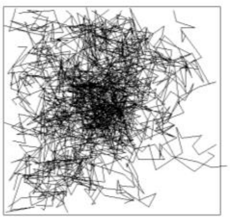
(2)



(2)

Fig. 7b
N-W asymmetry
12 games
a **1°** realization

Fig. 6c
N-W asymmetry
7 games
a **2°** realization



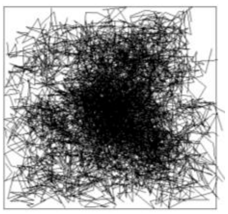


Fig. 7c
N-W asymmetry
12 games
a **2°** realization

As we saw before, an essential feature of fBm modelling for each fighter is the presence of long-term correlations between past and future increments.

This can be assessed by the scaling regimes *H*. ***This means that a fighting path can show if correctly analyzed if the fighter has a whole fighting strategy or a random strategy during his competition***. For example, a median value of 0.5 for *H* indicates no correlation, suggesting that the trajectory displayed a random distribution (Brownian motion).

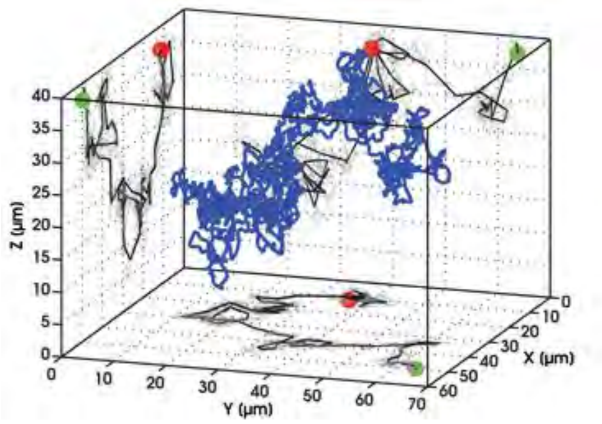
On the other hand, if *H* differs from 0.5, a positive (0.5 > *H)* or negative (H < 0.5) correlation with his fighting way can be inferred, indicating that a given part of the initiative is under control. Depending on how *H* is positioned, concerning the median value 0.5, it can be inferred that the subject more or less controls the trajectory (and the fight evolution in time): the closer the regimes are to 0.5, the larger the contribution of stochastic processes (random attacks without strategy) — in addition, depending on whether *H* is greater or less than the 0.5 thresholds, persistent (attacking) or antipersistent (defending) behaviours can be revealed, respectively. Suppose the CM projection at a specific time is displaced towards a given direction. In that case, the more significant probability is that it drifts away in this direction (persistent attacking behaviour). Or, on the contrary, it retraces its steps in the opposite direction (antipersistent defensive behaviour).
Equality between these two probabilities indicates there is not the presence of a defined strategy in fighting, like simple random motion or stochastic process.
But the natural motion is a 3D motion. How can we reconstruct the most complex three-dimensional information from the two-dimensional path of the Couple of Athletes movement?

The projection theorem

The proposed problem is that the motion path is a 2D projection of a 3D complex structured motion.
The assessment of volume properties from this 2D data is far from evidence because few theoretical evaluations link 3D properties with 2D ones.
Only recently, a very advanced theoretical study has shown that the H parameter of an n-dimensional isotropic fractal is linked to the (n-1)-dimensional fractals by the following self-similarity function:

$$H_{(n-1)D} = H_{nD} + 0.5 \quad \text{that in our case is} \rightarrow H_{2D} = H_{3D} + 0.5 \qquad (5)$$

The following figure shows the meaning of the problem:



From the Brownian approach to the Newtonian ones

Generally, in real life, the linear approximation and the Newtonian Dynamics are in our everyday usage and knowledge. How the Brownian dynamics and Newtonian mechanics are connected? Einstein and other physicists solved the problem in the study of diffusion.
In this paper, we try to extend it to shifting paths in competition.
it is convenient to introduce the probability
$f(\mathbf{r},\mathbf{p},t)\, d^3\mathbf{r}\, d^3\mathbf{p}$ of finding Athlete's position **r** in the position-space volume $d^3\mathbf{r}$ and momentum **p** in the momentum-space volume $d^3\mathbf{p}$, at time *t* to describe the state of the fight observed. Let us start from the sharp distribution

$$f(\mathbf{r},\mathbf{p},t=0) = \delta(\mathbf{r} - \mathbf{r}_0)\delta(\mathbf{p} - \mathbf{p}) \quad (10)$$

Associated with the initial conditions of motion, where δ is the Dirac distribution. We do not observe, at time *t* > 0, the sharp distribution related to (10) f(**r**,**p**,t)= [**r** -**r**(t)]δ [**p** -**p**(t)], (11)

Such as predicted by the hamilton equations of the athlete's system

$$\frac{dr}{dt}=\frac{p}{m} \quad (12) \qquad \frac{dp}{dt}=F-\mu p \quad (13)$$

The solutions are quickly evaluated:

$$p(t)=F\tau+\left(p_0-F\tau\right)e^{-\mu t} \quad (14)$$

$$r(t)=r_0+\frac{F\tau}{m}t+\frac{\tau}{m}\left(p_0-F\tau\right)\left[(1-e^{-\mu t})\right] \quad (15)$$

$$with \quad \tau=\frac{1}{\mu} \quad the\ stationary\ solutions\ t>>\tau\ are$$

$$p(t)\approx\frac{F}{\mu} \quad (16)$$

$$r(t)\approx r_0+\frac{F}{\mu m}t \quad (17)$$

Langevin added to the right-hand side of the equation a stochastic force ξ (t), also called white noise, to account for the sharp distribution in mechanical terms.
It is a random function of time with zero mean and a covariance proportional to the Kinetic energy produced, in our case." athletes fight" by the work of push-pull forces (see appendix)
For which: $\langle \xi(t) \rangle = 0$.
Working out Langevin's picture, it is found that *f* is the solution of the so-called Klein–Kramers equation,

$$\frac{\partial f}{\partial t}+\frac{p}{m}\frac{\partial f}{\partial r}+\frac{\partial}{\partial p}\left[\left(F-\mu p-\frac{\mu m v^2}{2}\frac{\partial}{\partial p}\right)f\right]=0. \quad (18)$$

Letting $E_k=\frac{\mu m v^2}{2}=0$ in equation (18) gives a partial differential equation on *f* which, mathematically speaking, admits the Hamilton equations (12) and (13) as their characteristics
Physically speaking, if $E_k = 0$, equation (18) admits solution (11) given the initial condition (10).
Now we have to do with two equivalent approaches worded in two different languages.
Langevin's approach is cast in the language of dynamics with a novelty, namely the stochastic force ξ(*t*). When the latter is input into Newton's second law of motion, we obtain a stochastic differential equation. In contrast, the approach of Klein and Kramers is expressed in the language of statistical physics. The primary tool is probability density in phase space, which is a linear partial differential equation solution.
While Langevin's approach looks more intuitive at the first sight and indeed was put forth before, its mathematics is subtle and open to criticism. The method of Klein and Kramers looks clumsier at first because of its use of phase space, but it is based on standard mathematics.
Defining the average of any observable *O* from the probability density *f* in the usual way of classical statistical mechanics:

$$\langle O\rangle\equiv\iint Of(r,p,t)d^3rd^3p \quad (19)$$

It is possible to show by algebraic manipulations that equation (18) entails

$$\frac{d\langle r\rangle}{dt}=\frac{\langle p\rangle}{m} \qquad (20)\equiv(12)$$

$$\frac{d\langle p\rangle}{dt}=F-\mu\langle p\rangle \qquad (21)\equiv(13)$$

If we consider that F and μ are independent of positioning, the Hamilton equations (12) and (13) are recovered on average. Then the Newtonian approach is connected to the average on long time and space. At the same time, the fBm characterizes short time and microscopic space of observation.
The self-affinity connects microscopic and macroscopic trajectories and theoretical self-similarity (see Appendix II). Also, for anomalous diffusion H<0.5 and H>0.5, the scaling properties of these phenomena are connected sometimes to the long-term memory of the process.
Generally, for an ongoing fight, the correlation in time shows an inverse power law. Typically two is greater than 2H. This means that correlation between two points in time decreases with increasing time separation, the spectrum (Fourier Transform of Correlation) is an inverse power law in frequency:

$$C(\tau)=\langle X(t)X(t+\tau)\rangle\propto t^{2H-2} \qquad (22)$$

$$S(\omega)=FT\{C(\tau),\omega\}\propto\frac{1}{\omega^{2H-1}} \qquad (23)$$

For the anti-persistent evolution of fight the spectrum, instead becomes a direct power law in frequency.

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Appendix IV
Biomechanical Optimization of Judo

sharp Coaching tool

(Practical Application and Scientific background**)**

Attilio Sacripanti

Biomechanical Optimization of Judo: A sharp Coaching tool

(Practical Application and Scientific background)

1. Introduction

Optimization is a powerful and flexible tool applied in modern Engineering and Economics to "optimize" some situations, as income, structures.
Optimization theory is central to any problem involving decision making, both in engineering or in economics. The task of decision-making entails choosing among various alternatives.
This choice is governed by our desire to make the "best" decision. An objective function describes the measure of the goodness of the alternatives.
Optimization theory and methods deal with selecting the best alternative in the sense of the given objective function.
In simple mathematical words, optimisation aims to build an objective function (linear or nonlinear) describing the process and find a helpful extreme (Maximum or Minimum) of this function.
The ancestor of this approach in Physics is the ***Principle of Least Action***, or in a better and more correct way, the ***Principle of the Stationary Action,*** which is a variational principle that, when applied to the action of a mechanical system, can be used for example to obtain: the equations of motion of the system, the shortest path between two points, the best way of a minimum of energy consumption, the minimum time trip, etc.
Many physical-mathematical experts spoke about this principle in old times: Fermat, Euler, Maupertuis, Hamilton, Leibnitz.
Pierre Louis Moreau de Maupertuis is generally credited for its most general formulation, who asserted: "the laws of movement and rest deduced from this principle being precisely the same as those: observed in nature, we can admire the application of it to all phenomena: movement of animals, vegetative growth of plants are only its consequences; and the spectacle of the universe becomes so much the grander, so much more beautiful, the worthier of its Author, when one knows that a small number of laws, most wisely established, suffice for all movements." [1]
In application to physics, Maupertius suggested that the quantity called "Action" to be minimized the product of the duration (time) of movement within a system by the "vis viva". Which is the integral of twice what we call the kinetic energy K of the system, in formulas:

$$\delta A = \delta \int_t^t 2K(t)dt \qquad (1)$$

When we speak about the best decision or the best way to minimize energy consumption, these two extremals give us the amplitude of the Optimization Theory.
The calculus of variations is concerned with problems in which a stationary variational principle determines a function. In its simplest form, the problem is to find a function $y(x)$ with specified values at end-points x_0, x_1 such that the integral $J = \int_{x_0}^{x_1} f(x, y, y')dx$ (2) is stationary.
Usually apply the calculus of variation to sport to find a value to minimize energy, muscle effort, or the right angle to obtain the optimum performance in sport. [2]

2. Optimization in Sports

In terms of Biomechanics, sports can be classified as Cyclic, Acyclic, Cyclic - Acyclic Alternate and Situation Sports (dual and team) [3]. For cyclic and acyclic sports, optimization is complex but possible. For situations, sports Optimization is complicated and sometimes impossible.
It is known worldwide that the verbal expression of the principle of stationary action for the human locomotion is that the algebraic sum of all joint's angles in the human body must be zero" (which is a cyclic motion). This can be express by the following words: "necessary and sufficient condition to have locomotion.
When optimization is applied to simple cyclic sports like cycling and swimming, the ***objective function*** (in theoretical optimization) is to build the best performance, more often in practical optimization, for cycling. This ***objective function*** is connected to the maximization of the rational muscular effort finding the most effective angle of application of force on the cycle.
The best performance in practical optimization could also be applied to the minimization of external parasitic forces, like a drag, for example, in swimming. However, both goals can be prosecuted for these simple biomechanics cyclic sports when the performance is at a high-performance level.
In the following figures, it is shown the optimization for cyclic sports like Cycling and Swimming.Fig.1,4

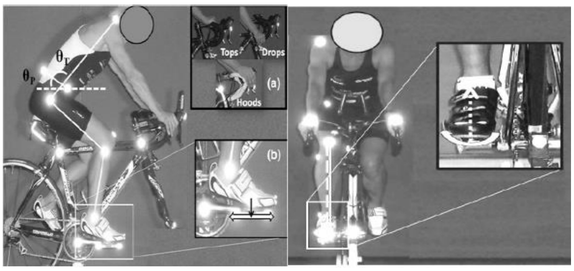


Fig.1,2 Cycling Optimization finding the best angles for athlete muscles [4]

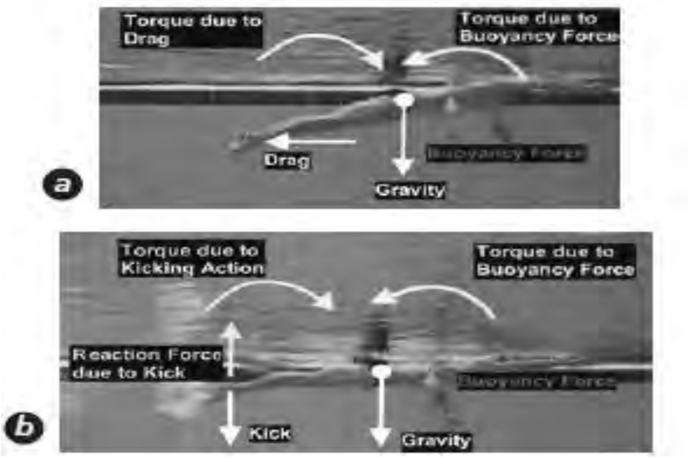


Fig.3,4 Swimming Optimization against Drag [5]

In the previous sports, for coaches, practical Optimization means finding the "optimum" angles to let muscles work in the best way or work efficiently with the minimum effort against Drag.
From the previous short example, it is easy to understand that in Sport, optimization is evaluated as an ***objective function*** theoretically but applied practically. Or it is maximizing the "internal" capabilities of the athletes or minimizing the "external" parasitic forces acting against the performance, where "internal" and "external" depend on the definition of the "athlete system".
Optimization [6][7] is a very flexible tool from variational physics calculus and is widely applied in modern engineering and economics. Theoretically, it is performed, by finding the algorithm to minimizing, for example, energy or maximizing income. In Sports Science, Performance Optimization is connected to biomechanics, ergonomics, nutrition, etc.

3. Optimizations in judo

A different problem is the Optimization of a complex Sport belonging to the Situation Sports group. In such a group, patterns are everywhere changing, the motion is very complex, and situations happen only with statistical frequency.
Then the ***objective function*** is tough to find or to build, and optimization is complicated.
Judo is a Dual Situation Sport, and its global optimization is very complex and sometimes not affordable.
But there is a way to overcome the structural difficulties shown before. Along with the Cyclic Sports Optimization line, it is possible to apply Optimization by the differential method, or in easy words: dividing Judo, step by step, in appropriately selected subsets.
It is interesting to understand that these subsets chosen based on the dynamics of movement of Couple of Athletes System can give us information about optimization of the "Attacker". That is a component of the Couple of Athletes System. Then associating to each subset a specific ***objective function,*** optimising all techniques to the best performance is possible.
For Coaches, the best way to perform practical Judo optimization is to apply qualitative Biomechanics in two situations and three areas:

Situations

Teaching lessons - Couple condition Static.
Competition– Couple condition Dynamic.

Areas

Couple Statics ⟶ OF = ***Minimum*** Energy
Couple Dynamics ⟶ OF = ***Maximum*** Effectiveness
Couple Long Development Dynamics ⟶ OF = Strategic (Overall ***Minimum*** Energy) Effectiveness

4. Situation 1: Teaching Lessons - Statics - Minimum Energy Optimization, The most feasible and straightforward approach to this complex sport,

is to analyze first the Couple System in a static situation for optimization. This means still Athletes and shifting velocity of Couple zero.
In a Static, fixed Situation, if Coaches analyze Judo Interaction (throws, hold-down, joint-pressure and choking).
Biomechanics let to optimize (as suggested by Kano) based on Minimization of Energy expenditure. [8].
Osaekomi waza (old down), Kansetzu Waza (Joint pressure), Shime Waza (choking) are performed, in accord with physics laws, with less energy consumption [9].
Suppose Coaches analyze Classical throws classified into five groups and arranged into the Go Kyo (five lessons) through Biomechanics. In that case, they find that they can be grouped into only two classes:

3. Lever System More Energetically expensive
4. Couple System Less Energetically expensive [10]

Fig.5-6 Most utilized throws in competition: Seoi (Lever), Uchi Mata (Couple)

The static action of throwing techniques goes through some specific phases: Unbalance, Positioning and Throw, or in Japanese tradition (Kuzhushi, Tsukuri, Kake) the first two phases can change during competition, generally speaking, all classical throws in judo need three types of trajectories to shorten the distance between athletes (rectilinear, inward rotation, outward rotation)

Trajectories (rectilinear or inward rotation)

Optimizing short trajectories

The short trajectories that shorten distances between athletes can be optimized in the light of the calculus of variation. In this specific situation, it is possible to apply the Euler/ Fermat form of the principle of the Stationary Action. Euler /Fermat principle:

The curve described by Athletes' Body to shorten the distance between two points A, B is the curve (among all the possible paths connecting A, B) that minimizes the momentum mv. Athletes travel between these two points along the path of shortest time.

$$\partial S = m\int_A^B v ds = \min . \qquad (3)$$

This principle, more understandable in terms of mechanical movement, will satisfy optimization trajectories during shortening distance between athletes.

In such a way, the three shortened distance trajectories, called General Action Invariants (GAI), will be minimized. The work performed by Athletes' Center of Mass (COM) shall be minimum.

Lift-up

The action of lifting can facilitate throwing motion by reducing the friction between the feet and Tatami. It is of great help both in the techniques of Couple in the frontal plane and with inward rotation, practically useless for Couple techniques with a straightforward approach (es. O Soto gari, etc.).

An almost plastic collision of extended soft bodies

All throws, after the shortening of mutual distance, need a collision between athletes' bodies.

In the case of Couple Group, both straight trajectory attack (O Soto Gari) and inward rotation attack (Harai Goshi, Uchi Mata), the greater surface contact collision depends upon the chest that must apply an upper force of Couple to opponent's chest, the collision of a smaller area is the responsibility of the leg that applies lower Couple force to the opponents' leg.

So in the case of a Couple at the end of the previous GAI trajectories, a simultaneous contact/collision can be considered almost plastic because the two athletes are closely related. Uke tends to rotate around his fixed Center of Mass. More is the simultaneous application of the forces and longer equivalent their intensity. The actual motion will more approach the theoretical ones. The mechanics are different from the Lever tool application.

In the Lever case, Uke, subjected to the Tori torque applied, tends to rotate not around its Center of Mass, as in Couple Group, but around the stopping point (fulcrum). His Center of Mass translates in space. All this is already analyzed in some old papers [11],[12].[13].

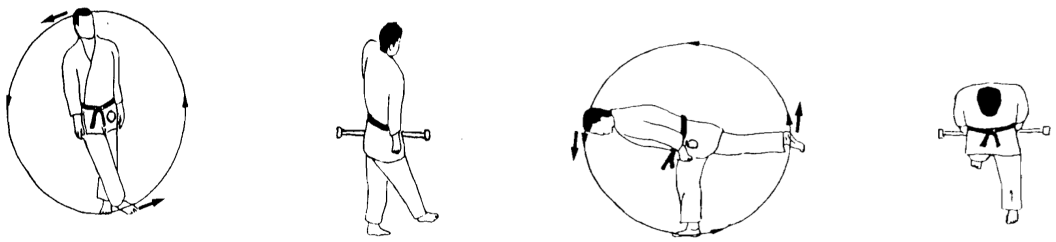
Flight Paths

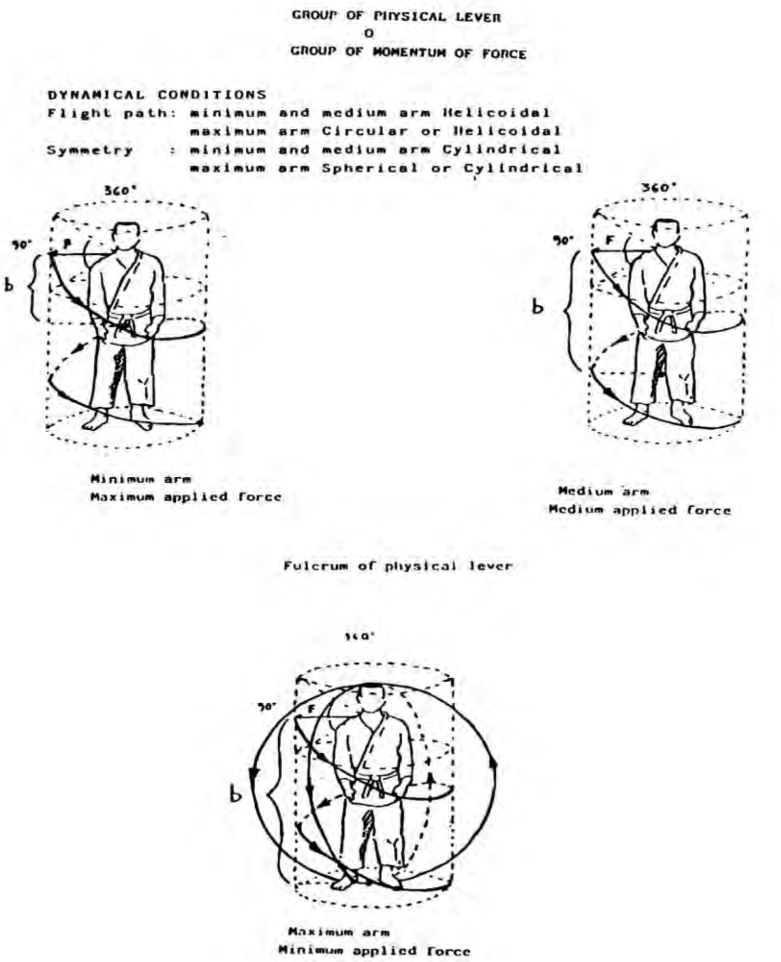
In accord with the Kano approach, astoundingly Classical form of judo throws, carefully chosen by Kano, are optimized. During their flight paths, after throwing tools (Couple or Lever), Uke's body goes through the geodesics of two symmetries: cylindrical or spherical.

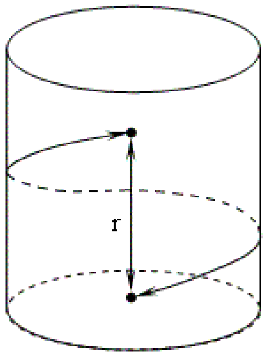
Geodesics are the shortest paths between two points on a specific curve, resulting from the calculus of variation [14] (See Appendix 1). In Formulas in our metric space considering the Cylinder and Sphere as basic symmetry figures for Tori, the two minimizing geodetics satisfy the relationship:

$$dist(c(t_1),c(t_2)) = |t_1 - t_2|$$

Fig 7,8,9,10,11.







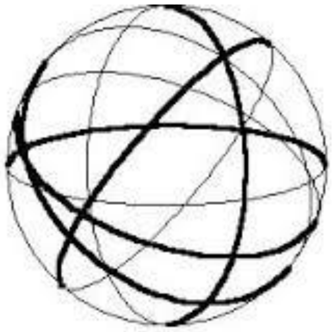


Fig.7,8,9,10,11 geodetics of symmetries of throwing actions [15]

From the previous short analysis, it is possible to underline:
In the Couple Group, Uke's Center of Mass (COM) turns around himself. All these throws are, theoretically speaking, gravity independent, less expensive, ***Fully Optimized.***
In the Lever group Uke's Center of Mass (COM) shifts in space, throws are gravity and friction dependent, more expensive, ***not fully optimized***.
However, they can be optimized by *changing length at the lever arm,* with the ***objective function*** Minimization of Energy.
For example, from standing Seoi [Ippon Seoi Nage] to Kneeling Seoi [Seoi Otoshi], till to Drop Seoi [Suwari Seoi], a passage that is only the Optimization of the same Lever throw.
But in Japanese vision, the previous optimization of one throw, they are three different throwing techniques!

5. Competition: Dynamics- Maximum Effectiveness Optimization

If Coaches analyze dynamic situations (competition), Optimization is grounded on the ***objective function*** Minimization of Energy Expenditure is a necessary condition but not sufficient.
It makes it appropriate to expand the Optimization goal with a broader ***objective function*** not simply connected to a minimum of energy but which also considers different energy consumption in the function of Maximum Effectiveness. Maximum Effectiveness means that minimization of energy is working as a static situation, But Classical application of Kano's Throws is also possible in competition if there is a big gap between athletes. Fig 12,13

Fig 12,13 Optimization of energy in classical throws

Coaches must also consider not full energetically convenient actions that could be Optimum as very effective like the following action is shown in the next fig. 14, 19

Figg. 14-19 Effectiveness Optimization, expensive but effective throwing action

Coaches must optimize and replaces Kano's theoretical unbalance concept or application with the practical exploitation of the "breaking symmetry" [12]
The "Breaking Symmetry" concept is a more subtle and practical way to optimize the application of Judo throws in highly dynamic situations.
In a Static situation, the Teacher unbalances Uke's body and applies the tool to throw. This preliminary unbalancing action is performed to simplify the throwing move using the gravity force and the unstable equilibrium of Uke as complementary tools.
In competition, it is challenging, if not impossible, to unbalance the adversary that defends himself hard. Tori, to attack effectively, must prevent fast avoidance, then forcing Uke's body to turn or bend practically he causes the centre of mass to move inside the body.
When the centre of mass shifts to one side, stability increases. Mobility decreases, and Tori must apply, on the right (more stabilized) side, a Couple or a Lever tool to immediately throw as soon as the bodies collide.
The previous one is the right and optimized sequence in competition to effectively throwing the adversary.
Practical Effectiveness Optimization passes through the use of specific complementary tools meant to improve the efficiency of throwing techniques, although at the expense of energy.
These complimentary tools are essentially based on exploiting the weak points of the human body from the biomechanical point of view or on the energy-specific application.
The main tools in Throws Practical Effectiveness Optimization are

9. Crosswise attack direction.
10. Makikomi and/or Fall down
11. Push + Torque
12. Change lever in couple and vice versa
13. Rotation in symmetry planes
14. Pure rotational application.
15. Use of Chaotic technical variation *like* (Reverse Seo i) [16]

6. Competition: Some Problems

Judo Competition in Biomechanical and physical terms is a complex, nonlinear system with self-similar fractal trajectories [8]
During Interaction, open skill evolves continuously in infinitive specific technical, tactical solutions. More often, in such fast-changing situations, for Coaches, it is not possible to plan any practical optimization.
In the following figures, there is one exemplum of fast-changing situations almost connected and grounded on the advanced personal skill of high-level competitors.
Judo as Open Skills Sports presents very complex situations that evolve continuously, from standing to lying fighting on the ground.

Fig 20-26 Ne Waza and Nage Waza continuous changing Skills combined

7. Competition: A broader Optimization Concept- Strategic Optimization

Strategic Optimization is theoretically connected both to the time of a *whole contest* and to a *sequence of matches.* Coaches could base on the minimum mechanical work made up of throws' right choice in practice for Coaches. They can also apply specific tactical tools to enhance throws effectiveness, practical ne waza's correct use, locomotion, defensive work, and active recovery among contests, all previously evaluated, such as O_2 consumption.
Theoretically speaking, Strategic Optimization of a judo contest or sequence of contests is defined as a *dynamic programming problem.*
A dynamic programming problem is an optimization problem in which decisions must be taken sequentially over several periods "linked" in some fashion.
A *strategy* for a dynamic programming problem is just a *contingency plan—a* plan of action based on what has happened up to that point.
It is possible to demonstrate, under some conditions, that a Markovian optimal strategy is an optimal strategy for the *dynamic programming problem* under examination. [17]
In more exact words, if we build a Heuristic Energy Equation of the contest by a Constructive Algorithm. It is an algorithm that constructs by iterations the final solution by building upon a partial (incomplete) solution.
It is possible to find an optimal solution strategy for the contest employing an equation like this.

$$\overline{E(O_2)} \cong (\sum_{j,c} A^{o_2}_{j,c} + \sum_{k=i} mgt_a \overline{v^{o_2}_{k=i}}) + \sum_{n,i} D^{o_2}_{n,i} + \sum_n G^{o_2}_n + \mu \overline{v^{o_2} x^{o_2}} + WAR^{o_2} - \sum_s \frac{t_s}{\tau} \overline{E(O_2)}$$

$$A^{o_2}_{j,c} = Tachi\ Waza\ attacks\ as\ O_2\,(j = classics; c = chaotics)$$

$$mgt_a \overline{v}^{o_2}_{k=i} = Work\ of\ Tachi\ Waza\ attacks\ as\ O_2$$

$$G^{o_2}_n = Ground\ Works\ as\ O_2$$

$$\underline{D^{o_2}_{n,i}} = Defensive\ Works\ as\ O_2\ both\ for\ Tachi\ and\ Ne\,waza$$

$$\mu v^{o_2} x^{o_2} = Work\ of\ couple\ motion\ as\ O_2$$

$$WAR^{o_2} = Work\ \ for\ Active\ \mathrm{Recov}ery$$

$$t_a = time\ of\ attack$$

$$t_s = time\ of\ stop\ (Matte)$$

$$\tau = regular\ fight\ time$$

Obviously, with this ***Objective Function,*** the optimization is connected to the minimum in the mean of the singular contributions less the Tachi Waza attacks that could also be optimized on the maximum effectiveness Optimization as already seen.
Practically for coaches, it is not possible to find a minimum point objectively by measurements. The best way to obtain the strategic optimization in real competition is by visual observation and expert vision (knowing the mean experimental measurements of athlete’s consumption) and then considering a reasonable range of conduct in competition in which energy consumption will be acceptably low.

8. Scientific Study of complex System: Shifting’s Paths Optimization

Throughout this chapter, we will describe different ways to determine stochastic processes' properties and classify such descriptions into microscopic, mesoscopic and macroscopic.
The microscopic description of a system consists in modelling the system Human shifting paths produced by the motion of a mass- point the Body’s Center of Mass. Evolution equations for random variables describe the dynamics of every single step both in time and space.
Then we use the Langevin equation, which cannot be solved except for particular realizations of the fluctuations (noise) but allows us to get macroscopic quantities as the moments of the resulting random variables.
The mesoscopic description consists of finding integral or integrodifferential equations for the probability that governs the system's evolution. Once the probability is known, one can obtain macroscopic quantities that can be experimentally measured. In comparison with the microscopic approach based on the Langevin equation, the mesoscopic description does not allow to get individual realizations of the process but still keeps the whole amount of statistical information of the underlying microscopic process.
Finally, the macroscopic description consists of finding equations for the PDF of the system in the large-scale limit by truncating in the time or the state space up to some finite order. In the case of the Fokker-Planck equation one additionally truncates the state space to second order.
However, we can analyze the Newtonian equations' at the macroscopic level. And connect the Brownian microscopic aspect to the macroscopic ones.

8.1 Macroscopic Level: Locomotion

Locomotion (Ayumi Ashi, Tsugi Ashi)

The Judo locomotion in competition (Aruki Kata) can be divided into two groups. Ayumi Ashi (normal locomotion) and Tsugi Ashi formally (foot follows foot).
Human walking biomechanics is a very complex branch of Kinesiology. The actual knowledge on walking mechanics came from a lot of researches, the first ones at the start of the previous millennium. As we demonstrate in the book “Biomeccanica del Judo”, Tsugi Ashi is energetically economic to Ayumi Ashi and a bit more stable to external interference from push/pull forces.

Walking is a cyclic activity in which one stride follows another in a continuous pattern.
We define a walking stride as being from a touchdown of one foot to the next touchdown of the same foot or from toe-off to toe-off.

There is a single support phase in walking when one foot is on the ground and a double-support phase when both are. The single-support phase starts with the toe-off of one foot, and the double-support phase begins with the touchdown of the same foot.

The coordinated human walking movements are generated not from an explicit representation of the precise trajectories of each anatomical segment as in bipedal robotics. But by dynamic interactions between the nervous system, the musculoskeletal system, and the environment.

Different types of movement exist and are associated with different kinds of commands.

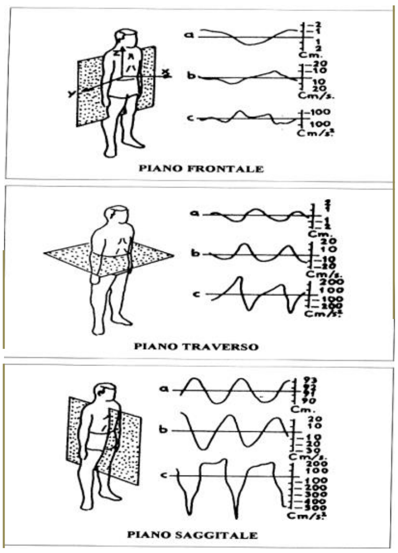
(1) Voluntary movements are integrated at the cortical level and can be initiated without any external stimulus.

(2) Automatic movements are memorized strategies that are elicited by internal commands or external stimuli.

(3) Spinal reflexes are genetically programmed responses to external stimuli, modulated by superior centres.

A primary concern of the CNS is to maintain dynamic stability during locomotion in competition. Dynamic stability during movement is the control of COM within a changing base of support and requires effective proactive and reactive recovery response strategies when exposed to perturbations

The motion of COM is not a simple motion, for reasons of dynamic stability of the athlete, as it is possible to see in the next figures in the symmetry planes of the human body. [18]



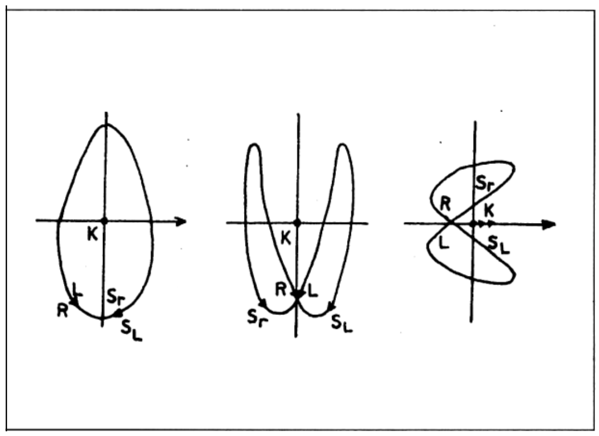


Fig.27-28 Motion of COM in the three symmetry planes of the human body and relative curves [18]

The symmetry planes of the Human body are shown in the following figures. They are in connection with the projections of the human body on the planes during the locomotion.

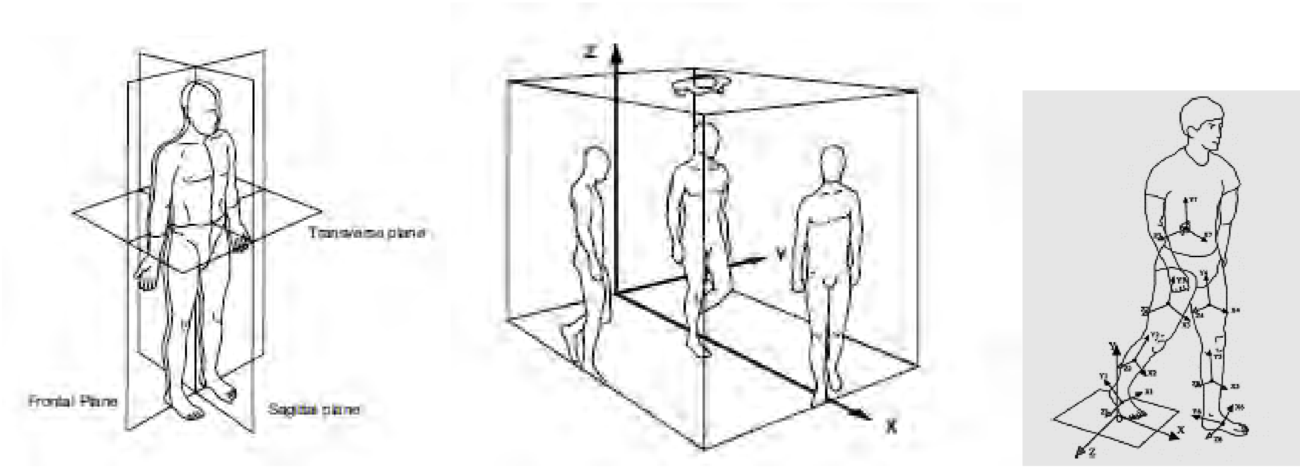


Fig.30-31 Human body symmetry planes, projections of the body on the planes during locomotion and reference systems. [19][20]

The curves presented in the previous figure 28 are the closed curves that the COM travels during a locomotion cycle. These curves represent the motion of the COM during a gait cycle. The interesting work of Minetti and co-workers [21] showed the basic equations for constructing similar curves in connection with the symmetry of the closed-loop and the Lissajous curves.

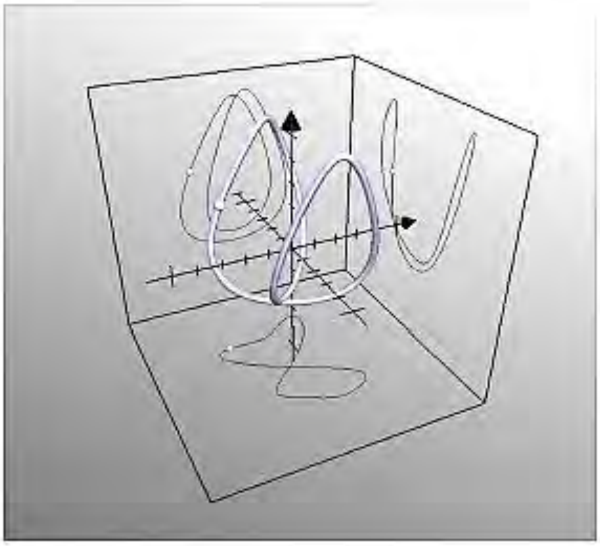


Fig 32 Curves of the average trajectories of COM for a cycle, during walking at 5 Km/h [21]

The equations are the following.

$$\bar{x}(t) = \bar{v}(t) + \sum_{i=1}^{6} \bar{c}_i^{\,x} \sin(2\pi f_i t + \bar{\phi}_i^{\,x})$$

$$\bar{y}(t) = \bar{a}_0^{\,y} + \sum_{i=1}^{6} \bar{c}_i^{\,y} \sin(2\pi f_i t + \bar{\phi}_i^{\,y}) \qquad (5)$$

$$\bar{z}(t) = \sum_{i=1}^{6} \bar{c}_i^{\,z} \sin(2\pi f_i t + \bar{\phi}_i^{\,z})$$

It is interesting to note that the previous curves apply only to the speed of 5km / h. With the increase of speed of locomotion, curves change shape while preserving similarity, as shown in the following figures

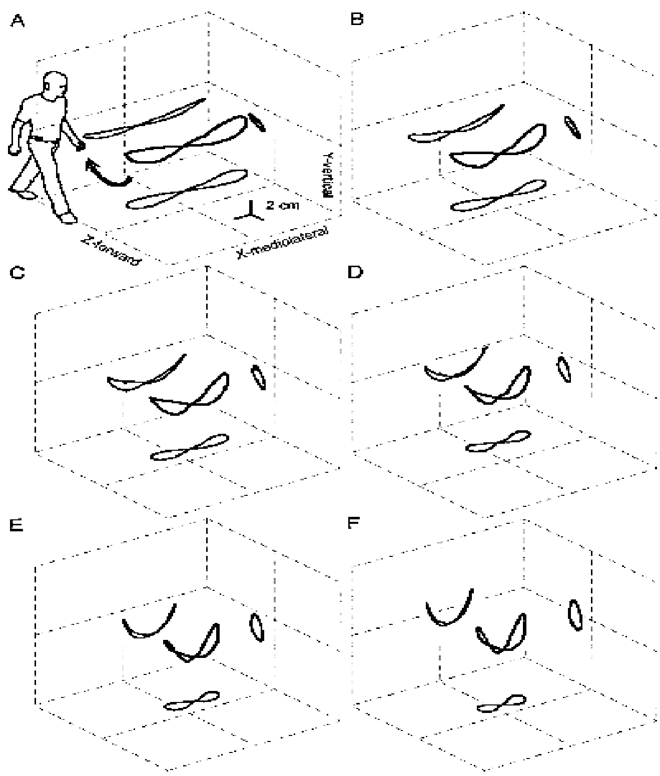


Fig 33 Relationship between COM 3D trajectories and walking speed [22]

Locomotion Optimization
Interestingly, at the macroscopic level, human locomotion is already the result of an optimization process on the Joint angles. Locomotion is possible only under the condition that the sum of the joints' angles is zero.
However, optimising human locomotion is a complex two-phase optimal problem because actual locomotion is a function of too many parameters.
By using optimal control methods, it is possible to simultaneously optimize the motion $x(t) = [q(t), v(t)]^T$. This optimisation consists of the positional variables $q(t)$ and the velocities $v(t)$ of the generalized coordinates of the model. The torques at the actuated joints are described by $u(t)$.
Additional model parameters, such as spring-damper constants or step length and velocity, are considered in the vector p. There are two equations (one for single– and one for double–support), there are two-phase optimal control problems.
The following Objective Function can express the complete optimal control problem

$$\min \int_0^{t_n} L\left(x(t), u(t), \rho, t\right) dt + M(t_n) \qquad (6)$$

In which we have the Lagrangian, which minimizes both the torques $u(t)$ applied to the system and the motion of the head, plus the Mayer term $M(t_n)$ that contains the impulse at the foot on touch-down[23]. During stance into locomotion, the barefoot change its contact surface with the tatami, as shown in the following figure.

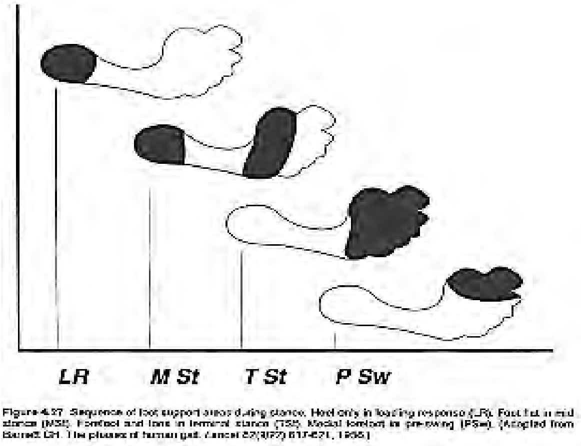


Fig 34Sequence of the barefoot surface during stance [23]

The mean interactions in judo competition are push and pull forces applied into a couple of athlete's systems.
Few studies have been applied to this particular part of the competition's response to the human body at such perturbation during walking.
During maintenance of postural equilibrium, COM is kept within the support base by activating appropriate muscles that move the Center of Pressure (COP). During locomotion, the same principle for COM control applies, with one crucial difference: foot placement at the end of each swing phase provides the primary method of moving COP in the sagittal and frontal planes.
The results from a recent study on locomotion illustrate this clearly.
In this study, individuals were walking on a treadmill. At the same time, unexpected mechanical perturbation (push) to the upper body in the frontal plane was applied during the two single support phases.
A push to the right when the left foot is in the single support phase produces abduction of the correct swing limb and subsequent increase in step width.
In contrast, a push to the right given when the right foot is in the single support phase produces adduction of the left swing limb and a subsequent decrease in step width see the following figure

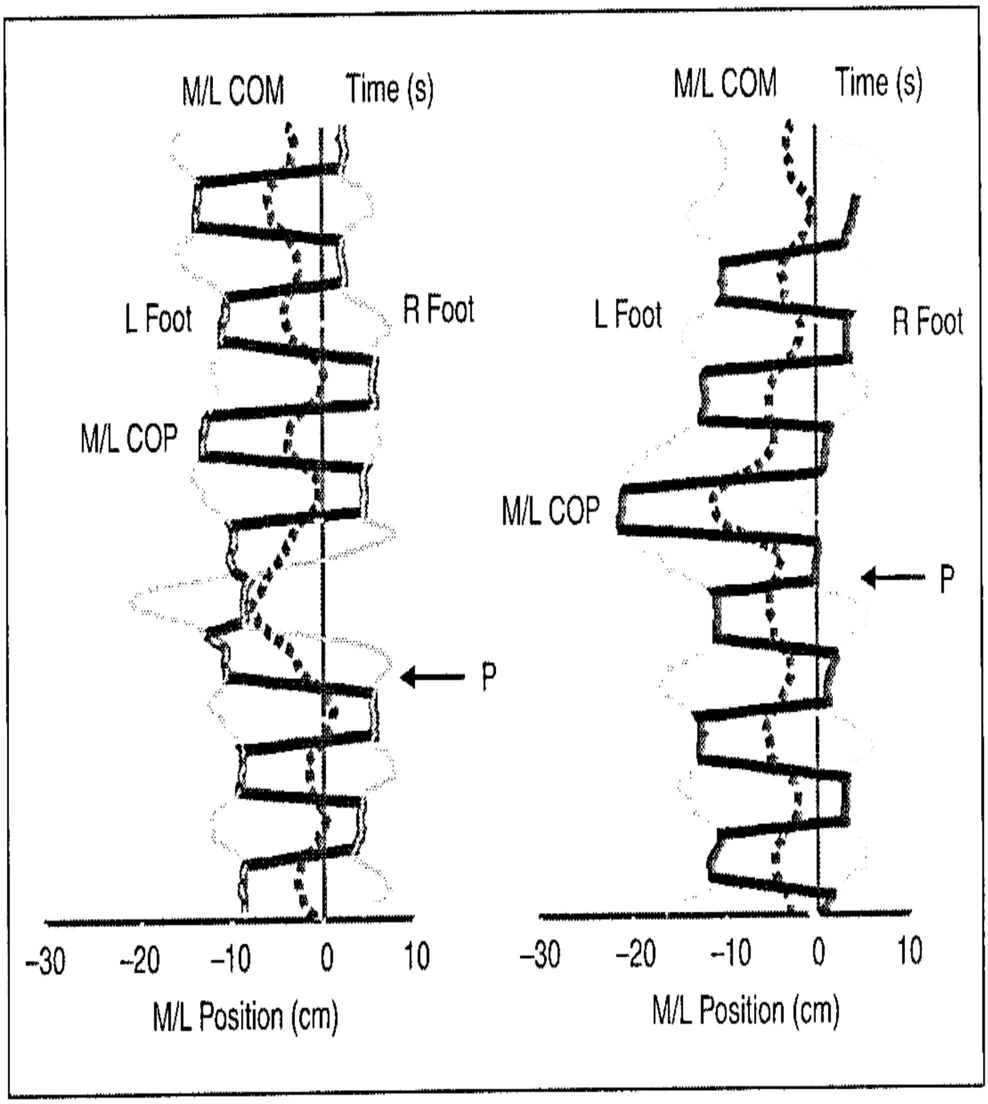


Fig. 3. COM and COP profiles before and following a push from the right at the shoulder level while the person was walking on a treadmill are shown. COP profiles are estimated from foot marker profiles. The left panel shows response when the left foot is on the ground: note how the right foot crosses over to be placed ahead of COM. The right panel shows response when the right foot is on the ground. Perturbation onset (P) is indicated by an arrow.

Fig.35 Response reversal observed during medio-lateral perturbations, applied during Human locomotion [24]

8.2 . Mesoscopic Level approach.

Center of Mass motion in still position

In static equilibrium, the CM (centre of Mass) projection and the COP (centre of pressure) would lie on the same plane. On the vertical line, COP would coincide as a proportional model with the projection of the CM on the ground. Both motions are similar, but the COP motion is always larger than the CM projection motion. This can be illustrated in Biomechanics using a simple model, the inverted pendulum, Winter 1998, Pedotti 1987 for the anterior, posterior balance.

The pendulum rotates around the ankle joint, which we take as the origin of the Cartesian system. If we denote as F, the force acts on foot by force plate at the point (-ζ, η), the COP.

The system is described in Newtonian approximation by the equations:

$$\begin{aligned} m\ddot{y} &= F_y \\ m\ddot{z} &= F_z - mg \\ I\ddot{\alpha} &= \eta F_z + \zeta F_y - mgL\cos\alpha \end{aligned} \qquad (7)$$

The component F_z is the same force as is obtained from the readings of the force transducers.

For a slight deviation around the vertical z-axis, we may replace cosα with y/L. And in the first approximation, we may also set, F_z= mg then the last equation will be:

$$y - \eta \approx \left(\frac{\zeta}{g} + \frac{I}{mgL} \right) \ddot{y} \qquad (8)$$

After some easy manipulation and putting the equation in terms of the angle π/2- α= θ we obtain:

$$\ddot{\alpha} - \left(\frac{mgL}{I} \right) \alpha = 0 \qquad (9)$$

This equation, of course, describes an unstable situation; the inverted pendulum topples over.

However, this classical procedure does not explain the Random Walks characteristics of quiet standing coordinates of the COP. They can be defined by the equation of Hastings & Sugihara 1993 [26] that combines a random walk with a friction term like a Langevin equation:

$$dx(t) = -rx(t)dt + dB(t) \qquad (10)$$

Here dB is the uncorrelated noise with zero mean

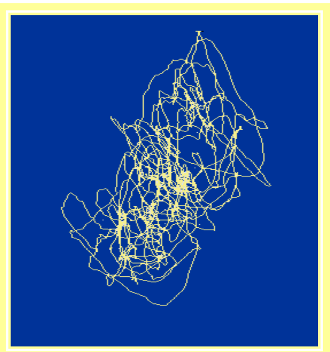


Fig.36 Posturogram- Random Walk of the COP coordinates(for still athletes).

Multifractals in Human Gait

Walking is a very complex voluntary activity. The typical pattern shown by the stride interval time series suggests particular neuromuscular mechanisms that can be mathematically modelled.
The fractal nature of the stride time series of humans was incorporated into a dynamical model by Hausdorff using a stochastic model. This model was later extended by Askhenazi et others to describe the analysis of the gait dynamics during ageing.
The model was essentially a random walk on a Markov or short-range correlated chain. Each node is neural that fires an action potential with particular intensity when interested by the random walker.
This mechanism generates a fractal process with multifractals aspects. The Holder time-dependent exponent depends parametrically on the range of the random walker's step size.
The multifractal gait analysis is also used to study the fractal dynamics of body motion for patients with particular ageing problems or diseases, like Parkinson or post-stroke hemiplegic.
In the following figures, we can see.
The variation of the time-dependent Holder exponent, with the walker step size for free pace and metronome pace at different speeds. [27]

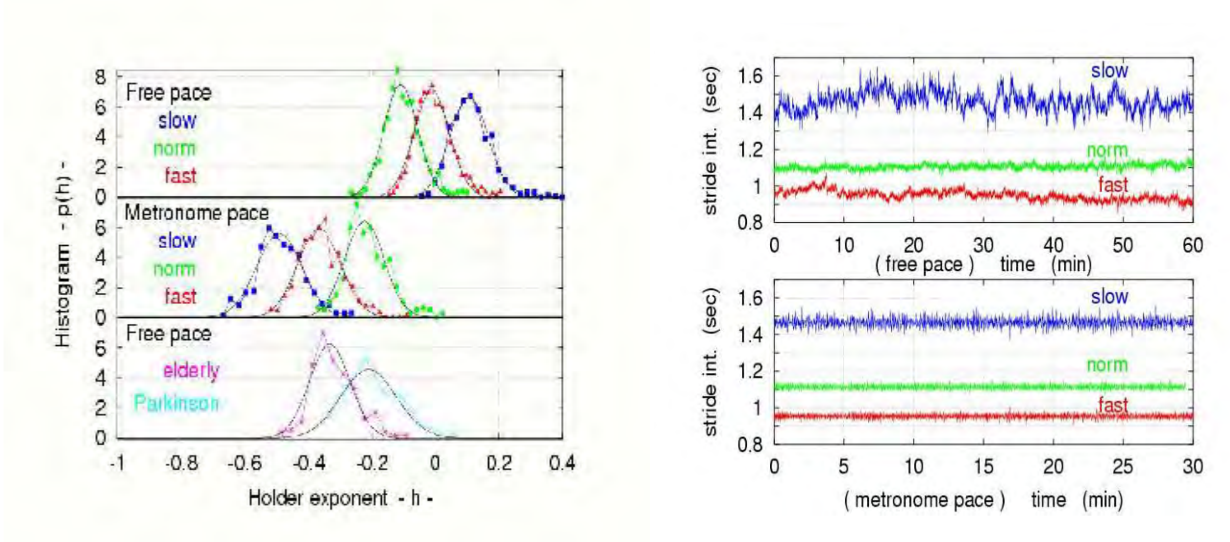


Fig.37, 38, different time series produced by the free pace and metronome pace at different speeds.

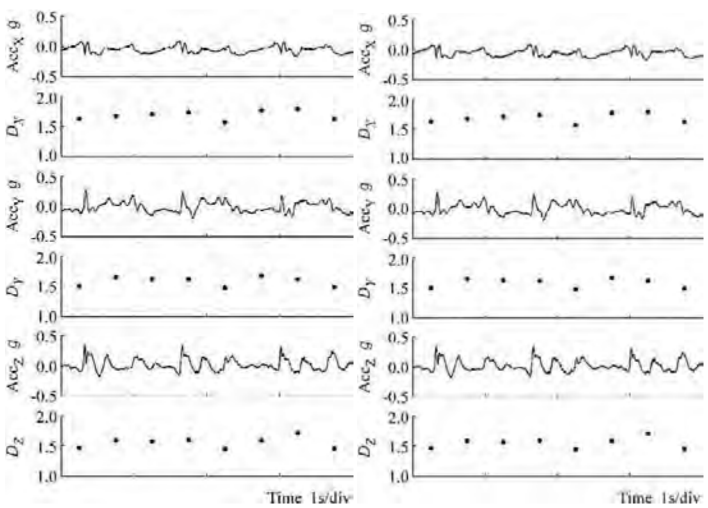


Fig.39, 40 Relative acceleration signals and the corresponding fractal values in post-stroke and Parkinson patients.

Let's analyze the shifting paths in competition. They are not simple lines, but the true paths are affected by standard error produced by the deviation of the centre of pressure during gait.
The mean standard deviation for centre-of-pressure paths during normal barefoot walking for judoka is shown as an example in the following figure.

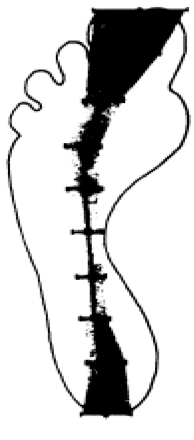


Fig.41 The standard deviation of barefoot during normal locomotion (Ayumi Ashi)

Then the paths shown in the Japanese figures are the most probable shifting paths in time, not considering the standard error present.
If the function f(q,t) gives us the most probable shifting path in time, we can draw the path. This path is singled out by the maximum probability points of the same function during its time evolution. In the following figure, we show the choice that is produced when the shifting paths are drawn.

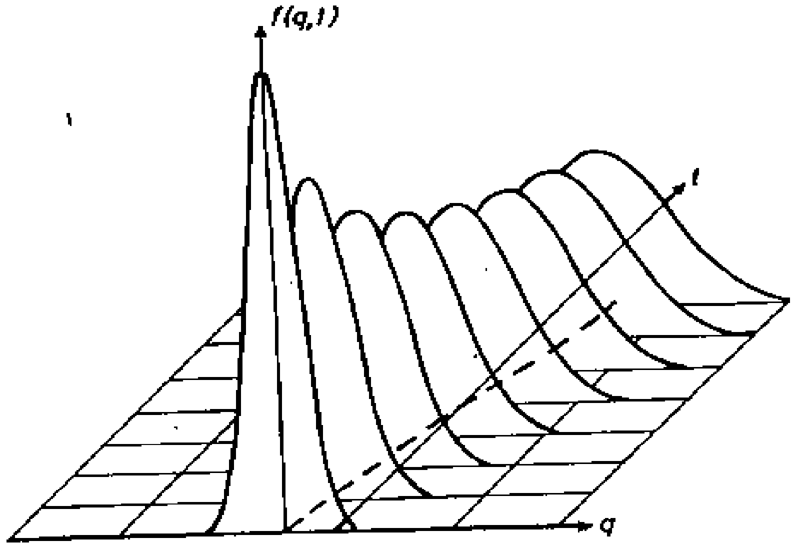


Fig.42 Shifting paths as maximum probability trajectory

A micro/meso approach to Locomotion

A couple of athletes' motions in the contest is ruled by a Langevin type equation.
It is the Second Sacripanti's model (1989-90). It is possible to write, for the global motion

$$F = ma = -\mu v + u\sum_j (\pm 1)_j \delta(t - t_j) = F_a + F' \qquad (11)$$

If the Couple of Athletes system moves by Brownian motion, it will be possible to find the trajectory most probable and demonstrate that this probability satisfies the Fokker-Plank equation, which describes the variation of the probability of Couple of Athletes presence on the Tatami during the time of competition

$$\frac{\partial f(q,t)}{\partial t} = -\frac{\partial}{\partial q}\left(Kf(q,t)\right) + \frac{1}{2} D \frac{\partial^2}{\partial q^2} f(q,t) \qquad (12)$$

- K= - μq is the push-pull coefficient;
- D is the diffusion coefficient.
- Now remembering the Einstein relationship, the diffusion coefficient D can be correlated with the motion time evolution of the CM of Athletes couple.

In the limit of a brief time interval or very long-time interval, as regards to the square mean shift on the mat, which is connected to the energy; it is possible to write: for short times:

$$\langle x^2 \rangle \equiv \langle q^2 \rangle = 2Dt = 2\eta O_2 t^2 \qquad (13)$$

and for very long times :

$$\langle x^2 \rangle \equiv \langle q^2 \rangle = 2Dt = 4\eta O_2 \frac{t}{\mu} \qquad (14)$$

Then the diffusion coefficient D (motion capability of couple) for very long times is proportional to the double of energy consumption and inversely proportional to the friction coefficient, for very short times is proportional both to the energy consumption and to the time (this means that D in the last case it is not constant in time).
If we consider not the motion of CM of a couple but every single athlete, it is a system of two masses connected by a spring (arms). The singular Langevin equations are:

$$\begin{aligned}
\dot{v}_1 &= -\gamma_1 v_1 - \frac{kx_1}{m_1} - \frac{k}{2m_1}\left(\frac{\partial}{\partial x_1}(x_1 - x_2)^2\right) + \Gamma_1 \\
\dot{v}_2 &= -\gamma_2 v_2 - \frac{kx_2}{m_2} - \frac{k}{2m_2}\left(\frac{\partial}{\partial x_2}(x_1 - x_2)^2\right) + \Gamma_2
\end{aligned} \qquad (15)$$

If we assume that both random forces $\Gamma_2 \Gamma_1$ are not correlated (each athlete fights against the other)

the Fokker Plank equation that describes the dynamic of couple gives us the distribution function from which an average of the macroscopic variable is obtained by integration:

$$\frac{\partial W}{\partial t} = \left\{ \frac{\partial}{\partial x_1} v_1 + \frac{\partial}{\partial v_1} \left[\frac{kx_1}{m_1} - \frac{k}{2m_1} \frac{\partial (x_1 - x_2)^2}{\partial x_1} + \gamma_1 v_1 \right] + \gamma_1 \frac{\kappa T}{m_1} \frac{\partial^2}{\partial v_1^2} - \frac{\partial}{\partial x_2} v_2 + \right\}$$

$$\left\{ + \frac{\partial}{\partial v_2} \left[\frac{kx_2}{m_2} - \frac{k}{2m_2} \frac{\partial (x_1 - x_2)^2}{\partial x_2} + \gamma_2 v_2 \right] + \gamma_2 \frac{\kappa T}{m_2} \frac{\partial^2}{\partial v_2^2} \right\} W \qquad (16)$$

For example, for the mean shifting velocity during the contest:

$$\langle v(t) \rangle = \int_{-\infty}^{+\infty} v(t) W(v,t) dv \qquad (17)$$

The only experimental solutions of this equation are evaluated by Kodokan Association Japanese Researchers of the in the far 1971:

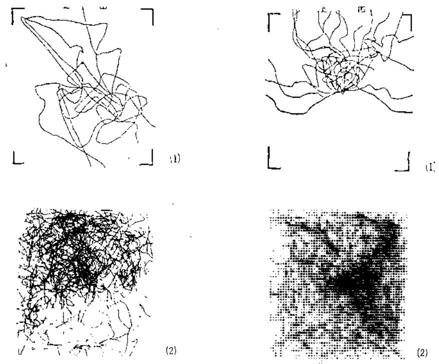


Fig43. Judo contest shifting paths [9]

1. The mean shifting velocity (***0.30 m/s***) during the contests [9].
2. The mean distance covered by judokas (***121,1 m***).

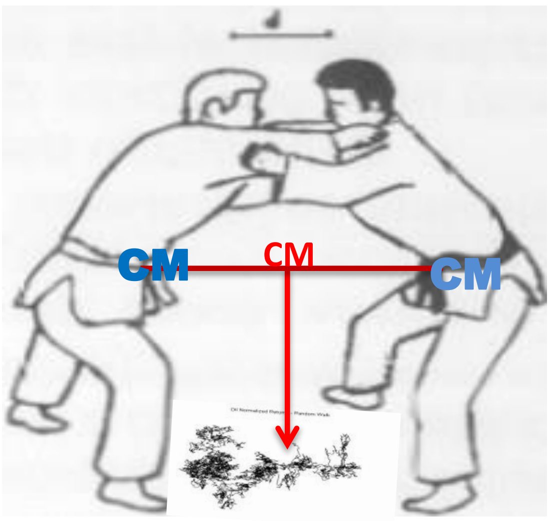


Fig 44 Shifting paths in the contest are produced by projection on the tatami of CM Couple System

But the actual motion is a most complicated 3D motion. How can we rebuild the most complex three-dimensional information from the two-dimensional path of Couple of Athletes motion?

The projection theorem

The proposed problem is that the motion path is a 2D projection of a 3D complex structured motion. The assessment of volume properties from this 2D data is far from evidence because few theoretical evaluations link 3D properties with 2D ones.

Only recently, a very advanced theoretical study has shown that the H parameter of an n-dimensional isotropic fractal is linked to the (n-1)-dimensional fractals by the following self-similarity function:

$$H_{(n-1)D} = H_{nD} + 0.5 \quad \textit{that in our case is} \rightarrow H_{2D} = H_{3D} + 0.5$$ [28]

The following figure is shown the meaning of the problem:

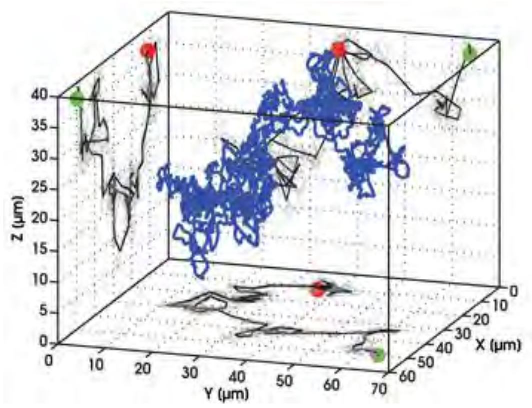


Fig.45 Projection theorem for COM motion in Space

From the Brownian approach to the Newtonian ones

Generally, in real life, the linear approximation and the Newtonian Dynamics are in our everyday usage and knowledge.

How to relate Brownian dynamics and Newtonian mechanics?

The problem was yet solved by Einstein and other physics in the study of diffusion.

We try to extend these results to shifting's paths in competition.

It is convenient to introduce the 3D probability. To find the Athlete's position f (r,p,t) d3r d3p, r in the position-space volume d3r and momentum p in the momentum-space volume d3p, at time t describe the state of the fight observed.

Let us start from the sharp distribution

$$f(\mathbf{r},\mathbf{p},t=0) = \delta(\mathbf{r} - \mathbf{r}_0)\delta(\mathbf{p} - \mathbf{p}) \quad (18)$$

It is associated with the initial conditions of motion, where δ is the Dirac distribution.

We do not observe, at time $t > 0$, the sharp distribution associated with (18)

$$f(\mathbf{r},\mathbf{p},t) = [\mathbf{r} - \mathbf{r}(t)]\delta[\mathbf{p} - \mathbf{p}(t)], \quad (19)$$

Such as predicted by the Hamilton equations of the athlete's system

$$\frac{dr}{dt} = \frac{p}{m} \quad (20) \qquad \frac{dp}{dt} = F - \mu p \quad (21)$$

The solutions are quickly evaluated:

$$p(t) = F\tau + (p_0 - F\tau)e^{-\mu t} \qquad (22)$$

$$r(t) = r_0 + \frac{F\tau}{m}t + \frac{\tau}{m}(p_0 - F\tau)\left[(1 - e^{-\mu t})\right] \qquad (23)$$

$$\text{with} \quad \tau = \frac{1}{\mu} \quad \text{the stationary solutions } t >> \tau \text{ are}$$

$$p(t) \approx \frac{F}{\mu} \qquad (24)$$

$$r(t) \approx r_0 + \frac{F}{\mu m}t \qquad (25)$$

Langevin added to the right-hand side of the equation a stochastic force ξ (t), also called white noise, to account for the sharp distribution in mechanical terms.
It is a random function of time with zero mean and a covariance proportional to the Kinetic energy produced, in our case.” athletes fight”, by the work of push-pull forces made by the third principle of dynamics between Athletes’ bare feet and friction on the tatami.
For which: $\langle \xi(t) \rangle = 0$.
Working out Langevin’s picture, it is found that *f* is the solution of the so-called Klein–Kramers equation,

$$\frac{\partial f}{\partial t} + \frac{p}{m}\frac{\partial f}{\partial r} + \frac{\partial}{\partial p}\left[\left(F - \mu p - \frac{\mu m v^2}{2}\frac{\partial}{\partial p}\right)f\right] = 0. \qquad (26)$$

Letting $E_k = \frac{\mu m v^2}{2} = 0$ in equation (26) gives a partial differential equation on *f,* which, mathematically speaking, admits the Hamilton equations (20) and (21) as its characteristics.
Physically speaking, if $E_k = 0$, equation (26) admits solution (19) given the initial condition (18).
Now we have to do with two equivalent approaches spoken in two different languages.
Langevin’s approach is cast in the language of dynamics with a novelty, namely the stochastic force ξ(*t*).
When the latter is input into Newton’s second law of motion, we obtain a stochastic differential equation.
In contrast, the approach of Klein and Kramers is expressed in statistical physics language.
The primary tool is a probability density in phase space, a linear partial differential equation solution.
While Langevin’s approach looks more intuitive at first glance and indeed was put forth before, its mathematics is subtle and open to criticism.
The approach of Klein and Kramers looks nebulous at first because of its use of phase space, but it is based upon standard mathematics.
We define the average of any observable *O* from the probability density *f* in the usual way of classical statistical mechanics:

$$\langle O \rangle \equiv \iint O f(r, p, t) d^3 r \, d^3 p \qquad (27)$$

It is possible to show by algebraic manipulations that equation (26) entails

$$\frac{d\langle r\rangle}{dt}=\frac{\langle p\rangle}{m} \qquad (28)\equiv(20)$$

$$\frac{d\langle p\rangle}{dt}=F-\mu\langle p\rangle \qquad (29)\equiv(21)$$

If we consider that F and μ are independent of positioning, the Hamilton equations (20) and (21) are recovered on average.
Then the Newtonian approach is connected to the average on long time and space. At the same time, the fBm characterizes a very short time and meso/micro space of observation.
The self-affinity and theoretical self-similarity connect meso/microscopic and macroscopic trajectories. For anomalous diffusion H<0.5 and H>0.5, the scaling properties of these phenomena are connected sometimes to the long-term memory of the process.
Generally, for an ongoing fight, the correlation in time shows an inverse power law. Usually, two is greater than 2H. This means that correlation between two points in time decreases with increasing time separation, the spectrum (Fourier Transform of Correlation) is an inverse power law in frequency:

$$C(\tau)=\langle X(t)X(t+\tau)\rangle \propto t^{2H-2} \qquad (30)$$

$$S(\omega)=FT\{C(\tau),\omega\} \propto \frac{1}{\omega^{2H-1}} \qquad (31)$$

For the anti-persistent evolution of fight the spectrum, instead becomes a direct power law in frequency.
The evaluation, previously produced, is based on classical mechanics and classical statistical mechanics at meso /micro. The fBm is the cornerstone of modelling.
Calculus of variation applied to the concept of ***Action*** is the most general and elegant form of classical mechanics.
The real world is a non-conservative world. Modelling the real world by two different approaches is similar in appearance. However, a deep analysis shows that the second one is very far from the previous one.
For conservative systems, the calculus of variation is equivalent to the method utilized by Newton However. At the same time, Newton allows non-conservative forces. The techniques used by Lagrangian and Hamiltonian mechanics have no direct way to deal with them.
In 1931, Bauer [29] demonstrated that it is impossible to use a variational principle to derive a non-conservative linear equation of motion with constant coefficients.
Thirty years later, Riewe [30] demonstrated that fractional derivative provides an elegant tool to solve this problem.
If Lagrangian is built by fractional derivative, the resulting equation of motion can be non-conservative.
Then in the natural world, friction is a ubiquitous presence, and a non-conservative system is a normality. In such a way to model the actual situation speaking is more complex than classical Newtonian, Hamiltonian approaches, and we need the help of fractional dynamics.

Fractional approach: Real description of microscopic dimension

The shifting patterns study, in the microscopic process, is more complex. However, it could be a source of instrumental data. However, the price to extract the hidden information is a non-trivial mathematical analysis of these unique time series (both length and time of stride).
The general principle of the fBm framework is that the aspect of a trajectory. Expressed as a function of time can be calculated by a fractional space dimension, hence providing a quantitative measurement of the evenness of the trajectory.
It is possible to write in mathematical form:

$$D_t^a\left[X(t)\right]-\frac{X(0)}{\Gamma(1-\alpha)}t^{-\alpha}=\xi(t) \qquad (32)$$

The first term is a fractional derivative. The second is connected to the initial condition of the process. The third is always the random force acting on the COM.
The fractional Brownian motion has the following covariance

$$\langle x(t_1)x(t_2)\rangle = D_H\left[t_1^{2H}+t_2^{2H}-\left|t_1-t_2\right|^{2H}\right]=\Gamma(1-2H)\frac{\cos\pi H}{2\pi H}\left[t_1^{2H}+t_2^{2H}-\left|t_1-t_2\right|^{2H}\right] \qquad (33)$$

In this case, it is essential to know the mean square displacement of the Athlete:

$$\left\langle\left[X(t)-X(0)\right]^2\right\rangle=\frac{\langle\xi(t)^2\rangle}{(2\alpha-1)\Gamma(\alpha^2)}t^{2\alpha-1}\propto t^{2H} \qquad (34)$$

By this expression, we can understand that we are in the presence of different spontaneous motions of Couple of Athletes System on the Tatami. These can be compared to other diffusion processes identified by the Hurst parameter.
The presentation of diffusion by a stochastic equation (Langevin Equation) is often the most challenging to solve. Usually, we use an analogous Fokker-Planck equation.
As previously discussed, to complete the solution of a macroscopic system, we would have to solve all the system's macroscopic equations for the Brownian motion.
Because we cannot generally do this, we use a stochastic description (Langevin) instead, we describe the system b
For the Fokker-Planck equation (16), this would mean that we neglect the diffusion term.
In particular, the H parameter is time- independent. It describes the fractional Brownian motion with anti-correlated samples for 0<H<1/2 and correlated samples for ½<H<1.
If H is = to ½, we can speak of pure Brownian motion.
It is also essential that an fBm is connected to a Fractal based Poisson Point Process. This particular feature will be handy to find the suitable theoretical basis to evaluate victory probability and short-term forecasting in a Judo match.
Davidsen & Schuster [31] pay attention to a plausible but straightforward method for generating fractal-based point processes from ordinary Brownian motion.
Their construct resembles a conventional *integrate-and reset process*. However, it differs in that the threshold, rather than the integration rate, is a stochastic process.
This kind of behaviour is present in nature. It occurs in the body's neurophysiology; for example, ion-channel current fluctuations give rise to random threshold fluctuations.
In the model considered by Davidsen & Schuster, the rate remains fixed, and the threshold process is taken to be ordinary Brownian motion.
When the integrated state variable reaches the threshold, an output event is generated. The state variable is reset to a fixed value, as with a conventional integrated- reset process.

It is also essential to see the autocorrelation coefficient of fBm that, as well known, depends only on the time increment.
The autocorrelation coefficient for all sorts of fBm depends only on the ratio τ/t where τ=t'-t
y macroscopic variables which fluctuate in a stochastic way.
The Fokker-Planck equation is just an equation of motion for the distribution function of fluctuating macroscopic variables. For a deterministic treatment, we neglect the fluctuations of the macroscopic variables.

$$\rho(\tau,t)=\frac{1}{2}\left(\left|\frac{t}{\tau}\right|^{H}+\left|\frac{\tau}{t}\right|^{H}-\left|\sqrt{\left|\frac{t}{\tau}\right|}-\operatorname{sgn}\left(\frac{\tau}{t}\right)\sqrt{\frac{\tau}{t}}\right|^{2H}\right) \quad (35)$$

For the particular case (τ = -t), we have

$$\rho(\tau,t)=\rho(-t,t)=1-2^{2H-1} \quad (36)$$

We also remember that only for H=1/2 (Regular Brownian Motion) autocorrelation coefficient for t and -t is independent, whereas fBm (t) and fBm(-t) are connected depending on the previous history. [31]
Athlete's Tracks (***Dromograms***) are the evolution in time of a couple of Athletes COM projection on the tatami area result of a spontaneous motion connected to the strategic thinking of Athletes.
Generally, in the Match Analysis study, each technical action and throw is considered belonging to a class of the Markovian System. This means that it depends on the previous instant only, without correlation with the past movements.
The more advanced mathematical approach based on Fractional Dynamics let able to overcome this conceptual limitation and mathematical simplification.
As we have seen before, an essential feature of fBm modelling for each fighter is the long-term correlations between past and future increments.
This means that the system is not Markovian and then more similar to the actual situation.
It is interesting to note that the human paths produced by strategic thinking are very similar to track produced by inanimate elements. The scaling regimes can assess this.
In this way, a fighting path can show, if correctly analyzed, when the fighter has a specific fighting strategy or not (kind of random motion) during competition.
For example, a median value of 0.5 for *H* indicates no correlation between actions, suggesting that the trajectory displayed a random distribution (Brownian motion) that is Markovian.
On the other hand, if *H* differs from 0.5, a positive (0.5 > *H)* or negative (H < 0.5) correlation with his fighting way can be inferred, indicating that a given part of the initiative is under control.
In fact, in the first case, *H>0.5,* the Fractional Brownian motion exhibits a long-range dependence; in contrast, if *H<0.5,* fractional Brownian motion is a short memory process.
Then depending on how *H* is positioned, concerning the median value 0.5, it can be inferred that the subject more or less controls the trajectory (and the fight evolution in time).
The closer the regimes are to 0.5, the larger the contribution of stochastic processes (random actions without strategy). In addition, depending on whether *H* is greater or less than the 0.5 thresholds, persistent (attacking), anti-persistent (defending / counter striker) behaviour can be revealed, respectively.
In other words, if the COM projection, at a particular time, is displaced towards a given direction, the larger probability is that it drifts away in this direction (persistent attacking behaviour). Or on the contrary, it retraces its steps in the opposite direction (anti-persistent defensive/counter striker behaviour). The trajectory contains more information than the mean squared displacement. In particular, one can measure the waiting time distribution from stalling events in the trajectories.

For pronounced anti-persistent processes, immobilization events should be observed. i.e., for specific periods, neither coordinate should show significant variation (athlete stops the shifting action). [32] Due to the scale-free nature of fBm anti-persistent, these stops should span multiple time scales [33]. If such events occur, they indicate the nature of the process of prolonged fighting with a high deep study of the adversary.
The absence of such features in shorter time series cannot necessarily rule out the fBm dynamics, particularly for H closer to one (ballistic motion). Distinct stops are relatively rare events and possibly require a very long time and high intensity of the fight.
Equality between these two probabilities (H= ½) indicates that there is not the presence of a defined strategy in fighting, like simple random motion or stochastic process.
This information obtained by a pure "mathematical lecture" of trajectories; can be enhanced by adding to the previous mathematical lecture other complementary Biomechanical fighting information. Like Competition Invariants, Action Invariants, Attack practical polygonal surface, Direction of displacement, Time and position of gripping action, Sen No Sen on grips, Throws "loci", Length or Amount of displacement, Mean Speed, Surface Area Utilization and so on. It is possible, with this added complementary information, to obtain much useful strategic information.
Information, ordered by importance or effectiveness, is helpful for coaching and athletes as well. This is one example of the advanced information obtainable by this underestimated practical tool: Athletes' shifting patterns.
Our analysis started from macroscopic Locomotion till the microscopic approach to COM motion in 3D space [34] that is fBm. From which derives the connection to the fBm described by the perpendicular of Athlete COM on the mat. Also, without considering the standard error connected. After that, it is easy to discover that the motion of the Couple of Athletes COM perpendicular is again an fBm at the microscopic level, but it was also proven that thanks to the self-affinity, scaling at a macroscopic level on the long time interval and long space track, the motion is always Brownian. In support of this connected reasoning, a theoretical demonstration was presented in another paper [35]. It presents a physical Langevin-based theory (Newton connected, remembering that it is a formal derivation of a Langevin equation from classical mechanics). He explains the emergence and the pervasiveness of the 'fractional motions' like Brownian motion, Levy motion, fractional Brownian motion and fractional Levy motion.
A general form of "micro-level" Langevin dynamics, with infinite degrees of freedom, is presented in the article. By scaling from the micro-level to the macro-level, the many degrees of freedom are summarized in only two characteristic exponents. The Noah and the Joseph exponent and the aforementioned fractional motions emerge universally.
The previous two exponents categorize the fractional motions and determine their statistical and topological properties. This practical theory establishes unified 'Langevin bedrock' to fractional motions that, we know, is the basic description of Judo shifting paths.
As shown, Shifting's Trajectories study is arduous and complex work because it falls among fractal, self-similar trajectories produced by Chaotic (irregular) Dynamics.
Into such a complex area, is it possible to Optimize Athletes' motion planning in judo fights?
Optimization of stochastic systems is very complex and probably not solvable. However, it is possible to overcome this difficulty by changing the global vision of the design, considering it among traffic problems. Traditionally in traffic theory, motion planning is defined as finding a collision-free trajectory from the start configuration to the goal configuration.
It is possible to treat athletes motion as an optimization problem, considering the interaction between athletes and searching the trajectory that drives the adversary into the final broken symmetry position. It is possible *to collide* and apply one of the two throwing tools (*Lever or Couple*).
In this new global vision, it is easy to find for Coaches an Optimization solution.
In fact, into this new field of study for Coaches: no matter how long the path in the contest is. The important is connecting and studying carefully *two or three steps that can bring to the goal*

configuration. After symmetry break and collision, an athlete applies to throw tools *Lever or Couple* to throw the adversary.

Conclusions

This paper faces the problem of the Optimization of a Dual Situational Sport in is a complex behaviour, the solution found very useful for teachers and coaches, starts from the Kano solution Minimum of Energy consumption that is driven to a variational principle.
However, this principle is strictly applicable only to instil and simplified situations and then good for teaching purposes. For the competition, a new, wider, variational principle must be used, the “Principle of maximum effectiveness”.
This principle that includes the principle of minimum energy consumption takes into consideration also technical actions that are energetically disadvantageous but very effective for the victory.
It is always in the area of variational calculus focalized on one extreme of the mechanical energy function.
However, not all situations can be optimized in competition. During Interaction, open skill evolves continuously in infinitive specific technical, tactical solutions.
More often, in such fast-changing situations, for Coaches, it is not possible to plan before optimization.
It is also introduced the notion of “Strategic Optimization” considering the Optimization of a whole judo contest or sequence that is called: *dynamic programming problem.*
A dynamic programming problem is an optimization problem in which decisions have to be taken sequentially over several time periods "linked" in some fashion.
A *strategy* for a dynamic programming problem is just a *contingency plan.* i.e., a plan that specifies what is to be done at each stage as a function of all that has transpired up to that point.
It is possible to demonstrate, under some conditions, that a Markovian optimal strategy is an optimal strategy for the *dynamic programming problem* under examination.
From that, we build a Heuristic Energy Equation of the contest by a Constructive Algorithm that is an algorithm that constructs a final solution iteratively by building upon a partial (incomplete) solution.
This equation is again a variational problem considering the minimum of each contribution during the sequence of contests.
Finally, a complete study of the hard problem of Couple of Athletes shifting paths is produced with many interesting points. However, in term of Optimization, only a short section of the complete shifting paths can be utilized to build a goal situation in which will be possible to collide and apply the throwing tools to produce a winning interaction.

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Appendix V
The complexity of Judo Experimental Research

(Safety on Judo Children: Methodology and Results)

Safety on Judo Children: Methodology and Results

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Safety on Judo Children: Methodology and Results

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Introduction

The perennial issue is :
Are Judo Throws really dangerous for trauma in children?
On the web or in some books, it is possible to find information like that:
"Because Judo involves throws, flips and takedowns, it has a higher rate of injuries to the upper extremity. Injuries to the shoulder, elbow, wrist, hand and fingers are common."…. "Kids in judo suffer more shoulder, upper arm and neck injuries than kids in karate or taekwondo"[1]
Theoretically speaking, falls produced by Judo throwing techniques could be potentially dangerous, especially for kids, if poorly managed.

Tableau I
Répartition des lésions en fonction de l'âge et du sexe.

Lésions	Sexe	Âge < 10 ans	Âge ≥ 10 ans	Variation (%)
Contusions	Filles	11	17	+54.5
	Garçons	19	30	+58
Fractures	Filles	4	6	+50
	Garçons	20	24	+20
Entorses/Luxations	Filles	0	1	—
	Garçons	1	3	—

TABLE 2
Severity of injuries and relationship of the occurrence Training *vs.* competition

	Gender		General total	Total (%)	Training			Competition		
	M	F			M	F	(%)	M	F	(%)
Grade I – mild	7	1	8	10	5	0	8	2	1	5
Grade II – moderate	1	6	7	9	0	6	9	1	0	2
Grade III – severe	30	19	49	63	23	11	54	7	8	22
None	1	0	1	1	0	0	0	0	0	0
Total injuries	38	26	64	83	28	17	71	10	9	29

Fig 1 ***Injuries in the function of year and sex (children) [2]*** **Fig2** ***Injuries in training and competition [3]***

Obviously, all judo people know this situation [4] and teachers are very attentive to teach the ukemi, whether alone or connected to judo throws, especially to children.
But it is also very clear that *affirmations like the previous ones are generalist and negative*, and they are the main obstacle to increase the enrollment of new children in the Dojo (gyms) of the world.
Against these doctoral affirmations, the judo teacher knowledge is based only on various personal experiences, and never a totally complete Scientific Research supported this knowledge.
Why? Because it is very difficult to evaluate all main parameters that allow these experiences in a scientific way. Since they belong to many interconnected scientific fields, among all:
Physics, Mechanics of Composite Materials, Thermodynamics, Biomechanics of trauma, Forensic Medicine, Biology, Bioengineering of Crash Test, Risk Analysis, Safety Science, and last but not least, the most complex one: JUDO

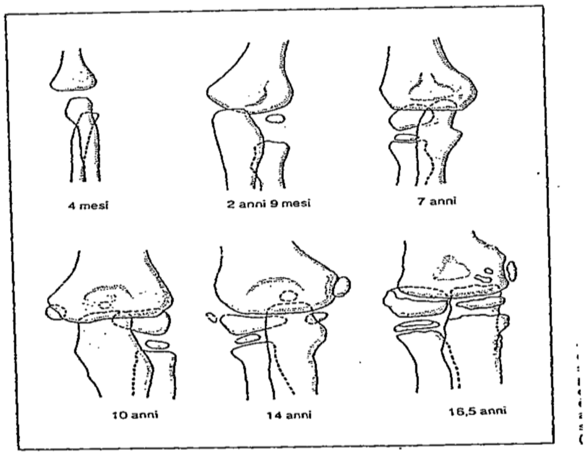
System Safety Criteria

The basic philosophical approach in this "situation" that must be studied is safety for falls due to throws of children's judo, which leads us to evolve the concept of safety, normally accepted into the safety engineering world.
In this field, the safety concept requires a risk management strategy based on the identification of hazards and the application of remedial controls using a systems-based approach. [5]
In our situation, "Falls produced by Judo throwing techniques," the hazard is the condition that can cause injury to children thrown by judo techniques.
Obviously, our study is not focalized on the ukemi poorly managed, but on the normal situation: children and kids that throw each other, with their "beginners" knowledge about ukemi and throws.
Normally, people think of safety as the absence of accidents and incidents (or as an acceptable level of risk). In this perspective, Hollnagel, Wears and Braithwaite define this common vision: Safety-I.

In our situation, safety-I could be defined as a state ***whereas few ukemi as possible go wrong***.
A Safety-I approach presumes that ukemi go wrong because of identifiable failures of specific situations. It was tacitly assumed (in engineering practice) that the "situation" analyzed could be decomposed into steps, and such steps could be improved.
As "situations" continue to develop more complex, adjustments become increasingly important to maintain a safe outcome, but they also become more complex to understand.
The challenge for safety improvement is, therefore, to understand these adjustments, in other words, to understand how the outcome usually goes right.
Despite the obvious importance of ukemi going right, traditional safety management has paid little attention to this.
Our Safety management should, therefore, move from ensuring that '***as few ukemi as possible go wrong***' to ensuring that '***as many ukemi as possible go right***'. Hollnagel, Wears and Braithwaite call this perspective Safety-II. [6]
All this philosophical talk flows for us, as a practical aspect, into the analysis of the 90th percentile of Ukemi's Gaussian, studied by the right-side limit, that is the area of ukemi "***that go right***", to understand if they are risky for children in everyday conditions.

Mechanics of Throwing Techniques and Impact Biomechanics

It is meaningless for this specific work to analyze the mechanics of throwing techniques because, for each one, there are infinite time-varying parameters. [7][8][9][10][11][12][13][14][15]
Even trajectories are infinitely variable. For example, in one Japanese study on breakfasts, we can find an expression like the following: "The kinematic data of the breakfall motion for both Osoto-gari and Ouchi-gari were collected using a three-dimensional motion analysis technique (200 Hz). It is observed significant differences between the movement patterns for the two techniques, especially in the lower extremity movements." There is the need to change the approach to our problem if we like to obtain significant, valuable and general solutions. Then to study each technique in his specific mechanical aspects is meaningless because variation is infinitive, and a statistical approach is also not good. However, the instant of impact and its biomechanical results is the only reproducible time with traumatic meaning. Its mechanics is concerned with reaction forces that develop during the collision and with the dynamic response of structures to these reaction forces.
This subject has a wide range of engineering applications, from designing sports equipment to improving the crashworthiness of automobiles. His analytical methods of solution in our situation derive from the simple Newton collision theory of rigid bodies.
Generally speaking, medical people know that falls are dangerous for human bodies because, more often, the collisions are a plastic collision of a "visco-elastic" body against a rigid one. Today there are mathematical tools that combine mechanics of contact between elastic-plastic bodies with dynamics of structural response. [16]
But how children are potentially more exposed in judo to the danger of falls than adults?
Because children's bodies are under development and therefore their bones, within certain limits, are more flexible, this means a decreased capability to absorb energy and an increased danger for internal organs, the developing joints are not completed tendon insertion more fragile, and their bodies in standing position are more unbalanced than men.



In our case: a child's body falling, thrown by a judo technique, the biomechanical result connected to the impact instant is the only reproducible point with general traumatic meaning. [17][18]
Then in the light of our safety approach criteria and remembering both the Principle of independence of simultaneous actions and the property of the vector added together, it is significant to study the instant of impact in its worst conditions, as shown in the following way.

Safety Criteria Mechanical Analysis of falls produced by Judo throws

If we are interested, at the impact instant, the general motion equation from Galileo is:

$$h(t) = \frac{1}{2} g t^2 + v(t) \qquad (1)$$

v(t) is the added velocity by Tori. To consider the worst conditions, we can hypothesize that the added velocity at the contact instant on the Tatami is proportional, a part of a multiple of the final velocity of free fall (for h=1m) equal to:

$$v_f(t) = k\sqrt{2gh} \qquad (2)$$

If we remember that collision is an impulsive phenomenon, the conservation of momentum and the Newton definition of force gives us the capability to state the following equation:

$$\int_0^t F dt = \int_v^v m dv \Rightarrow\cong F = \frac{mk\sqrt{2g}}{\Delta t} + \frac{m\sqrt{2g}}{\Delta t} \quad with\ h \equiv 1m$$

From the well-known equation of the kinetic energy, it is possible to evaluate the Maximum, time-independent, Impact Force on the Tatami when added velocity by Tori is, as hypothesized, proportional to maximum impact velocity.
Then:

$$E_f = \frac{1}{2} m\left[(1+K)\sqrt{2g}\right]^2 \Rightarrow F_f = \frac{1}{2}\frac{m}{h}\left[(1+K)\sqrt{2gh}\right]^2 \ for\ \ h = 1m$$

$$F_f = (1+K)^2 mg$$

And K=0,1,2,3…,n .

Now, remembering the Principle of independence of simultaneous actions and the property of the vector to add together, we can show both: how flight time and velocity and how velocity and Impact Force are connected.

All this could be shown by parametric curves depending on the k parameter. Then the Added-up Velocity increases, Maximum Impact Force increases, and Flight Time consequently decreases. The two curves are valid for all judo players for whatever age and mass.

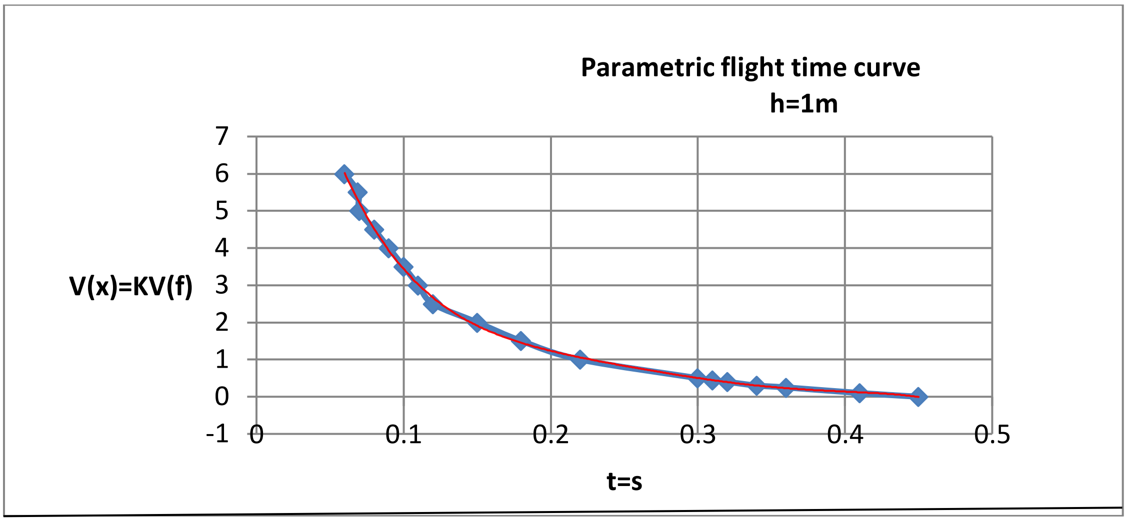


Fig 4 Flight time vs velocity at impact

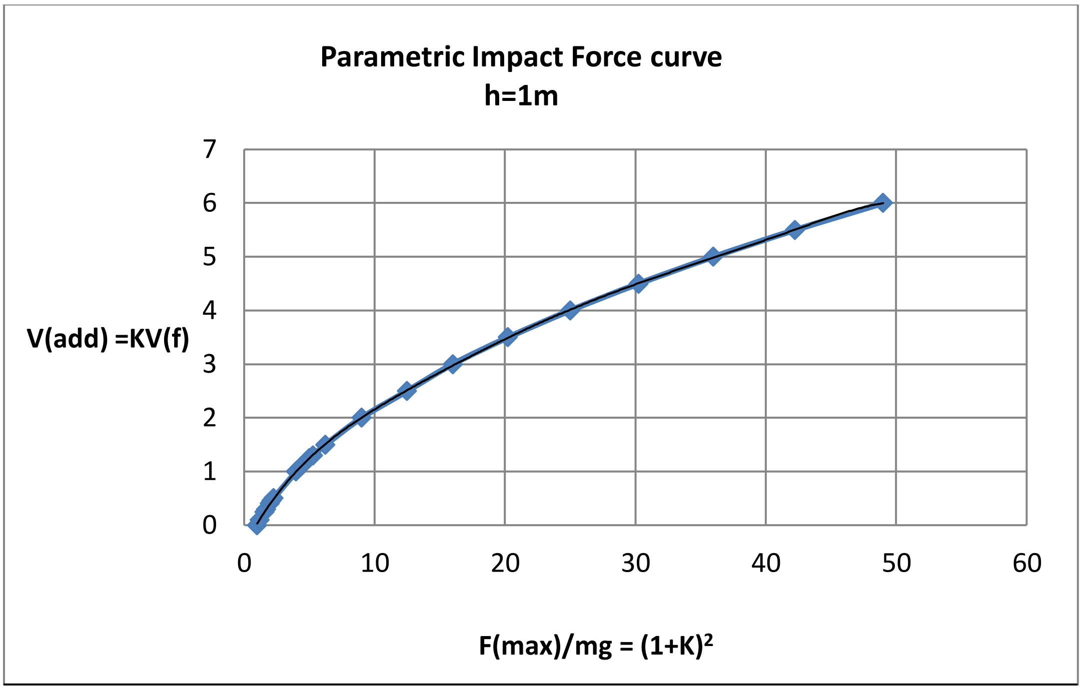


Fig5 Maximum velocity at impact vs Par Maximum Force at impact

From these two curves valid for every judoka, from children to high-level competition, falling from 1 meter, it is clear that falls can be theoretically dangerous if the added velocity is high.
However, we must remember that the velocity added is directly proportional to the force applied to throw the adversary.
For kids or children that throw each other, forces are small with respect to high-level competitors and consequently should be small both the added velocity and the maximum impact force, as clearly show in the next two diagrams.

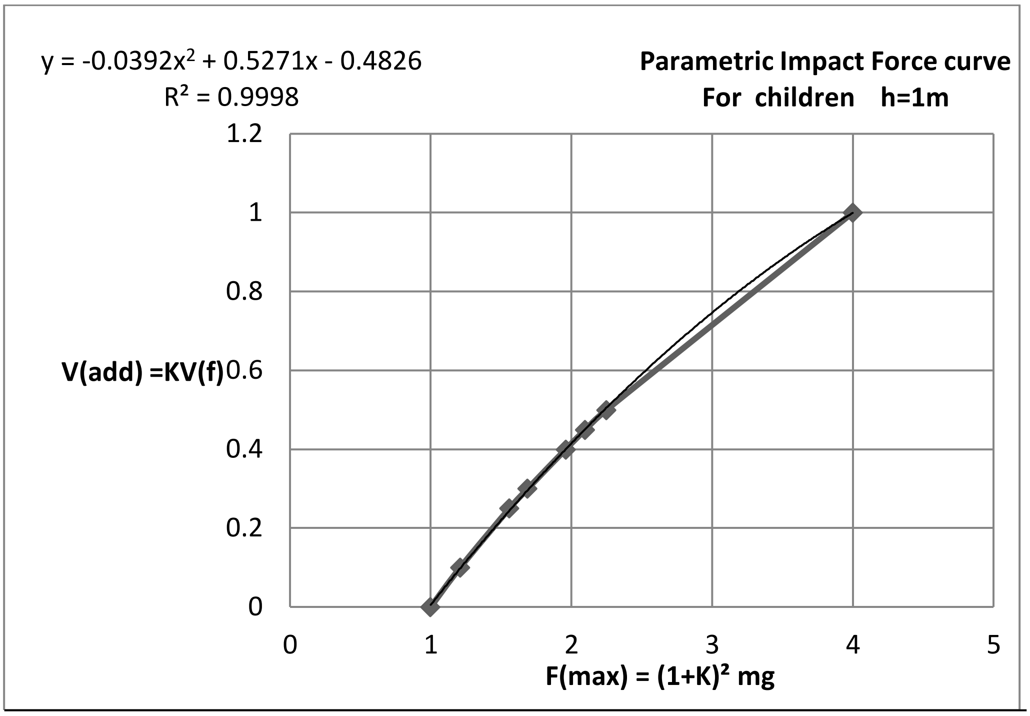


Fig 6 Velocity vs Maximum Force at impact for children

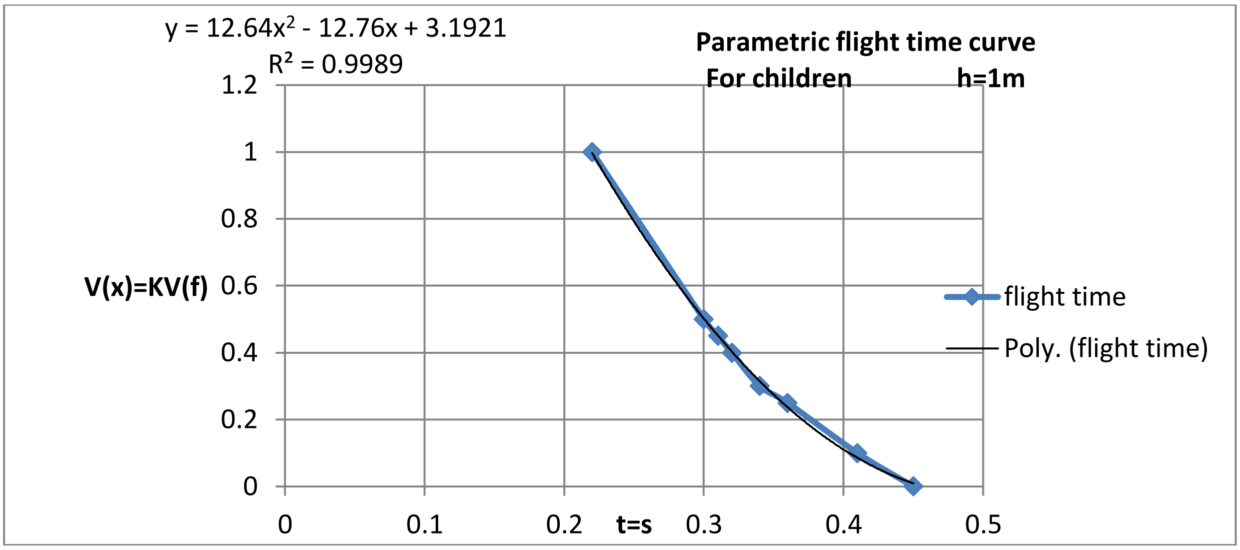


Fig 7 Flight time vs velocity at impact for children

Tatami Material Science and Thermodynamics.

Material science is an essential part of this research because safety outcome depends both from the Tatami material and quality. In this research, we analyzed one Tatami built by polyurethane foam and soft polyurethane covered by PVC and Approved by IJF, with a thickness of 4 cm and overall density of 240 kg/m³. tensile strength 2480 N/5 cm, theoretical Force reduction ≈ 25%-40%

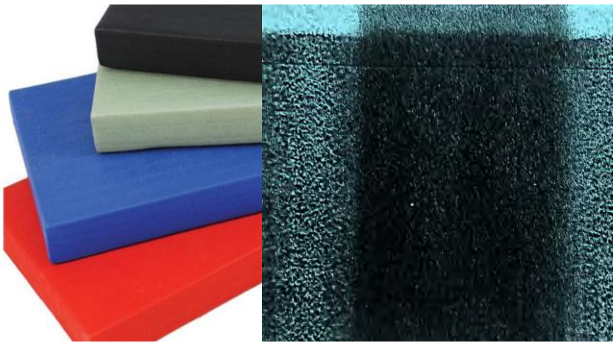


Fig 8 Tatami and vertical constituents section

PU, invented by Bayer in Germany around 1937, has a history of slightly more than 75 years. They have become one of the most dynamic groups of polymers. Their use covers all fields of polymer application practically: foams, elastomers, thermoplastics, thermorigids, adhesives, coatings, sealants, and fibres.

PU is obtained by the reaction of an oligomeric polyol [low-molecular weight (MW) polymer with terminal hydroxyl groups] and a polyisocyanate.

The structure of the oligomeric polyol used for PU manufacture has a very profound effect on the properties of the resulting polymer, as assure us, Ionescu, in his encyclopedic work [19]. The tatami analyzed was built by three layers first layer PVC, second Polyurethane foam, and third Polyurethane semi-rigid.

The foam is important, but his mechanical evolution is quite complex.

The response of foam gets stiffer with an increase in strain rate, and densification (lockup) occurs well below the strains at which lockup occurs for foam deformed at quasi-static strain rates. Consequently, the energy absorption characteristics of foam are altered with a change in strain rate.[20]

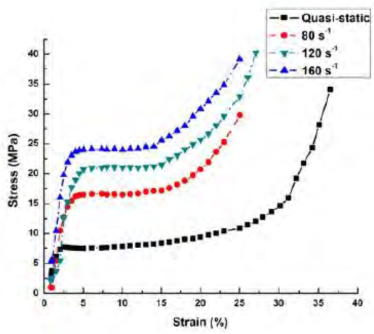


Fig 9 Stress-strain foam curves

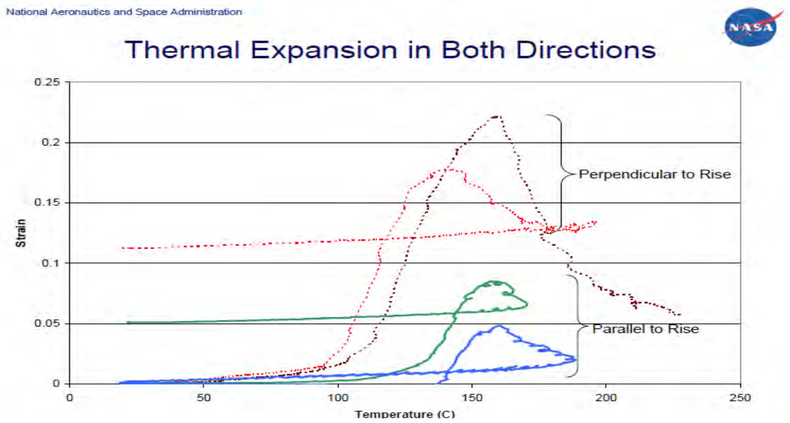


Fig 10 Polyurethane Foam thermal expansion

Also very complex is the thermal behaviour of polyurethane foam, as NASA researchers showed in some very interesting works [21].
Since the foam is not a material but a structure, the modelling of the expansion is complex. It is also complicated by the anisotropy of the material. During the spraying and foaming process, the cells become elongated in the rise direction, and this imparts different properties in the rise direction than in the transverse directions.
However, we are much more interested in expansion in his compression and related thermo-dynamical effects.
If the compression produced by children's bodies is fast, the situation can be approximated in thermo-dynamical terms to an adiabatic transformation.
This specific transformation was named by Viecheslav Sychev in his book "Complex thermodynamic System" [22] Elastocaloric Effect.

Elastocaloric Effect

When a body falls, on the tatami, after a Judo throw, the impact produces one adiabatic compression of the tatami, the impact energy will partially be absorbed, and one of the main effects that change the mechanical energy into heat is the *Elastocaloric Effect*.
The induced variation of temperature is expressed by the following easy calculation:

$$T = T_0 + \int_0^{\Psi} \left(\frac{\partial T}{\partial \Psi} \right)_{S,P} \partial \Psi \qquad (6)$$

To solve the kernel of the integral, we can use the Maxwell equation

$$\left(\frac{\partial T}{\partial \Psi} \right)_{S,P} = -\left(\frac{\partial l}{\partial S} \right)_{\Psi,P} = -\left(\frac{\partial l}{\partial T} \right)_{\Psi,P} \left(\frac{\partial T}{\partial S} \right)_{\Psi,P} \qquad (7)$$

And after a few simple calculations, we have the following final Relationship:

$$T = T_0 - \frac{\alpha_l \overline{T}}{c_p \rho} \Psi \Rightarrow \Delta T = -\frac{\alpha_l \overline{T}}{c_p \rho} \Psi \qquad (8)$$

When the Tatami is compressed, the stress Ψ is negative and the Tatami temperature increases, absorbing energy.

The previous final relationship (8), remembering the Hookean Elastic Equation, can be changed as:

$$T = T_0 - \frac{\alpha_l \overline{T}}{c_p \rho}\Psi \Rightarrow \Delta T = -\frac{\alpha_l \overline{T}}{c_p \rho}\Psi = \frac{\alpha_l \overline{T} E \Delta\varepsilon}{c_p \rho} \qquad (9)$$

To have a first indicative order of magnitude in our research, a very simple "theoretical" evaluation assures that with Polyurethane Foam as Tatami material IJF Licensed, with **density 244 Kg/m³**, with energy absorption, **around 25%- 35%**, hypnotized ***Theor. Compr*** ≈ 2 mm , temperature will have a "theoretical" increase of : **296.15<T(°K) <297.0** or in Celsius **23 < T(°C) <23.8**
Mechanics and Elastocaloric effect are connected by means of Strain that Produces Tatami Compression by Hook law. Compression is produced by Children bodies falling down, and part of this Strain, after energy absorption, is returned to the children body for the Action-Reaction Principle. In formulas:

$$\Psi = \frac{F}{A} = E\Delta\varepsilon \Rightarrow \Delta\varepsilon = \frac{\Delta l}{l} \qquad (10)$$

$$\Psi' = -e\Psi \qquad (11)$$

In which (**e** < 1) is similar to the restitution coefficient and depends on the Tatami Material. Remembering that:

$$\Psi' = -e\frac{F}{A} \qquad (12)$$

A (The Children Body Impact Surface) is the key parameter that we ask to find in this research to evaluate potential trauma in children produced by falls of judo throws.
How to evaluate these key parameters by means of the thermal image of the children body surface of contact with the tatami after the falls produced by a judo throw.
This phenomenon is well known in thermodynamics, and it is similar to iron burning. It is a problem of transient conduction from the children body to the contact surface that heats the Tatami surface layer, and if the children go away fast, it is possible to fix with a sensitive Thermo camera the image of the contact body area during a convective cooling.
A possible example equation of this phenomenon is presented with some differences in the well-known book of Professor Latif [23]. Modelling the skin-layer of Tatami as an insulated plate of thickness L, conductivity k and convention coefficient α, using Duhamel's integral to determine the one-dimensional transient temperature of the skin layer, a solution for constant heat flux will be:

$$\overline{T}(x,t) = \frac{L}{k}\left[\frac{3x^2 - L^2}{6L^2} - \frac{2}{\pi^2}\sum_{n=1}^{\infty}\frac{(-1)^n}{n^2}\cos(n\pi x / L)e^{-\alpha(n\pi/L)^2 t}\right] \qquad (13)$$

However, we don't need a Thermo-dynamical numerical solution for our research but an arithmetical one connected with the numerical evaluation of contact surface area. For this purpose, the Tatami surface was divided into squares of 10 cm x 10 cm. as in the following figures that show the setup preparation.

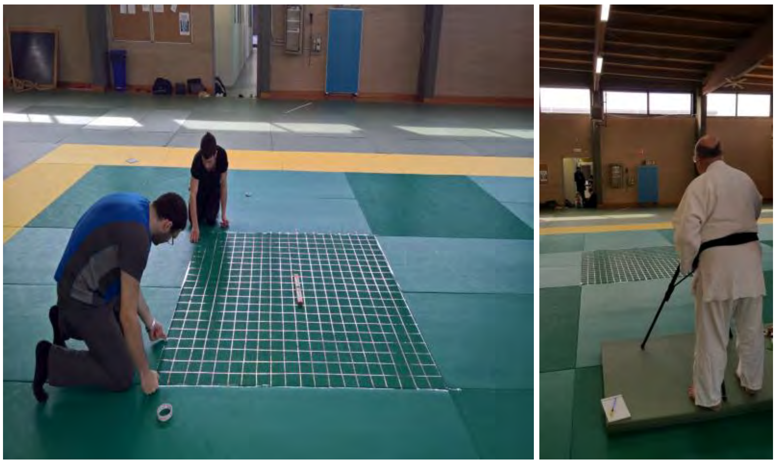


Fig 11 Experimental set up preparation

Judo Throws and Their Specific Way of Falls, in Safety Analysis

In our research, considering as the main parameter, from a safety point of view, the direction of free-fall velocity, standing judo throwing techniques, also considering the beginner training situation, have several ways to fall, depending on the general mechanics of the technique.
The safety approach results in having to assess differently, from the normally approved convention, the flight times of projection trajectories. As an exemplification of our safety approach, we consider two major throwing techniques:
Standing Ippon Seoi Nage and Tai Otoshi, these two throwing techniques from our point of view show two different flight times assessments.
For standing Ippon Seoi, because added velocity takes the equal direction to gravitational acceleration only towards the second half of the trajectory,
While in Tai Otoshi, the vector direction has been concordant since the beginning of the trajectory He was considering in our approximation a complete-time flight: the time that Uke detaches his feet from the tatami till his body lands on the tatami.
We must consider for Seoi Nage only the useful time to add the velocity to the fall, and this means to consider the only half time of flight in our approximation, while for Tai Otoshi, the complete flight time is useful to add velocity to the final landing.

Figg 12 13 Examples of times useful for the safety evaluation of the falls of two throws.

On the basis of previous evaluations, all the most important throwing techniques for children were divided into three main groups: Lever, Couple, and. Remembering that Sutemi for kids and children are not widely used. Makikomi (in which Tori uses his weight to throw) in such way all potential danger for Ukè will be covered by our safety analysis
Then we had analyzed :

For Lever Group	Ippon Seoi Nage	Half flight time
	Tai Otoshi	Complete flight time
For Couple Group	Uchi Mata	Half flight time
	O Soto Gari	Complete flight time
For Makikomi	O Soto Makikomi	Complete flight time

The Rational Goal of the Research

The soul of this research on safety for judo children about falls produced by judo throwing techniques is to define and apply a scientific methodology to evaluate the hazard in falls by judo throws for children.
Then as a summary, we evaluate and define:

1. The contact surface of children bodies with Tatami for five different throws.
2. The Elastocaloric Effect to evaluate the energy absorption by Tatami Material.
3. The impact reaction force on the children body
4. A "judo boy Dummy" to apply safety criteria was used in the crash test.
5. The probability of skull fracture (if any) applying risk analysis.
6. Both: Thoracic Trauma Index and Compression Index.
7. Finally, if correct falls of judo throws are safe or not, for "judo boy Dummy", they are so, also for children.

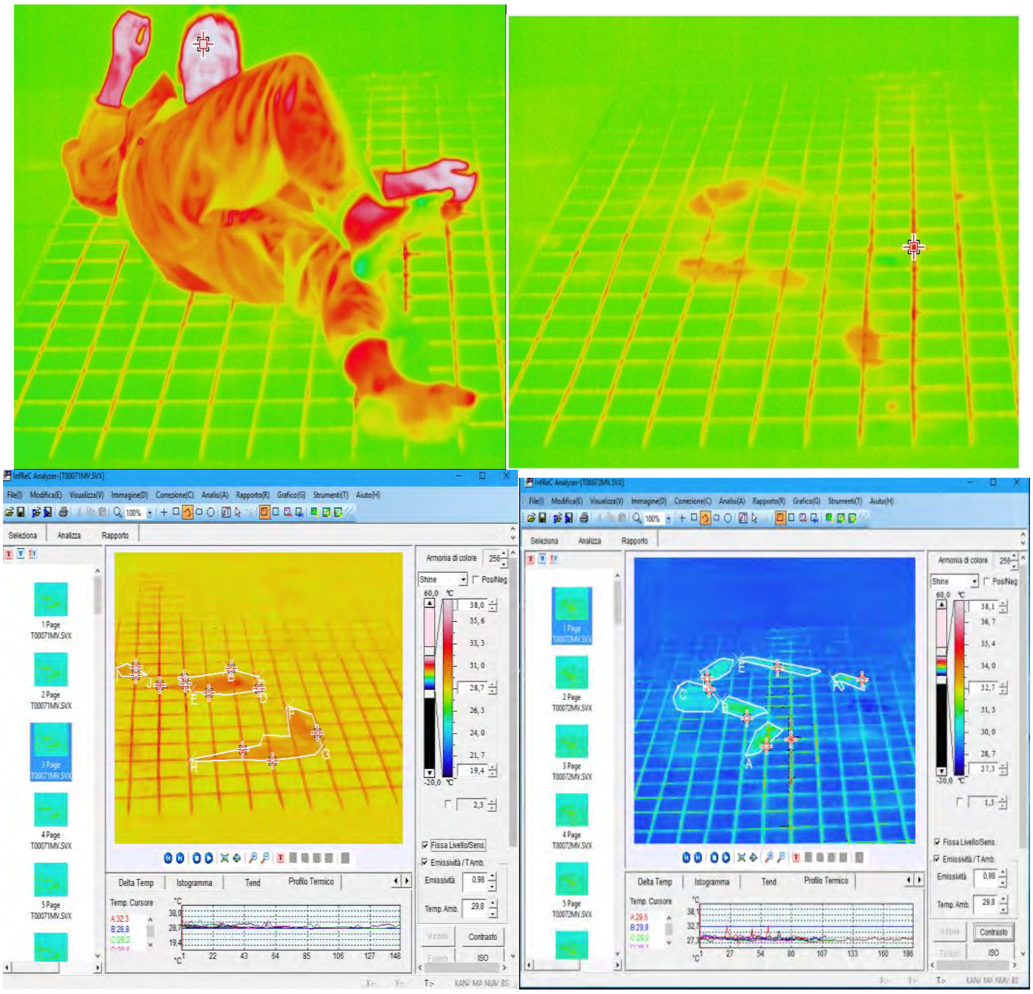
Avio Thermal Camera and impact surface measurement.

The impact surface measurement is based on the dynamic heat conduction between children bodies and the surface layer of the tatami.
However, also radiation can contribute. For example, easy theoretical calculations show that in our situation, a children body radiates on one square meter of Tatami at 23 C° on the basis of Stefan – Boltzmann law, more or less a radiant emittance of 430 W/m^2
in formulas

$$E_m = \varepsilon\sigma T^4 = (0.98)\ 5.67\ 10^{-8}\ (296{,}15)^4 \approx 427 - W/m^2 \qquad (14)$$

Few studies using infrared thermography have been devoted to sports performance diagnostic and to sports pathology diagnostic.
It is well known that sports activity induces a complex thermoregulation process where part of the heat is given off by the skin of athletes. As not all the heat produced can be entirely given off, there follows muscular heating resulting in an increase in the superficial skin temperature. In particular, the IRT method will enable, in the long term, to quantify the heat loss.
Just to make a historical correction to the history of thermography in sports [24] in Italy during the period 1989 - 1993, many types of research, with thermography, were produced by the author coordinating a joint research a group of researchers of three Italian Institutions ENEA, CONI and FILPJ, to assess, for the first time, the oxygen consumption of judo throws by Thermo cameras.
At that time, Thermal cameras were frozen by liquid Nitrogen.
These old researches were also remembered in the recent research publication [25].

The old researches were focalized to evaluate not only the difference of Energy consumption among two groups of throws Lever and Couple but also to build one heat exchange equation men-environment to evaluate the mean overall oxygen consumption in real competition.
This actual research is focalized on the capture of the thermal image of surface body contact left by Uke after the fall of throwing and on its measure.
When children body was falling touches the tatami, it leaves one thermal track produced by dynamic thermal conduction.
This is not visible; the thermal track disappears very fast due to the cooling by the convention of the surface layer when the body leaves the tatami.
The research idea is to capture by a fast and sensible thermal camera this evanishing image of the contact surface, measure it and evaluate for safety point of view, the stress received by children body that is the maximum impact force divided the measure of the vanishing thermal image of the contact surface.
The next four figures, there are shown some thermal captures obtained by the Japanese Thermal Camera AVIO 600 from Nippon Avionics.
Equipped with the software InfReC Analyzer 9500



Figg, 14-17 thermal capture of fall and track and two thermal tracks bounded and measured.

Data evaluating the Children Judo Maximum hazard for falls produced by judo throws: Mechanical and Thermal Information

In this paragraph are collected all the most important results of the research. These results are divided into three main areas
Source:
In the source, we consider all the starting data of children analyzed, the thermal environmental situation of the FIJLKAM Dojo measured by a Rocktrail atmospheric station-

Year	**Height m**	**Weight Kg**	**thorax cm**	**SBA (Costeff) m²**
2003	1,47	39,7	75	1,278
2003	1,49	35,4	67	1,185
2002	1,64	58,6	63,1	1,624
2005	1,52	50,7	83	1,491
2002	1,61	52,5	73	1,521
2006	1,42	41,8	80	1,322
1998	1,56	54,3	82	1,553
2008	1,31	27,2	63	0,988
2001	1,77	65,8	90	1,734
2002	1,76	65,6	90	1,731
2001	1,84	98	100	2,122
2000	1,71	52,8	89	1,528
2002	1,46	49,4	80	1,468
2005	1.58	45,2	65	1,389
2004	1,69	66,1	84	1,739
2007	1,51	38,1	70	1,244

Tab 1 Children data

Barometric values: Environmental Temperature 25-27 C°
Internal Dojo Temperature 23-25 C°, Humidity 55%-57%
Alt. 0 Level of the sea

Mechanical results

Fig, 18 the experiment in visible light

	Tai Otoshi s	Uchi Mata s	O Soto Gari s	Soto Makikomi s
0,365	0,55	0,245	0,25	0,68
0,415	0,69	0,34	0,34	0,46
0,44	0,65	0,35	0,57	0,73
0,315	0,56	0,31	0,4	0,44
0,37	0,5	0,47	0,44	0,84
0,265	1,00	0,395	0,29	0,81
0,35	0,69	0,37	0,26	0,87
0,33	0,58	0,3	0,33	0,68
0,57	0,41	0,315	0,53	0,6
0,495	0,68	0,4	0,4	0,71

Tab 2 Experimental flight time measured for five throws with a digital chronograph

Ippon Seoi Nage m/s	Tai Otoshi m/s	Uchi Mata m/s	O Soto Gari m/s	Soto Makikomi m/s
0,22	0	0,82	0,79	≤0
0,07	≤0	0,31	0,31	0
0,02	≤0	0,27	0	≤0
0,43	0	0,45	0,11	0,02
0,2	0	0	0, 02	≤0
0,7	≤0	0,12	0,55	≤0
0,27	≤0	0,2	0,73	≤0
0,36	0	0,5	0,36	≤0
0	0,09	0,43	0	≤0
0	≤0	0,11	0,11	≤0

Tab 3 Maximum Velocity parameter evaluated by fig. 7

Ippon Seoi Nage N	Tai Otoshi N	Uchi Mata N	O Soto Gari N	Soto Makikomi N
1,5	1	3,28	3,16	≤1
1,15	≤1	1,74	1,74	1
1,04	≤1	1,64	1	≤1
2,03	1	2,1	1,24	1,04
1,45	1	1	1,04	≤1
2,84	≤1	1,27	2,39	≤1
1,64	≤1	1,45	2,94	≤1
1,85	1	2,24	1,85	≤1
1	1,18	2,03	1	≤1
1	≤1	1,24	1,24	≤1

Tab 4 Maximum Force parameter evaluated by fig. 6

Mechanical results about hazard for children

Max Impact Force: 1,55 mg, mg, 1,78 mg, 1,76 mg, mg
Max Impact Velocity (m/s): 5,39; 4,79; 5,81; 5,71; 4,48
Maximum Stress (MPa) 0,13; 0,05; 0,09; 0,07; 0,05.

Max Stress Received by children body [25%](MPa) 0,09; 0,03; 0,06; 0,05; 0,03.
1 Atmosphere = 0,1 MPa
Rib experimental max compression 0,0075 mm

Thermal results about hazard for children

Ippon Seoi Nage cm²	Tai Otoshi cm²	Uchi Mata cm²	O Soto Gari cm²	Soto Makikomi cm²
45	60	80	85	120
70	75	110	140	85
55	70	115	120	100
75	85	95	95	95
65	85	110	140	95
70	105	75	180	130
55	140	90	80	100
50	105	80	75	80
60	110	90	150	70
55	95	75	90	115

Tab 5 Contact Surfaces evaluated by thermal images ±7%

Maximum Stress (MPa) 0,13; 0,05; 0,09; 0,07; 0,05.
Experimental evaluated Elastocaloric effect for five throws:

In Kelvin	In Celsius
296,15 <T(°K) < 296,17	23<T(°C) <23.02
296,15 <T(°K) < 296,16	23< T(°C) <23,01
296,15 <T(°K) < 296,168	23 <T(°C) <23,018
296,15 <T (°K) < 296,165	23 <T(°C) < 23,014
296,15 < T(°K) < 296.16	23 <T (°C) <23,01

These experimental measurements give us the capability to evaluate the connected tatami compression, which is around 0,5 mm!
2mm was the previous theoretical evaluation to have a reference measurement for temperature rise. This evaluation is one indirect measurement of the little intensity of forces applied among children that train judo throwing techniques.

Data for “Judo boy Dummy” and Crash test methodology.

There is one big problem in translating all the biomechanical and thermal calculations into physiological effects. In fact, there is not a worldwide accepted way to connect impact Biomechanics data to the hazard for traumas in children.
After large research [26] [27][28] [29] [30][31][32][33], the only way accepted in medical and engineering areas, in our opinion, is the Crash Test approach considered sufficiently objective.
Following this approach, to objectify and generalize the previous judo results, we define a “Judo Boy Dummy”, built by the mean data of the real boys, on which are applied the mean impact forces evaluated during the experiments.
Normally Dummy is utilized in a crash test to have data from real incidents among cars.
We retain the original diction “Dummy” in order to understand the use of the crash test method better, but in fact, in this research, the “Judo Boy Dummy” is referred to as the reference "judo boy ", which is defined as the average size of the children playing judo
From the medical point of view, the result is similar to the “Reference Man” approach for Radio-Protection [34], it is a human being of statistically average size and physiology, used in research models of nutrition, pharmacology, population, radiologic protection and so on,
Then we use “Judo Boy Dummy” for “Reference Judo Children” and utilize the accepted meaning in the Crash test methodology for similarity.
And following the Crash Tests Methodology, on this Dummy will be applied the average stress produced by each technique.
Thereby maybe used formulas validated in Crash Tests Methodology, and we will get the consequent hazard results for children associated with falls produced by judo throwing techniques.


Fig 19 20 from Crash test Dummy to Judo boy Dummy: “Gennaro Kano.”

Head Injury Criterion, Skull fracture Probability, Thoracic Trauma Index, Compression Criteria. Results for “Judo boy Dummy”.

In the crash Methodology, there are defined and accepted indexes that are the accepted connection between Impact Biomechanics and hazard or physiological injury. They are Head Injury Criterion that depends directly on the head acceleration and impacts time. This Criterion is directly connected to the probability of a potential skull fracture.

$$HIC = max\left[\frac{1}{t_2 - t_2}\int_{t_1}^{t_2} a(t)dt\right]^{2,5} (t_2 - t_1) \qquad (15)$$

$$p(fracture) = N\left(\frac{\ln(HIC - \mu)}{\sigma}\right) \qquad (16)$$

The other important index is the Thoracic Trauma Index, which is based as an important parameter on the Thorax acceleration multiplied by the actual body mass divided by the average man body mass, with a connection to the age of the subject.[35] This index is not directly connected to the hazard of impact biomechanics but is an indicative index of the potential blunt traumas.

$$TTI = 1{,}4AGE + 0{,}5(RIB_y + T12_y)(M / M_{std}) \qquad (17)$$

More physiological connected is the AIS index (Abbreviated Injury Scale) that well is connected to the Compression criteria.
I am defining compression (C) as the chest deformation divided by the thickness of the thorax.

$$AIS = -3{,}78 + 19{,}56C \qquad (18)$$

Evaluating with the mechanical and thermal data the Crash Test indexes for the “Judo Boy Dummy”, we can single out, if judo is, generally speaking. A safe sport for children or not.

TTI = 26,4 ; 22,3 ; 26,5 ; 26,7 ; 21,7 <<80 No Traumatic Event.
AIS=-3,74; -3,76; -3,76; -3,76; -3,76. <<0
Applying the theoretical compression 2mm in place of 0,5mm
AIS(0) ≤0 (Extremely Lightweight Blunt Trauma).

The problem arises not only by a direct blow from a fall produced by a stronger friend but, in safety vision, also by the accumulation of micro-trauma into the two major target organs: the Liver and Spleen. [40]
To help judo teachers in these ***two important but under-evaluated*** aspects of children safety. The software house ISS (Italian Software Solutions) is preparing a Digital Assistant, on the phone, PC, I-phone and Tablet based on this research, applied to all judo throws, so as to address these issues with sound objectivity:
The name of the software is the ***Hazard Training Sentinel***.

Fig21 HTS Phone App

This software is able not only to evaluate the stress produced by a single throw, for each boy, on the left and on the right but also to evaluate the micro-trauma in time and to alert the teacher when the kids /child needs to stop for some time falling down, to give recover time to children body playing judo without falls. Probably these findings will change the basic training for kids, with the introduction of without fall recovery time

.

Conclusions

The soul of this work is to build a sound methodology grounded on scientific criteria to evaluate the hazard in judo throws for children.

Because it is not possible to connect impact mechanics to the resulting traumas in a clear way; it is introduced the “Judo Boy Dummy” to utilize verified methods (crash tests) to do so.

The experimental measurements of flight times and body contact area for each fall, as input for the hazard evaluation, clearly show that for falls produced by judo throws among boys:

Judo is a Safe Sport For Children.

The hazard training sentinel will be friendly and useful software support for teachers to teach throws in a safe way during the first years of kids training

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Appendix VI

The truth about Safety in Judo by Experimental Research

(Suwari°Seoi Safety: From Children Dojo To High-Level Competition)

° The term Suwari means seated, often used in France and Italy, was introduced here due to the lack of a Japanese denomination that does not distinguish between Seoi Otoshi and Suwari Seoi. The distinction is important in this specific situation for Biomechanics because both are a technique of Lever Group, but the version named Suwari has an arm of the leverage longer and less application by Tori of the force projecting Uke

Suwari°Seoi Safety: from children Dojo to High-Level Competition
(Biomechanical Part)

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1 Introduction

In this paper, we face the problem of safety connected to a class of throws that are more often applied in every level of competition.
As normal in such a situation, most discussions are available about the right or danger to apply these techniques. Recalling the farsightedness of the founder of the judo, Jigoro Kano, on the safety of practitioners: establishment of the Ukemi Waza, and ban on the application of Yama Arashi, which has extended over time due to the sensitivity of the successors in the ban on Kawazugake and Kani Basami.
This complex work is focused on Tori safety in the application of the class of throwing applied with two knees on the mat. Both in seiza position with feet stretched and in Japanese style with feet pointed. These techniques are very effective in competition if right applied, but they seem to have a bad reputation, often connected to their premature application or to the chronic damage that can cause long-term agonistic activity, especially at a high level.
We must give credit to the Japanese Masters who seem to have, even in the texts, a greater sensitivity about the safety of the practitioners. In fact, it is possible to read affirmations like the following ones. *Dropping onto two knees, which has existed in judo for as long as anyone can remember- has always been regarded as a lesser form or even a bad form. Any young person who does it in a Japanese dojo will be severely criticized even now, for it is regarded as potentially damaging to their knees- which has turned out to be true. Numerous top judo competitors have had operations to remove damaged cartilages. As a result, too many drops with full force onto the knees. Currently (1990) in Japan, judo competitors under 16 (junior high school and under) are forbidden to attempt to drop Seoi Nage on both knees in competition. With this rule, Japan hopes to maintain an overall high standard of basic judo technique rather than give a handful of individuals the satisfaction of bringing home a few medals. However, it must be said that as much as 80% of Seoi Nage seen in competition are this dropping version. [1] There has been a recent increase in the incident where tori grapples in an extremely low posture and enters deep inside uke by dropping onto both knees for Seoi Nage or Seoi Otoshi. Seoi Nage with both knees dropped is, however, banned in the Kodokan referring rules and in junior judo[2]*
Then it is important to connect the right trauma developed in Judo with the technical application because the inverse solution will be to ban wrongly throwing techniques that are harmless.
We focus in this research on Seoi applied with two knees on the ground.
How is this technique named?
In Japan, Seoi Otoshi, both with one or two knees on the ground, there is no difference at all, in English speaking countries Drop Seoi, in France, Italy and few other countries Suwari Seoi.
The names of Japanese throws born, as Kazuzo Kudo inform us: " …*Judo names fall into the following categories:*

1. *Names that describe the action*
2. *Names that employ the name of the part of the body used*
3. *Names that indicate the direction in which you throw your opponent*
4. *Names that describe the shape of the action takes*
5. *Names that describe the feeling of the technique*

Most frequently, judo technique names will use the content of one or two of these categories [3]
The name Drop Seoi, for the English countries, where do he was born?
Personal research led me to the 60s, where I found for the first time the translation name: Seoi Otoshi as Seoi drop, in the golden text of Koizumi [4], then during time seoi drop, changed in drop seoi to show the two knees variation of Seoi Otoshi.
There are differences between Seoi and Seoi Otoshi, with one or two knees?
For Japanese people, we know that: *"It is important to discern the subtle differences between these two techniques….. Generally, tori should pull downwards with the body lowered when throwing with the knees dropped, but tori should load uke onto the back when throwing with knees not touching the mat. Therefore, we can define Seoi Otoshi as throwing with the knees dropped and seoi nage as throwing from a posture where the knees are not dropped."* [2]
In terms of Biomechanics among Seoi, Seoi Otoshi and Seoi Otoshi with two knees on the mat, there is no difference as a physical principle. It is always the same application of the lever principle. The only changing aspect is the arm of the lever that increases from Seoi to Seoi Otoshi to Suwari Seoi*, (* this name, as already underlined, is not in Japanese tradition but comes from France and Italian habit for *sitting Seoi*, that for English speaking is called Drop Seoi). for this reason, we face with three different energy consumptions and with three different stability and/or mobility situations for Tori.
Then basically, we face the same physical principle with three different mechanical properties On this basis, we follow, to the clarity of classification, the French denomination "Suwari Seoi" [5], specifically for the Seoi Otoshi variant with two knees on the mat.
From the technical point of view, rightly Japanese people, when speaking about Seoi, throws speak about a family of throws similar but whit different arm positions like Morote Seoi, Eri Seoi, Ganseki Otoshi, etc.
From the historical point of view about the naturalness and effectiveness of the two kneeling on the ground application, we are reminded by the two following figures, without wanting to go back to the examples of the wrestler's tomb in the Saqqara 3000 B.C. They are taken from the Greek-Roman world, in which Pancratius wrestlers and wrestlers are seen applying techniques of the "Suwari Seoi family".

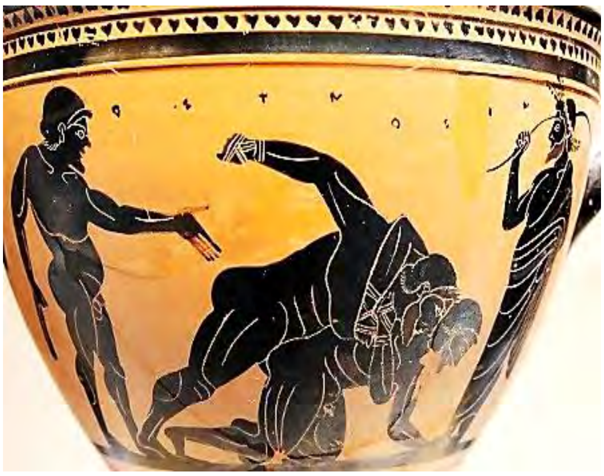


Fig. 1 Pancratius wrestler applying a suwari seoi family throws

Fig.2 wrestler applying a suwari seoi family throws

2 Safety on Suwari Seoi family

In our situation, "Knees' impact produced by Judo throwing techniques of the family of Suwari Seoi", the hazard is the condition that can cause injury to children applying these judo techniques or to adults used to apply them for long time life.
Obviously, the large range time of this study needs a mixed approach in the research that it is not focalized on the Suwari Seoi poorly managed, but on the normal situation: children and adults that throw each other, with their Suwari Seoi throw.
Only a few notations on the wrong application it is obvious that good teaching is a teacher duty, then big hazard is connected to teaching or to physically untrained subjects or by wrong technical methods.
The safety approach needs to consider both the potential instant trauma and the possible long-term trauma, very difficult to identify.
For the first kind of trauma, the medical literature [6] assures us that that from the position analyzed deep kneeling with feet pointed and seiza arriving position after the jump, amazingly it could produce the posterior cruciate ligament (PCL) tear.

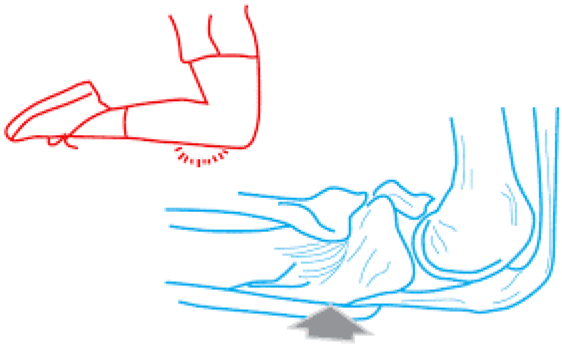


Fig 3 Classical mechanism of Posterior Cruciate Ligament Tear

The injuries to the posterior cruciate ligament (PCL) and posterolateral structures of the knee have received increased attention over the past decade; the result of this trauma is well known.[7,8]
The majority of patients who have isolated PCL tears can function with a minimal disability; however, if the PCL is torn in combination with injury to the posterolateral structures, significant knee disability can result. The first mechanism of PCL tear is front car impact. The fall on the flexed knee with the foot in plantar flexion is the second most common mechanism of injury to the PCL. When someone falls in this manner, the tibial tubercle hits the ground, forcing the tibia posteriorly

and tearing the PCL. A rotational mechanism associated with a varus or valgus stress may injure the PCL and collateral ligaments also. [9]
When we analyze the safety of Tori who apply a Suwari Seoi Family Throw, some thought must be focalized on the anatomical differences between male and female about the kinematics and kinetics of lower Kinetic Chains in Suwari Seoi Family techniques, as shown in the next figure.

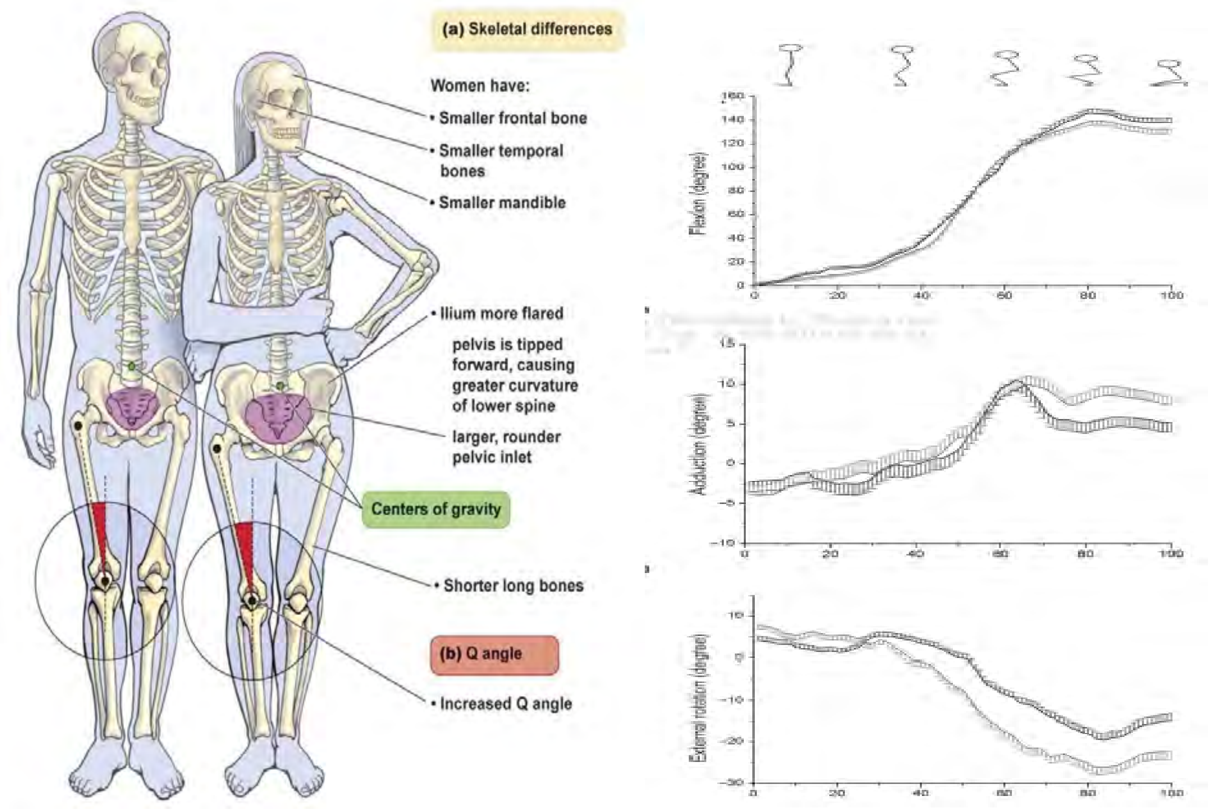


Fig4 Differences between male and female knee

Recent studies [10] on the kinematics of inferior chains during kneeling action showed interesting differences among males and females during deep kneeling action, which can affect the safety of Suwari Seoi techniques, especially in the frontal plane connected with the ACL and PCL strain.
The special care we must-have for female athletes because the differences among males and females became apparent, in a clear way, only when flexion angle was beyond 120°
These differences could be partially attributed to the difference in the strength of the respective connective tissues (ligament, joint capsule, tendon, etc.), which were linked to the joints and may heavily influence the general joint's movements.
For example, it is well known that the posterolateral bundle of ACL played a crucial role in knee stabilization at high flexion angles (>120).
As Han and coworkers affirm: "… *The differences in secondary joint motions at high flexion angles may indicate varying ACL laxity between genders. The joint laxity of females could diminish joint proprioception, resulting in lower knee sensitivity to potentially injurious loads.*
Meanwhile, ACL laxity would allow for a longer time for females to detect joint motion.
Due to a key role of ACL in controlling axial knee rotation, significantly higher knee rotations would be predicted in females".
Female athletes appear to rely more on their quadriceps muscles in response to anterior translation, whereas male athletes rely more on their hamstring muscles. But high quadriceps loads would induce greater patellofemoral forces in females, which could be connected with the increased incidence of knee joint osteoarthritis in the female population used to sit in a deep kneeling position.

Furthermore, the greater hip adduction, which was more apparent in females, could be another potential risk factor for ACL injury.
Generally speaking, all the ligaments injuries and the ACL Injury could be divided into Direct and Indirect trauma [11] genesis:
Direct trauma injury (rare):
they occur as a consequence of a joint impact against an external body (contact/contrast) that occurs according to three main mechanisms:
• Through a direct trauma on the sidewall of the knee that causes an external valgus-rotation;
• Through a direct trauma on the inner wall of the knee that causes a forced varus in internal rotation;
• Through a direct trauma to the back of the leg, which causes anterior translation of the tibia (the inverse mechanism figured in fig 33);
Indirect trauma injury:
especially if the knee is in the " almost extension " position (about 20 ° of flexion). This is because the anteroposterior stability of the knee in these degrees is totally dependent on the ACL, and the movement is poorly assisted by secondary stabilizers;

The four main damaging mechanisms are:
• Valgus - external rotation: the traumatic mechanism can occur during a fast movement, a deceleration followed by a change of direction: ***possible in the complementary movements,***
• Varus - internal rotation: the traumatic mechanism can arise during the cutting manoeuvres only performed by one knee during a complementary movement of turn plus elongation, when Suwari technique is applied with the majority of the weight, is put on one only leg stretched and stopped ;
• Hyperextension: the traumatic mechanism can arise through a vacuum kick or a landing not properly stabilized, with hyperextension;
• Hyperflexion: the traumatic mechanism can arise as a consequence of a hyperflexion of the knee, followed by a powerful contraction of the quadriceps in an attempt to re-establish the upright position to throw the adversary suddenly on the back. Normally this mechanism can arise to female athletes, as Han and Coworkers remind us;
The probability of getting an Anterior Cruciate Ligament injury is, in women than in men, from four to six times greater.
The reason for this increased harmful frequency lies, as shortly showed before, in the fact that women have some important anatomical and physiological differences.
• Less muscular strength, consequently also the lower stability control is lower;
• Flexor/extensor ratio more favourable to the extensors, therefore diminishes the defensive action of the ischi-crural muscle;
• Increased latency time, the action of the proprioceptive mechanism and the defensive mechanism of the hamstring is slower;
• Increased flexibility and laxity, increased knee instability;
• ACL anatomically smaller consequently withstands minor traumatic tensions;
• Larger pelvis to a greater external rotation of the tibia are elements that favour the valgus of the knee and therefore increase the predisposition to the lesion in valgus-external rotation, especially during the torsion in deep kneeling position during a complementary movement**.**
However, no PCL injuries, to our knowledge, were even diagnosed in judo as sudden trauma connected to Suwari Seoi Family.
This means that, if well performed, the throws are safe also for female knees that are “more fragile” than male knees.
The critical nature of the complementary movements on the safety of the knees will be shown through a purely theoretical calculation in order to focus the attention of the teachers on a correct study of this part of the technique.
The theoretic results will be obtained in the par. 8. utilizing the equation {28}.

The only European study [12] and at our knowledge in the world on the forces produced from a suwari seoi, shows interesting results. In the following two figures, we can see the layout of this research and some quantitative results in terms of forces suffered by Tori's knees as a reaction to the fall due to the application of the suwari seoi.
Forces are evaluated in BW (Body Weight). In the next figure, it is possible to see the contribution in N of the vertical force separated for components: for Tori in Red more or less 400 N for Uke in Blue more or less 3500 N.

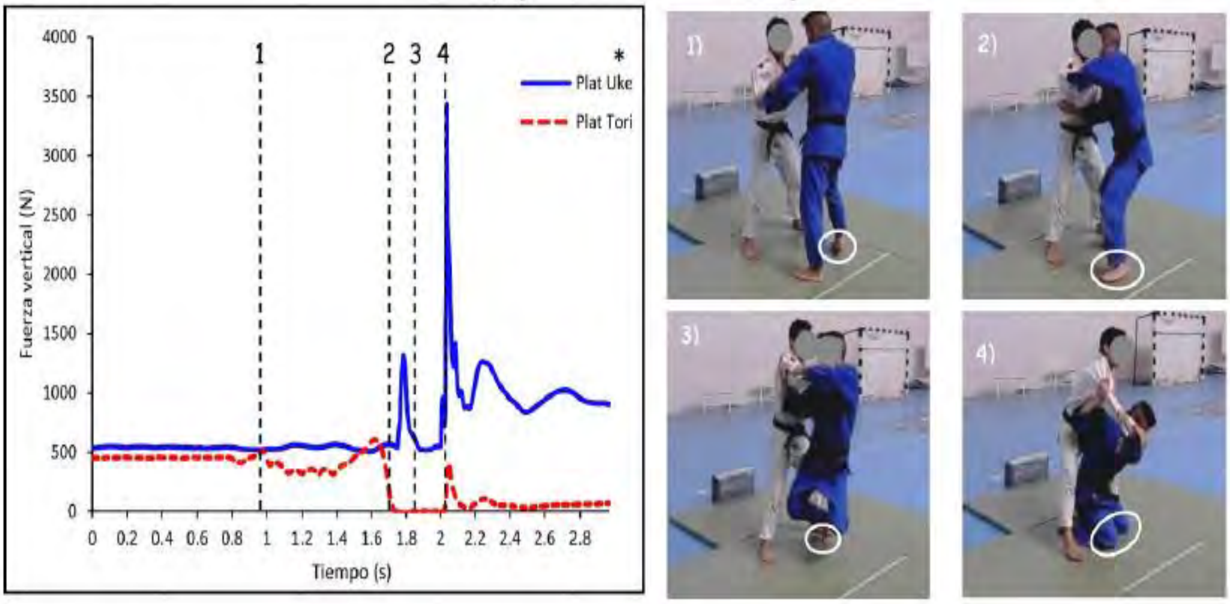


Fig.5 Layout and results in the Suwari Seoi analysis [12]

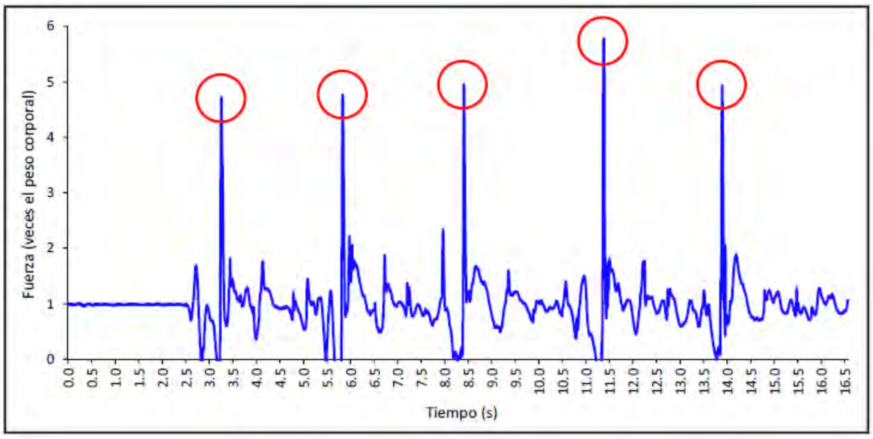


Fig6   Peaks of reaction force suffered by Tori's knees [12]

On the basis of this unique and specific work, some thesis was performed in Spain. One experiment was developed between two clubs in the Canary Islands. [13]
The experiment included one training children with Suwari Seoi, the other one training children with Standing Seoi to see differences in knees trauma between the two children groups. The total number was 80 children/cadets (male and female) for each club they were analyzed for ten months.
The results are shown in the next tables.

Children	Club 1			Club 2		
	Suwari Seoi			Standing Seoi		
Diagnostic	F	M	T	F	M	T
contusion with bruising and functional impotence right knee	9	6	15	4	2	6
Knee Sprain	1	1	2	1		1
Traumatic Pain and functional impotence right knee	1		1			

Tab 1 Traumas and Suwari Seoi for Kids [13]

Cadets	Club 1			Club 2		
	Suwari Seoi			Standing Seoi		
Diagnostic	F	M	T	F	M	T
contusion with bruising and functional impotence right knee	5	3	8	1	2	3
Knee Spill	1	1	2	1		1
Patella tendinitis Right knee	1		1			
Dislocation of the patella right		1	1			

Tab 2 Traumas and Suwari Seoi for Cadets [13]

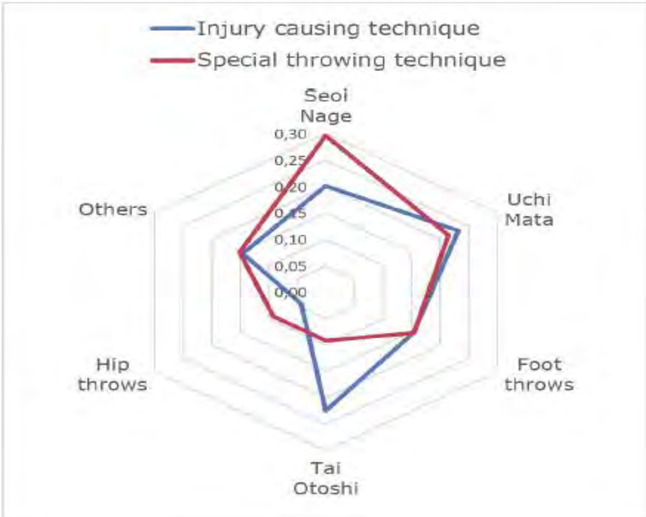
These results, all direct acute trauma, are very interesting because they focus our attention, in our opinion, probably more than the training mistakes, lacking teaching, and misuse of the throw, or not adequate tatami, than to the effective high danger of the techniques.
One notation is that every trauma is on the right knee. From that, we can understand that the support on the knees was not equally balanced, but there was a preponderance of support on the right knee/leg, with the consequent increase in pressure and actual risk of trauma.
These evaluations are supported not only by personal scientific experiences but also by the statistical analysis performed by the author, who demonstrated at the end of the work that there was no statistical difference between the results of these two techniques and that, therefore the traumatic results, even though appearing different, were to be considered statistically equivalent.
Two interesting studies for adults, by questionnaire of connection between acute or chronic trauma and type of techniques. Here we can face the lack of nomenclature. In fact, Suwari seoi or Drop seoi etc., because they are not defined as a name, we do not know if they have presented as Seoi or Seoi Otoshi in the following studies nomenclatures.

The first one is working on 78 Brazilian Athletes at a regional level, [14] the second one 260 German Athletes at the national level [15], the third one is Austrian Match Analysis on 69 competitions in Austrian National Championships 2014 and 2015 [16] which show not only the “safety” of the technique, here referred probably in the Japanese way as Seoi Otoshi, but also the knee very low danger connected.

TABLE 3
Relationship injuries vs. Type of stroke

	Gender M	Gender F	General total	Total (%)
Stroke				
Ippon seoi Nague	12	4	16	23
Tai otoshi	10	4	14	22
Uchi mata	2	4	6	9
Harai goshi	1	3	4	6
Briga de pegada	3	0	3	3
Chave de braço	1	1	2	3
O uchi gari	1	0	1	2
Sassae tsurikomi ashi	0	1	1	2
O goshi	1	0	1	2
Seoi otoshi	1	0	1	2
Hon-kesa-gatame	1	0	1	2
Koshi-guruma	0	1	1	2
Does not remember	8	5	13	22
Total	41	23	64	100

Tab 3. Brazilian Athletes traumas throw connection Questionnaire [14]



Diag 1 special and injury-causing throws

	Uchi mata	Seoi nage	Tai otoshi	Foot throws
Muscle injury	0.21	0.20	0.26	0.29
Contusion	0.38	0.70	0.43	0.21
Meniscus	0.50	0.30	0.52	0.43
ACL	0.46	0.15	0.26	0.07
PCL	0.00	0.05	0.04	0.07
Patella	0.04	0.15	0.17	0.36
MCL	0.25	0.10	0.22	0.21
LCL	0.13	0.10	0.13	0.43
Others	0.46	0.45	0.35	0.00

Tab 4- German Athletes Traumas/ Throws connection and kind of traumas, Questionnaire [15]

INJURY CAUSED TECHNIQUE GROUP	
grip fight	80,0%
sacrifice throwing techniques	6,67%
joint locking techniques	6,67%
leg throwing techniques	6,67%
TOTAL	100,0%

POSTURE AT INJURY	
standing posture	93,3%
ground posture	6,7%
TOTAL	100,0%

Tab. 5-6 Austrian Athletes techniques and posture connected to injuries [16]

INJURED BODYPARTS	male sex	female sex
face	9,1%	0%
nose	27,3%	25%
mouth	9,1%	0%
ellbow	9,1%	0%
hand & fingers	27,3%	50%
thorax / abdomen	9,1%	0%
knee	0%	25%
toes	9,1%	0%
TOTAL	100%	100%

Tab. 7 % of Injuries placement in Austrian Championships 2014-2015 [16]

3 The aim of this research.

Because we are corroborated by the absence in the scientific literature of immediate damage to the PCL connected to Suwari Seoi techniques, we started from the hypothesis that the two knees family of throwing techniques, defined for short. “Suwari Seoi” are not dangerous if properly executed on a good tatami, like all other throwing techniques accepted in Judo; the research group will analyze the correctness of the hypothesis, analyzing from the safety point of view, all sides of the problem.
We assume that the real problem could be for the long-term trauma, the overuse and if present for the acute trauma produced or by the wrong application of the throw or by the follow-up of the technique that is based on complex rotational movements starting from the kneeling position.
The only way is to prepare a questionnaire and spread it around is to collect data over the long-term trauma. This is the reason why we use the questionnaire as one focus of our research.
The other step is to demonstrate that (in safety term) Suwari Seoi it is not dangerous. Obviously, strange accidents are present every time, because of dynamic reasons, and we cannot prevent them! But if we are able both to demonstrate the safety of throw and his right biomechanical principle of application, then with correct teaching of the safe application in training, we can decrease the possibility that accidents happen from the wrong use of the throw.

This is the second focus of our research
How is it possible to demonstrate that?
The research protocol is made with specific attention to the motion and impact of Tori's knees to prevent acute trauma.
We have not to Force platform because simple physics let us know both the impact force and velocity, then we ask for each subject two specific trials with three subcases, six performances of the throw.
The first trial is with knees falling down with both feet pointed touching the tatami, then the mechanics of this way of application it is a fall with control, specifically a mechanical paradox (see biomechanics paragraph 6), and the area of percussion is smaller than the other way to touch the Tatami, only the tips of pointed feet and small tibial area, we take time of fall's trajectory, to evaluate the mean speed of fall.
The second trial is the other way to apply Suwari Seoi in competition, jumping with the feet stretched out not touching at all the tatami, in that case, the mechanics of the action is a free fall, and the contact area is larger, long tibial surface projection and back of the feet.
We take the contact surface by the thermal image on the tatami. This area is a % of total body surface area BSA that is evaluated by Du Bois and Du Bois formula. [17]
For both trials, the safest approach is translated as a fall from the knees' height, measured before the trial.
The third focus of the research is to develop a mathematical model of the impact. The mathematical model is a knee (very simplified model) that collides with a Tatami that is built with a viscoelastic substance. The model will be understandable and will show the differences among the knee impact starting from the previous feet positions.
The mathematical model is built because it is possible to change values at some specific parameters like hardness or softness of the mat, falling velocity, the height of fall, and see the effect produced without any other use of children or athletes
The fourth focus of the research is the confrontation between children and adults in terms of styles velocity and other aspects like safety, etc.
The fifth focus is the analysis in competition to know how many times the throw is performed, in which fashion (feet pointed or stretched), how it is effective. and try to classify the further movements after the knee impact used to perfect the final part of the throw, the so-called "Complementary Tactical Tools" (CTT). [18]
From all that, we will try to single out the best biomechanics form to apply the technique in such way we are able to give some suggestion for children training in safety and some to optimize the adult way to throw.
For a high level, we will try to give some global indication about how to perform this technique in an effective but safer way.

4 Biomechanics of Suwari Seoi family

As it is well understood, the mechanics of the Suwari family is a lever mechanics, with maximum arm, but there is a more subtle difference between the applications studied A) with feet pointed, and B) with feet stretched, when we analyze the motion and the fall of the knees: in the first example we face with a mechanical paradox, and in the second one with a pure free fall example.
This means that equations that explain the motion dynamics of legs and knees are different also from the theoretical point of view. In the first case A) under some specific conditions, the knees vertical downward acceleration can be higher than g, while in the second case B) the acceleration will always be g, but the conservation of energy assures us that the impact force of the knee will be higher than

the athlete's weight because inside there is the restitution of jumping up energy before utilized for the starting jump of the throwing movement. [19]

A) The situation of the pointed feet is very interesting. The net moment on the leg is
$\tau = k\,Lmg\cos\varphi$ {1}
With L= length of leg, k= <1 (variable location of CM) , m =body mass, g =gravity acceleration,

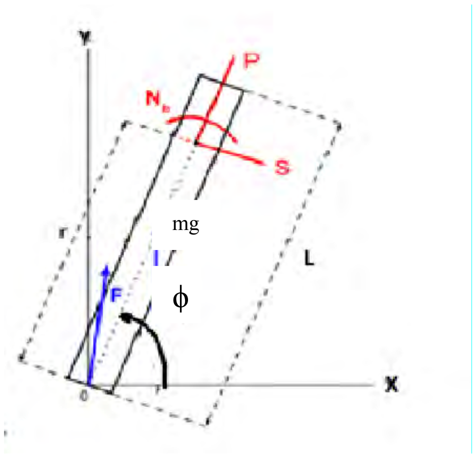


Fig 7 Model representation of lover's leg

The equation of the dynamic motion of the leg is: $\tau = I\alpha = I\dfrac{d\omega}{dt} = I\dfrac{d^2\varphi}{dt^2} = kLmg\cos\varphi$ {2}

The inertial momentum is $I = \beta mL^2$ {3} from the equations 1.2 and 1.3 it is possible to evaluate the angular acceleration α.

that is : $\alpha = \dfrac{kg}{\beta L}\cos\varphi$ {4}

if we define the constant, $\omega_c^2 = \dfrac{kg}{\beta L}$ {5}

it is possible by integration to obtain the angular velocity ω :

$$\omega^2(t) = 2\omega_c^2\left(\sin\varphi_0 - \sin\varphi\right) + \omega_0^2 \Rightarrow \left(\frac{d\varphi(t)}{dt}\right)^2 = 2\omega_c^2\left(\sin\varphi_0 - \sin\varphi\right) + \omega_0^2 \quad \{6\}$$

The differential equation gives us the variation in time of the angle by the solution of the elliptical integral. It is also very important to analyze the position of the total CM of the body, because normally if the mass is put before the collision centre of the leg, it can accelerate the vertical velocity of the knee.
In fact, the acceleration of the knee is:
$a_T = \alpha L$ {7} and the normal component of this acceleration to the mat is:

$$a_n = a_T\cos\varphi = \frac{kg}{\beta}\cos^2\varphi \Rightarrow \frac{2}{3}g\cos^2\varphi \quad \{8\}$$

In some conditions of throws, body weight, during the controlled falling in deep kneeling with feet pointed, is moved near the feet position

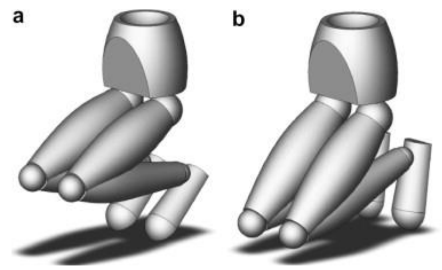


Fig 8. way to fall with feet pointed

In such condition, if we call M the body mass and m the mass of the leg calf (% of M), the tangential acceleration of the knee in the horizontal position is [20] :

$a_T = \frac{3}{2} gL \left[\frac{Ml + mL}{Ml^2 + mL^2} \right]$ {9} we can analyze the two limit situations: Ml=mL and M>>m, and easily we obtain:

$a_T \equiv a_n \approx 3g$ {10}

$a_T \equiv a_n \approx \frac{3L}{2l} g$ {11}

From the previous two equations, it is easy to evaluate the range of falling velocity of the knee in these limit situations, and we see that it ranges among 2.6 m/s < v < 6 m/s.

In terms of safety, we are now able to evaluate the maximum impact force of the knee on the tatami.

Other important information from this theoretical approach is the evaluation of time to hit the tatami, calculations are difficult, but readers can find it in references [a,b,c] we give only the final result useful for our safety analysis in terms of the ratio between the time of free fall divided by the time of knee point if the ratio is less than one the condition of faster than g is satisfied.

$\frac{T_0}{T_1} = \sqrt{\frac{2k \sin\varphi_0}{\beta I_1^2}}$ {12} in which the time of free fall is $T_0 = \sqrt{\frac{2L}{g} \sin\varphi_0}$ {13}

Moreover, with good mechanical approximation, it is possible to consider this situation as a model of a falling chimney to obtain rough data about internal stress of the knee following and adapting the results of Varieschi and Kamya [21] to our specific situation.

For the leg calf that progressively bends in some situation potentially, it is under the combined actions of a longitudinal force P and a bending moment N, the stress at knee considering the bone leg composed by one homogenous piece is in the non-dimensional form:

$$\frac{\pi\rho^2}{mg}\sigma_k = \frac{1}{2}\left(1-\frac{r}{L}\right)\left[\left(5+3\frac{r}{L}\right)\cos\varphi - 3\left(1+\frac{r}{L}\right)\right] + \frac{3}{2}\frac{L}{2\rho}\frac{r}{L}\left(1+\frac{r}{L}\right)^2 \sin\varphi \quad \{14\}$$

This equation depends on the L/2ρ, with L= length of the calf and 2 ρ = bone diameter, in the human body case, the dimension is about 66 times, this means that the second term of this equation is enhanced by the previous ratio and the term depending by the bending moment plays a more important role in the safety of athletes' knees.

On the other side, shear stress can be the other leading cause of the rupture. It is easily seen that, for any specific angle, the magnitude of the shear force has an absolute positive maximum and usually originate near the ankle, meaning that large shear forces can affect the ankle joint that serves as a pivot in the throwing action.

B) In this other situation, the athlete jump and land on the tatami with feet stretched, landing in the “seiza” position. The mechanics under this throwing style is the simple mechanics of human body free fall.

In terms of safety, we must consider that the impact energy is the function of the height of the jumping. In equations, we can write remembering the conservation of mechanical energy:

$$\frac{1}{2}mv^2 = mgh \quad \{15\}$$

The applied load on the knees and legs during free landing varies according to the height, ground softness, joint flexion, landing positions and direction. The magnitude of the load obviously increases as the height of the jump increments, whereas the impact time decreases. Considering that no significant differences can be found among the falling periods from various heights because athletes and children are used not to jump high, but they jump as slipping between the Uke legs.

The impact time (impact duration) was quite short.

Therefore, an average time of 0.04 s was applied in the analysis. The landing time was evaluated for each trial.

The velocity of each subject during free-fall in terms of safety was evaluated starting from the knees’ height, using the following well known elementary equations:

$$\frac{1}{2}mv^2 = mgh \Rightarrow v_f = \sqrt{2gh} \quad \{16\}$$

whereas the average theoretical time to fall was calculated by the following relation:

$$t = \sqrt{\frac{2h}{g}} \quad \{17\}$$

The average impact time derived during the experimental test was, as previously expressed, equal to 0.04 s. This time allows that the impact load to be identified using the following equation:

$$\int_0^t F dt = \int_0^{v_f} m dv \quad \{18\}$$

Many studies are performed on the biomechanics of judo throwing techniques, but to our knowledge, very few on the Suwari Seoi, mainly in France and Japan, whereas from Spain comes the highest number of theses and papers that advise against the use of this technique for children.

The main aim of biomechanical studies is to understand “how things work “, for this reason, the studies’ approaches are very similar because the things to understand are the same. From this point of view, the French study [22,23] was focalized on the “principles” of the effectiveness of the execution of Suwari Seoi by mechanical measurements of the movement. To single out the fundamental skill of the techniques.

In the following figures, we can see: the motion capture of Suwari Seoi, Fig 7, the velocity of CM during five throws from 5 World champions Fig.8, global rotation around the z-axis, Fig.9 global rotation around the y-axis.Fig.10 from this figure, we can understand the different specific styles of throwing action in Suwari Seoi

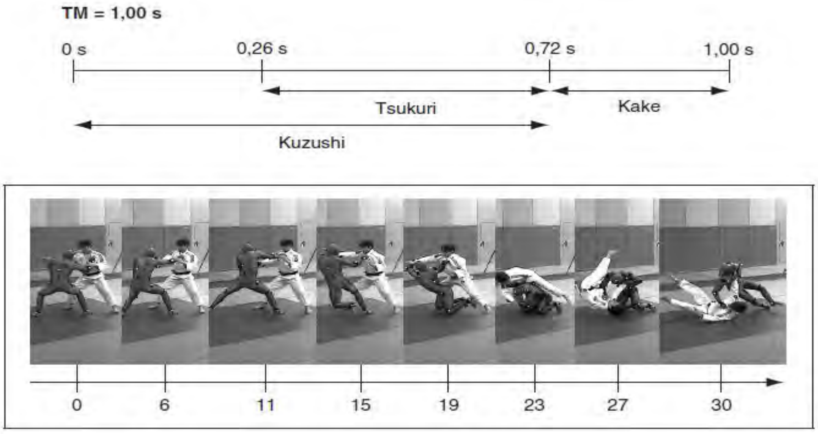
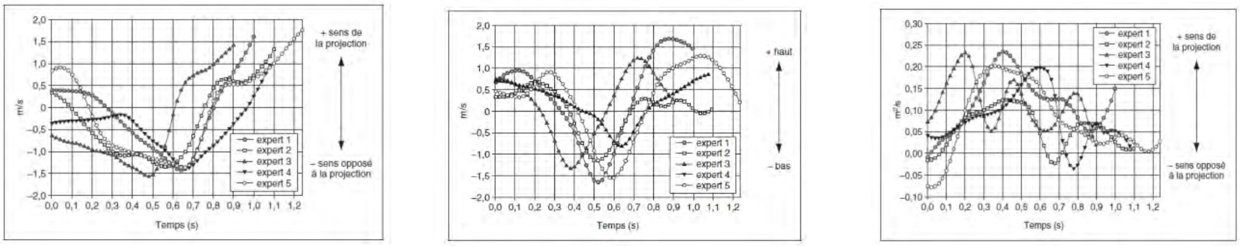


Fig 9 Motion Analysis of Suwari Seoi [21]



Figg. 9,10,11 Cm and Global rotations around axis [21]

Ishi e coworkers performed a very long study on Seoi [24,25,26,27,28] from 2004 till 2016 also comparative between Japanese champions and students to understand the effectiveness of Seoi action, studying the front turn movement, the kinetics of legs, CM motion, angular movements and so on.
In the following figures, it is possible to see some results of these researches.

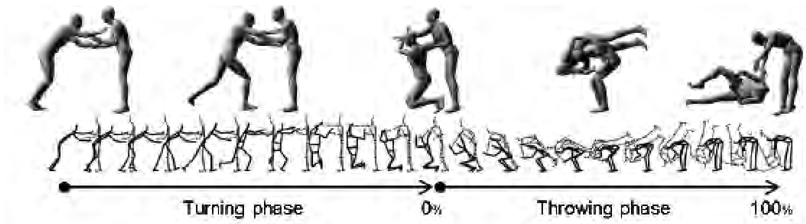


Fig.12 Definition phases in Ishi experiment

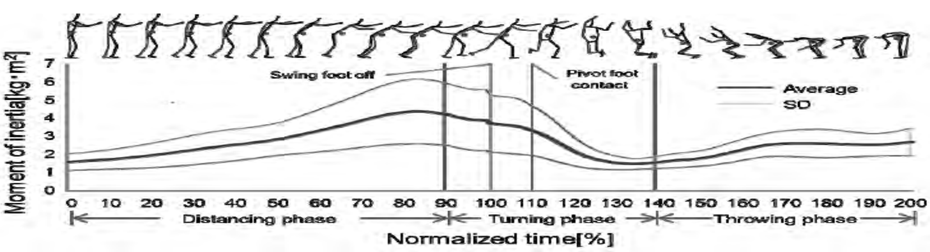


Fig 13 Time evolution of Moment of Inertia [24]

Table I. Difference in the kinematic and kinetic variables between elite and students athletes.

	Elite A	Elite B	Elite C	Students (M ± SD, n=7)
Peak angular velocity (rad/s)				
Knee of pivot leg	6.4	7.5	7.5	4.0 ± 1.8
Knee of swing leg	7.0	8.2	8.6	4.7 ± 3.0
Hip of pivot leg	-5.7	-7.6	-6.3	-3.6 ± 1.2
Hip of swing leg	-9.0	-10.7	-9.1	-4.9 ± 4.5
Peak extension torque (Nm/kg)				
Hip of swing leg	2.42	4.80	3.53	1.60 ± 0.83
Peak flexion torque				
Knee of swing leg	-1.14	-1.49	-1.19	-0.50 ± 0.75
Peak positive torque power (W/kg)				
Hip of swing leg	7.99	15.73	9.19	3.12 ± 3.46
Peak negative torque power (W/kg)				
Knee of swing leg	-6.96	-9.69	-10.20	-1.95 ± 4.10
Hip of swing leg	-5.47	-16.98	-9.38	-1.72 ± 2.52

Tab. 8 Comparative analysis of Seoi kinetic and kinematics variables [26]

About the standing seoi technique, many studies have been performed around the world, starting from the historical Japanese work of Ikai and Matsumoto 1958 [29], most it is now known but about his biomechanics physiology and so on [30,31,32,33,34,35, 36,37,38,39,40,41,42,43].

Instead of the Biomechanics of Suwari, only the French study was performed, and in terms of safety, only the present one and the cited Spanish study [12] were developed.

5 Tatami Material Science and Thermodynamics.

Material science is an essential part of this research because safety outcome depends both from the Tatami material and quality [44]. In this research, we analyzed one Tatami built by polyurethane foam and soft polyurethane covered by PVC and Approved by IJF, with a thickness of 4 cm and overall density of 240 kg/m³. tensile strength 2480 N/5 cm, theoretical Force reduction ≈ 25%-40%

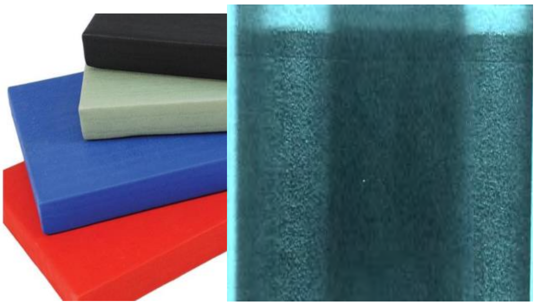
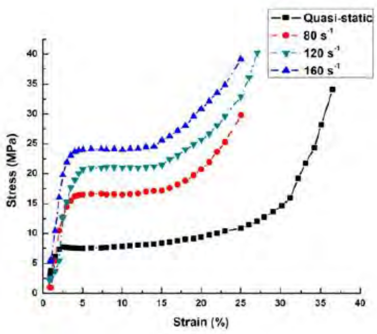
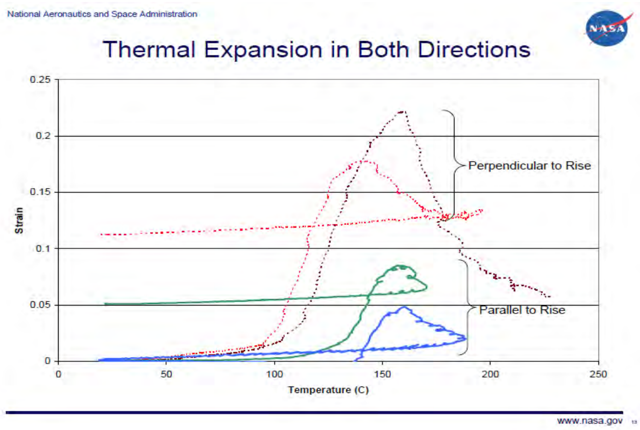


Fig 14 Tatami and vertical constituents section

PU, invented by Bayer in Germany around 1937, have a history of slightly more than 75 years. They have become one of the most dynamic groups of polymers. Their use covers all fields of polymer application practically: foams, elastomers, thermoplastics, thermo-rigids, adhesives, coatings, sealants, and fibres.
PU is obtained by the reaction of an oligomeric polyol [low-molecular weight (MW) polymer with terminal hydroxyl groups] and a polyisocyanate.
The structure of the oligomeric polyol used for PU manufacture has a very profound effect on the properties of the resulting polymer, as assure us, Ionescu, in his encyclopedic work [45].
The tatami analyzed was built by three layers first layer PVC, second Polyurethane foam, and third Polyurethane semi-rigid.
The foam is important, but his mechanical evolution is quite complex.
The response of foam gets stiffer with an increase in strain rate, and densification (lockup) occurs well below the strains at which lockup occurs for foam deformed at quasi-static strain rates. Consequently, the energy absorption characteristics of foam are altered with a change in strain rate. [46]





Diag 2 Stress-strain foam curves[46] Diagg 3 Polyurethane Foam thermal expansion [46]

Also very complex is the thermal behaviour of polyurethane foam, as NASA researchers showed in some very interesting works [47].
Since the foam is not a material but a structure, the modelling of the expansion is complex. It is also complicated by the anisotropy of the material. During the spraying and foaming process, the cells become elongated in the rise direction, and this imparts different properties in the rise direction than in the transverse directions.
However, we are much more interested in expansion in his compression and related thermo-dynamical effects.
If the compression produced by children's bodies is fast, the situation can be approximated in thermo-dynamical terms to an adiabatic transformation.
This specific transformation was named by Viecheslav Sychev in his book "Complex thermodynamic System" [48] Elasto-caloric Effect.

5.1 Elasto-caloric Effect

When a body falls, on the tatami, after a Judo throw, the impact produces one adiabatic compression of the tatami, the impact energy will partially have absorbed, and one of the main effects that change the mechanical energy into heat is the *Elasto-caloric Effect*.
The induced variation of temperature is expressed by the following easy calculation:

$$\mathbf{T=T_0+\int_0^{\Psi}\left(\frac{\partial T}{\partial \Psi}\right)_{S,P}\partial\Psi} \qquad \{19\}$$

To solve the kernel of the integral, we can use the Maxwell equation

$$\left(\frac{\partial T}{\partial \Psi}\right)_{S,P} = -\left(\frac{\partial l}{\partial S}\right)_{\Psi,P} = -\left(\frac{\partial l}{\partial T}\right)_{\Psi,P}\left(\frac{\partial T}{\partial S}\right)_{\Psi,P} \qquad \{20\}$$

And after few simple calculations, we have the following final Relationship:

$$T = T_0 - \frac{\alpha_l \bar{T}}{c_p \rho}\Psi \Rightarrow \Delta T = -\frac{\alpha_l \bar{T}}{c_p \rho}\Psi \qquad \{19\}$$

When the Tatami is compressed, the stress Ψ is negative and the Tatami temperature increases, absorbing energy.
The previous final relationship {21}, remembering the Hookean Elastic Equation can be changed as:

$$T = T_0 - \frac{\alpha_l \bar{T}}{c_p \rho}\Psi \Rightarrow \Delta T = -\frac{\alpha_l \bar{T}}{c_p \rho}\Psi = \frac{\alpha_l \bar{T} E \Delta\varepsilon}{c_p \rho} \qquad \{22\}$$

To have a first indicative order of magnitude in our research, a very simple "theoretical" evaluation assures that with Polyurethane Foam as Tatami material IJF Licensed, with **density 244 Kg/m³**, with energy absorption, **around 25%- 35%**, supposed: ***Theor. Compr*** ≈ 2 mm , temperature will have a "theoretical" increase of : **296.15<T(°K) <297.0** or in Celsius **23 < T(°C) <23.8**
Mechanics and Elasto-caloric effect are connected by means of Strain that Produces Tatami Compression by Hook law.

$$\Psi = \frac{F}{A} = E\Delta\varepsilon \Rightarrow \Delta\varepsilon = \frac{\Delta l}{l} \qquad \{20\}$$

Compression is produced by Tori's knee falling down in the two ways analyzed, and part of the Strain, after energy absorption, is returned to Tori body for the Action-Reaction Principle. In formulas:

$$\Psi' = -e\Psi \quad \{24\}$$

In which (**e** <1) is similar to the restitution coefficient and depends on the Tatami Material. Remembering that:

$$\Psi' = -e\frac{F}{A} \quad \{25\}$$

A in the equation {25} is the surface that in our current research corresponds to the actual impact surface of Tori carrying out the Suwari Seoi, which in our two experimental trials examined corresponds to two basic positions:

- Pointed feet: summation of the tibial protuberance area and the tip of the toes. Fig A
- Stretched feet: total area of the contact of the tibia plus that of the back of the foot. Fig B

Fig. 15 Deep Kneeling feet pointed

Fig. 16 Kneeling with feet stretched " Seiza" position

6. *The throw*

The application of the suwari seoi family in competition needs some specific biomechanical situation.
It is well known that both Seoi Nage and Suwari Seoi Nage are among the most utilized and successful judo throws in the world. As it is easy to see in the next tables: Tab 9,10.

FRA		JPN		URSS		Autres	
Uchi-mata	25,5 %	Uchi-mata	15,8 %	Uchi-mata	11,4 %	Suwari-seoi-nage	13,8 %
O-uchi-gari	11 %	Suwari-seoi-nage	13,3 %	Seoi-nage, Kata-guruma	9,6 %	Uchi-mata	13,4 %
O-soto-gari	7,7 %	Ko-uchi-gari	10,7 %	Suwari-seoi-nage	7 %	O-uchi-gari	8,7 %
Sode-tsuri-komi-goshi	7,4 %	O-uchi-gari	9 %	Kuchiki-daoshi	7,7 %	Ko-uchi-gari	7,4 %
Ko-uchi-gari	7,4 %	O-soto-gari	7,3 %	O-soto-gari	7,4 %	Seoi-nage, Kata-guruma	7,4 %
Kuchiki-daoshi	7,4 %	Tomoe-nage	6 %	Sode-tsuri-komi-goshi	7 %	Hara-goshi	7 %
Suwari-seoi-nage	5,3 %	Seoi-nage, Kata-guruma	5,1 %	Tai-otoshi	7 %		

Tab. 9 % of utilization of judo throws by athletes from France, Japan and Russia [5]

	FRA	JPN	URSS	Autres
1	Uchi-mata	Suwari-seoi-nage	Seoi-nage, Kata-guruma	O-soto-gari
2	Kuchiki-daoshi	Seoi-nage, Kata-guruma	Uchi-mata	Suwari-seoi-nage
3	Seoi-nage, Kata-guruma	Sode-tsuri-komi-goshi	Ura-nage	Sode-suri-komi-goshi
4	O-uchi-gari	Ko-soto-gari-gaké	O-uchi-gari	O-uchi-gari
5	O-soto-gari	Tomoe-nage	Sode-tsuri-komi-goshi	Tai-otoshi
6	Hiza, Sasae	O-soto-gari	Maki-komi	Tomoe-nage

Tab 10 Throws effectiveness for athletes from France, Japan and Russia [5]

Biomechanical analysis shows other interesting findings of Seoi throws. Generally speaking, it is impossible to perform Seoi techniques without unbalancing. Carefully all the Seoi techniques that are kuzushi (unbalance) dependent also need to stop for a moment for the adversary motion to be carried out. Then the Seoi family throws are complex movements that need the highest coordination and timing in motion, especially to obtain the optimal tsukuri position and overcome the strength defensive opposition of Ukes' grips (Kumikata). These are, in general, with the specific mechanics of throw, the reasons for the high energy needs for Tori. But the maximum of Kano: the best use of energy and the maximum effectiveness with the least possible effort, is unconsciously applied in high-level competitions by all athletes and therefore, the family of Suwari Seoi is very often applied with great success. Having, for Tori, a series of undeniable advantages over the standing Seoi family.


Fig17 Male and Female version of Suwari Seoi Family

Tori's Advantages toward Classic Seoi

1) ***Energetically less expensive (the arm of the lever is longer).***
2) ***Less important Kuzushi (the drop-down movement acts as kuzushi)***
3) ***Easier Tsukuri positioning (it is Uke's body that fits Tori's body and not the inverse).***
4) ***Useful in overcoming Uke's grips (arms are less able to stop up and down movement than push/pull actions).***
5) ***Useful in increasing rotational speed***
6) ***Most difficult is Uke's Avoidance vs drop action***

However, these previous multiple and undeniable advantages obtained that simplify the action of Tori are, on the other hand, paid with two important complications.

Tori Disadvantages

1) **Less control over Uké body defensive direction**
2) **The drastic increase in stability and decrease in mobility**

In high-level competitions, due to athletes' defensive acrobatic skills, it is difficult for Tori, with his knees touching the tatami, to manage the direction of throwing forces according to the defensive movements of Uke when the throw is not perfect.
This is the reason why it becomes necessary to use additional movements aimed at perfecting the action in order to obtain an effective result. So, dynamicity of a throwing action, high defensive skill and lesser mobility are the three main reasons to apply tactical support tools (specific movements) to refine action in competition because, during the fall down, Tori have little control of Uke movement, and the end of trajectory is a situation of multiple direction choices for Tori, and this is also the main difficulty to manage this throw in an effective way.

Fig 18 Esoteric, but effective, Variation of Suwari Seoi Family

7. The complementary movements (tactical tools)

When athletes perform Suwari Soi in competition because it is very difficult for Tori to control the defensive body direction of Uke, [50] arises the necessity to perfect the final part of throw using some complex movements usually called *"tactical tools"[51].*
Starting from the two body's positions (a) Seiza and (b) Kneeling, which represents the basic arrival position of Tori body after the drop-down, all tactical tools start with a leg extension in different directions (mainly: up, forward, diagonal) connected with some complementary body movements, like torque, push, body's rotation or flexion, helped by some specific arms movements

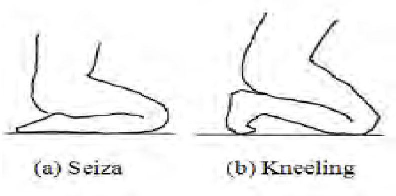


Fig 19 feet positions

Figg.20-23 complementary movements to obtain full point (Ippon)

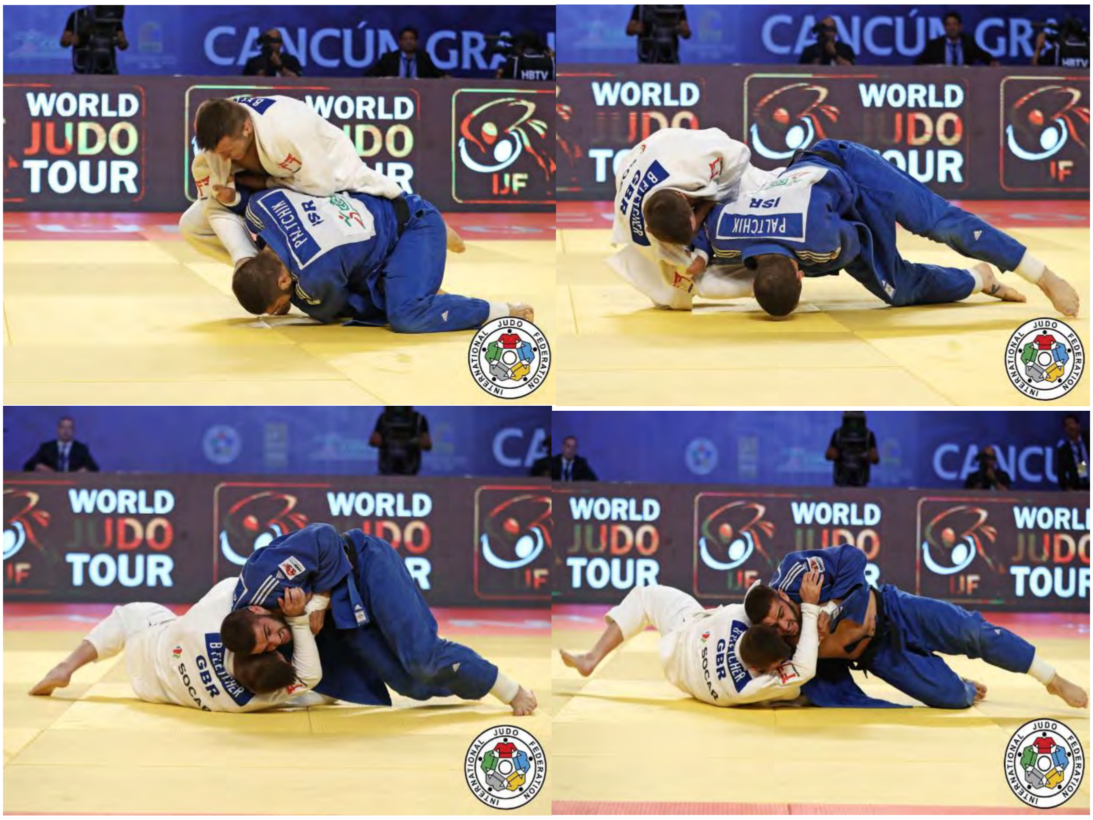


Fig24- 31***different Complementary Tactical Tools applied to perfect the Suwari Seoi final action***

8. Biomechanics and safety of complementary movements

In the fully flexed position, the extensor muscle pulls at less than 7º relative to the tibia. This gives the extensor muscle a mechanical handicap relative to the ground of between 1/150 and 1/260 (it is hard to measure accurately). And the muscle has to produce a very great deal of force in order to produce a quite modest thrust on the ground.
For example, if the at the start of jump in kneeling position with feet pointed, each leg pushes on the ground with a force of about 0.05 N, it means that the muscle must be producing a force of 10-15 N more or less 100 – 200 times the starting push.
If we think to the resistance that must be overcome in a Suwari Seoi techniques: mainly the sum of Tori and Uke body's masses, for example respectively 63 and 65 Kg, then muscles needed to apply a force to move 1255,6 N this means that each leg must push the ground with a force of 627,8 N and produces a force of 62780 N if the static, dynamic situation could be more favourable, but the force production must also be very high.
Even more expensive could result from the same action starting from a seiza position. For these reasons, more often, a different basic variation is applied in real competition. It is a form intermediate between seiza and deep kneeling. Normally Tori takes support not on both legs but differentiated support, more on one leg than on the other. This different weight distribution varies the stability of Tori, which becomes more mobile and can apply complementary tools more easily.
Obviously, the price of this greater freedom of movement is the potential danger due to the choice of one only support base for the dropping down the action, rather than
with two, in which the pressure due to the impact of the fall on the knees can decrease.

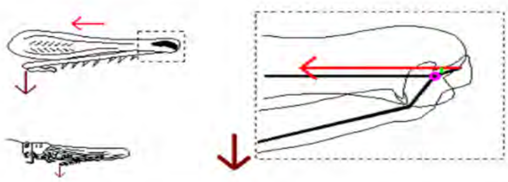


Fig 32 quadriceps action pushing on the mat

Deep Japanese studies have been performed to study the force production to the knee in seiza and deep kneeling, both descending and rising [52, 53,54]

The complex mathematical model is based on the evaluation of moments and external and internal forces on the hip, knee and ankle. But the solution of the system is undetermined because there are three equations with six variables (the six muscles forces) that are unknown.

However, with some assumptions and simplifications, it is possible to decrease the number of unknowns to three and to have the force acting on the knee with good approximation.

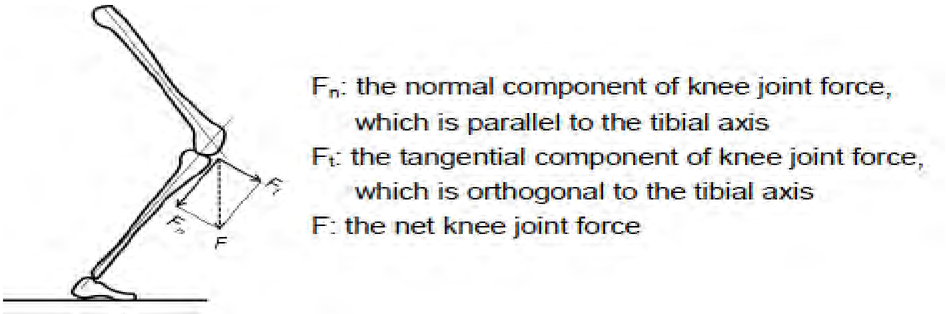
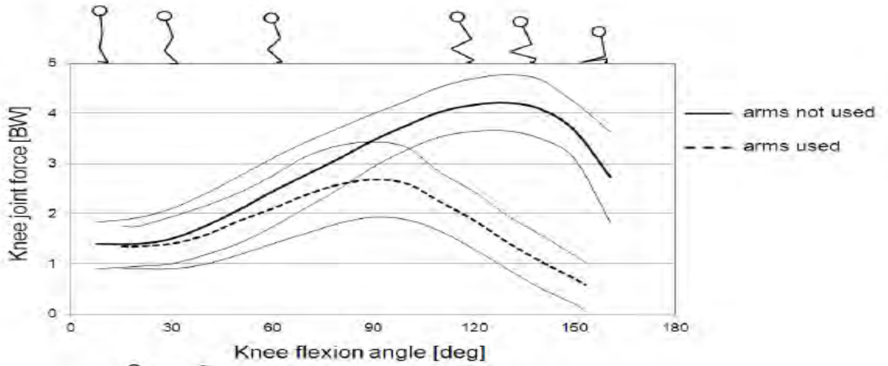


Fig.33 Forces on knee

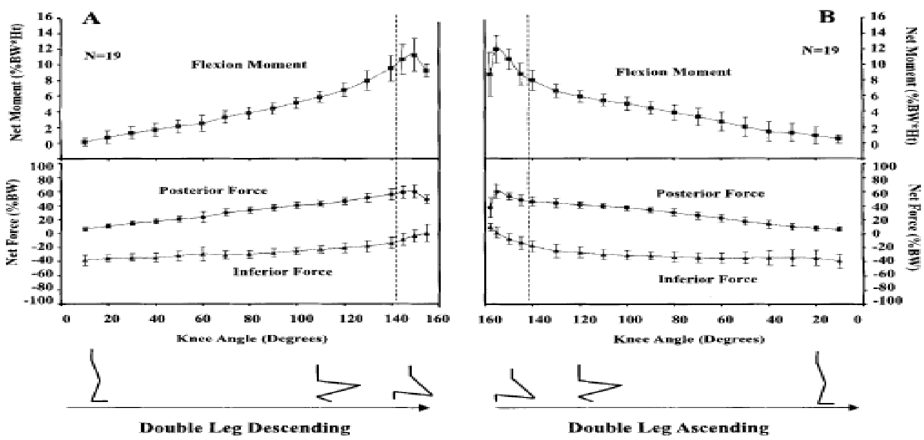
$$F = \sqrt{F_n^{\,2} + F_t^{\,2}}$$
$$F_n = Q' + G + H\cos\theta \qquad \{21\}$$
$$F_t = H\sin\theta$$

$$\Rightarrow F = \sqrt{Q'^2 + G^2 + H^2 + 2Q'G + 2Q'H\cos\theta + 2GH\cos\theta} \qquad \{22\}$$

The experimental results for the Knee joint force evaluated in function of the angle of knee flection are presented in the next Fig



Diag. 4 Knee joint force in rising without and with the help of arms [52]



Diag.5. Knee Joint force and momentum (ascending and descending) [53]

The follow up to refine the throwing action of one of Suwari Seoi family techniques, the complementary movements, called Tactical Tools, can be modelled as a linear combination of different contribution lift up plus elastic force plus torsional force:

$$F_{TT} = (m_1 + m_2) a \frac{t_l}{t_{TT}} - k(L \sin\varphi) \frac{t_f}{t_{TT}} + \tau_{\max} \frac{d^3}{5L} \frac{t_r}{t_{TT}} \quad \{23\}$$

With variable in time contributions, where: m_1 m_2 = body masses of Tori and Uke, k= elastic constant of Tori thigh muscle, $\tau_{\max}$ = Torque produced in the leg, d= Tori thigh muscle diameter L = Tori thigh muscle length, t_{TT}= time of Tactical Tool application, t_i= time: lift, forward, rotation.
This equation let us be able to evaluate the order of magnitude of the effort in the knee in order to verify if the ligament structures of Tori's knees can be possibly put at risk during the execution of these movements.
If we put inside the right physiological values, for a theoretical movement performed in 0,26 s divided into three sub-movements of the same time duration, all this applied to two athletes of the category up to 65 kg, a category that often applies these techniques.
The critical nature of the complementary movements on the safety of the knees is shown through a purely theoretical calculation in order to focus the attention of the teachers on a correct study of this part of the technique. Remembering the previous equation {28} and that the physiological parameters are related to the most used thigh extensor muscles (quadriceps femoris for women, and hamstring group for male) [55]

$$F_{TT} = (m_1 + m_2) a \frac{t_l}{t_{TT}} - k(L \sin\varphi) \frac{t_f}{t_{TT}} + \tau_{\max} \frac{d^3}{5L} \frac{t_r}{t_{TT}}$$

The theoretical evaluation, for a 65 kg against a 62 kg, shows us that for females and males, the relative results are: 1750 N and 1560 N, with a rotational contribution of about 400 N.
Remembering that normal resistance to traction is: for ACL 2000 N, PCL 1500 N and lateral structures around 500 N [56] we, easily understand how delicate the perfect execution of this part is.
The last notation is that, during the competitive application, most of the rotatory efforts applied, in a safe way, are performed by the trunk-hip complex, lightening the task of the knees.

Fig 34-37 Torsional application in complementary movements

9. *The experimental protocol*

Each subject performed two specific trials with three subcases and six performances of the throw. All these trials, for four times, for obvious statistic reasons, to decrease the variance among performances.
This means that each child Tori performed 24 actions, the national athletes, for time and training reasons, only two trials, that is 12 actions. But both for safety reasons and time, Children performed the trials in three days, Athletes in two days.
Each trial was divided into three special performances: one to perform suwari seoi alone, two with uke without throwing him, and three with uke, throwing him to complete the technique.
This diversification is made to study the influence of the ukè body on the speed of falling of Tori's knees in the dynamic equilibrium of the couple.
Thus Tori falls first on his own, then with the holds to uke's judogi and finally by performing the projection of uke's body.
The first trial is with falling down with both feet pointed touching the tatami, then the mechanics of this way of application it is a fall with control, specifically a mechanic paradox (see biomechanics paragraph 6), and the area of percussion is smaller than the other way to touch the Tatami, only the tips of pointed feet and small tibial area, we take time of fall's trajectory, to evaluate the mean speed of fall.
The second trial is the other way to apply Suwari Seoi in competition, jumping with the feet stretched out not touching at all the tatami, in that case, the mechanics of the action is a free fall, and the contact area is larger, long tibial surface projection and back of the feet
The impact surface measurements are based on the dynamic heat conduction between the human body and the surface layer of the tatami and followed by the natural cooling for convection.
Few studies using infrared thermography have been devoted to sports performance diagnostic and to sports pathology diagnostic. No studies have been developed for sport safety and prevention.
It is well known that sports activity induces a complex thermoregulation process where part of the heat is given off by the skin of athletes. As not all the heat produced can be entirely given off, there follows muscular heating resulting in an increase in the skin superficial temperature. In particular, the IRT method will enable, in the long term, to quantify the heat loss.
This research is focalized on the capture of the thermal image of surface body contact left by Tori after the fall to throw by Suwari Seoi and on its geometrical measure, in both cases, feet pointed, and feet stretched.
When Tori body falling touches the tatami, it leaves one thermal track produced by dynamic thermal conduction.
This is not visible. The thermal track disappears very fast due to the cooling by the convention of the surface layer when the body leaves the tatami.
In a formula, the eating of Tatami surface due to conduction between human body contact and Tatami surface is driven by the classical equation:

$Q_{cond} = -k\nabla T$ {24}

The cooling [49] of the Tatami surface is driven by the natural convection in a closed environment

$Q_{conv} = \rho c_p V T$ {25}

Remembering also that the general equation for convection is well-known:

$Q_{conv} = h(T - T_0)$ {26}

It is possible to obtain the differential equation that shows the variation in time of temperature during cooling.

$\frac{dT}{dt} = \left(\frac{h}{\rho c_p \Delta x}\right)(T_0 - T)$ {27} The solution of this differential equation is:

$$T = T_0 + (T_1 - T_0)e^{-\left(\frac{h}{\rho c_p \Delta x}\right)t} \quad \{28\}$$

The evaluation of the inverse of the exponent gives us the order of magnitude of the time of cooling phenomenon, that is, replacing the parameters of the materials, about 45 s.
That is very slow.[57, 58]
The research idea is to capture by a fast and sensible thermal camera this evanishing image of the contact surface, measure it and evaluate from the safety point of view the stress received by the body that is the maximum impact force divided the measure of the evanishing thermal image of the contact surface. [59, 60]
Then the protocol is very simple on a prepared Tatami to see the next figure

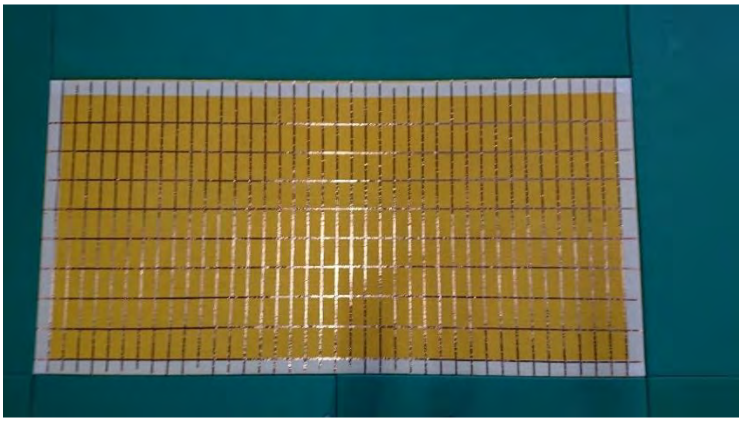


Fig.38 Tatami prepared with a special chopper tape useful for thermal images

Both children and or athletes perform the two trials of throws in the two-ending condition.
Feet pointed, feet stretched.
The layout of the research this time is organized with two tatamis prepared and a cooling system to cool the tatami and speed up the research time.

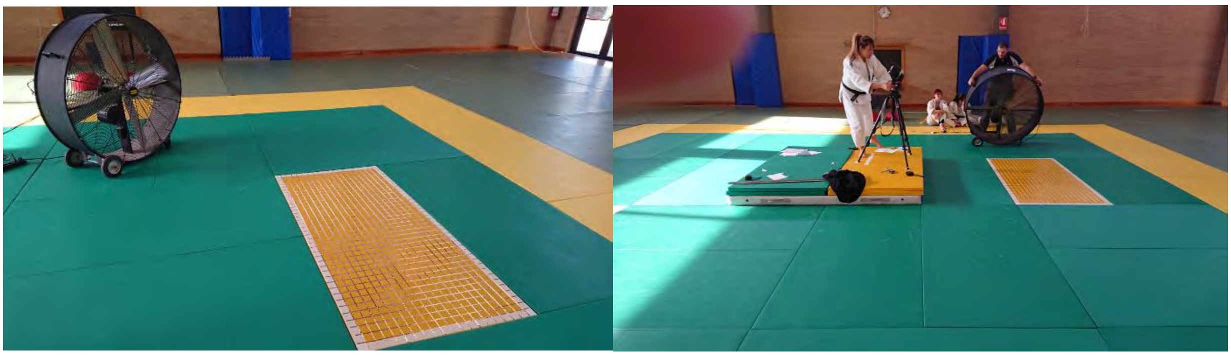


Fig.39-40 Cooling system and tatami

Fig.41 Complete lay-out of Research with two tatami prepared

Two digital chronometers are utilized to evaluate the flight time or the trajectory time of the subjects to have a better evaluation.
Then with the thermal camera are sampled the surface of contact for each trial.
The next figures, there are shown some thermal images of the contact surface relative to the two stiles analyzed. It is easy to see the difference in surface obtained.
By the Japanese Thermal Camera AVIO 600 from Nippon Avionics.
It is equipped with the software InfReC Analyzer 9500.

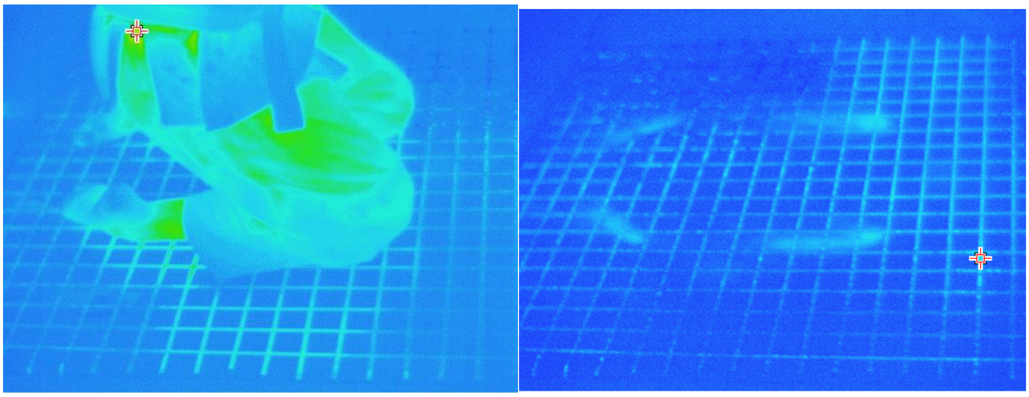


Fig42-43 Children Feet Stretched and Thermal image

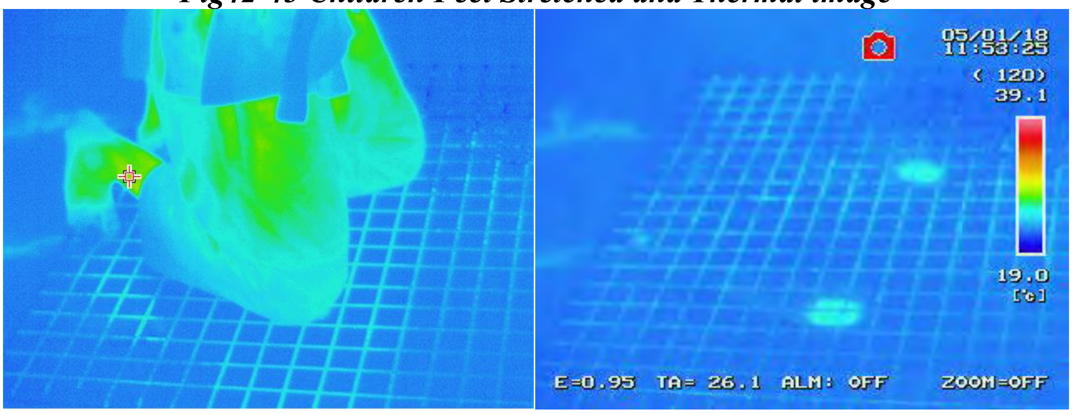


Fig44-45 Children Feet Pointed and Thermal Image

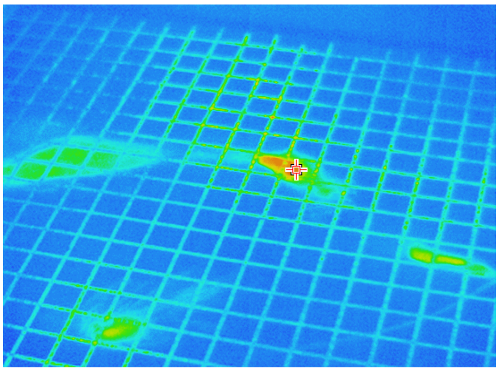


Fig.46 Adult Feet stretched Preponderance from one side

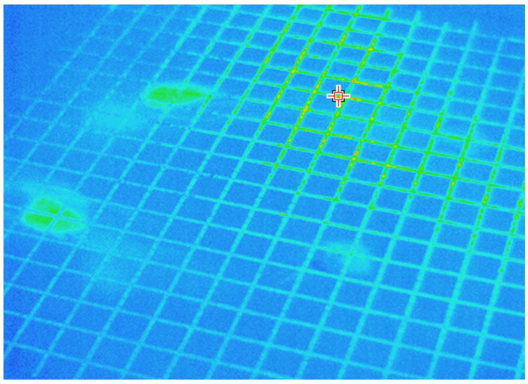


Fig47 Adult knees feet pointed

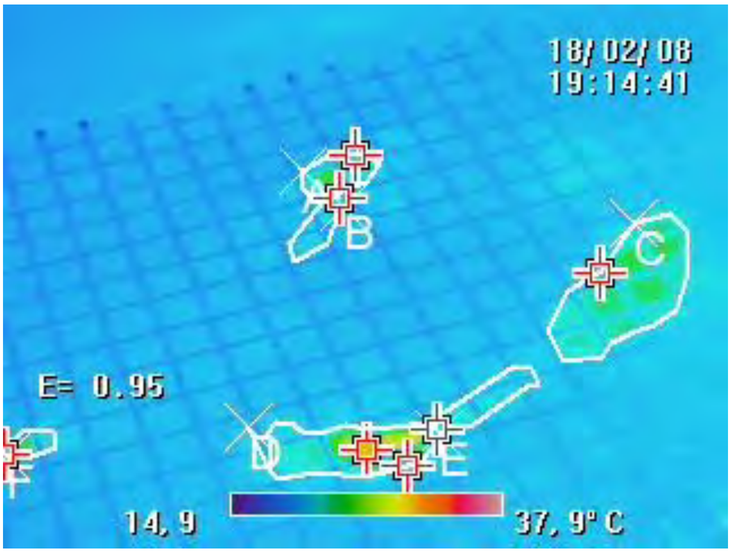


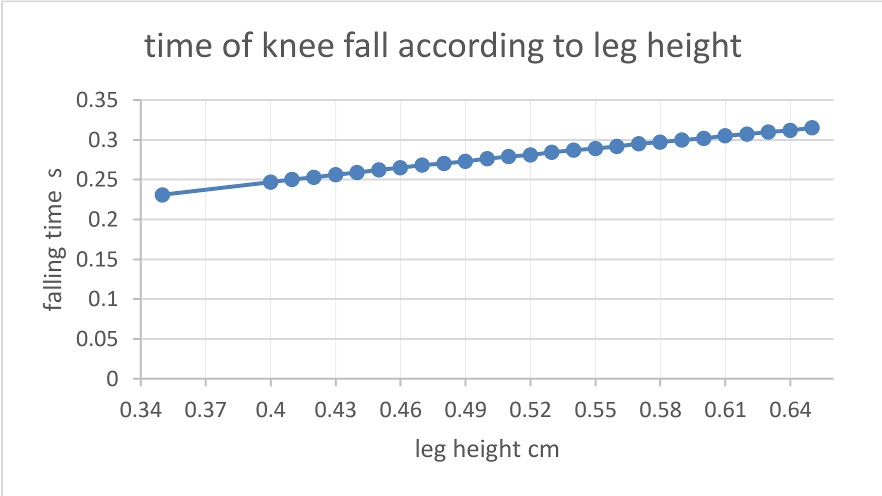
Fig48 measurement of the surface area of Suwari with a right preponderance

YEAR	H BODY	W	H Knee-heel	Costeff	DUBOIS
	m	Kg	cm	m^2	m^2
male					
1999	1,56	55,3	44	1,25643	1,53829
2001	1,77	71	47	1,44596	1,87469
2000	1,70	56,5	49	1,27235	1,65219
2002	1,70	54	50	1,23888	1,62072
2006	1,50	45	42	1,08148	1,36977
Female					
2005	1,65	50	48	1,18285	1,53498
2000	1,60	58,7	45	1,30087	1,60703
2003	1,65	55	43	1,25241	1,59843

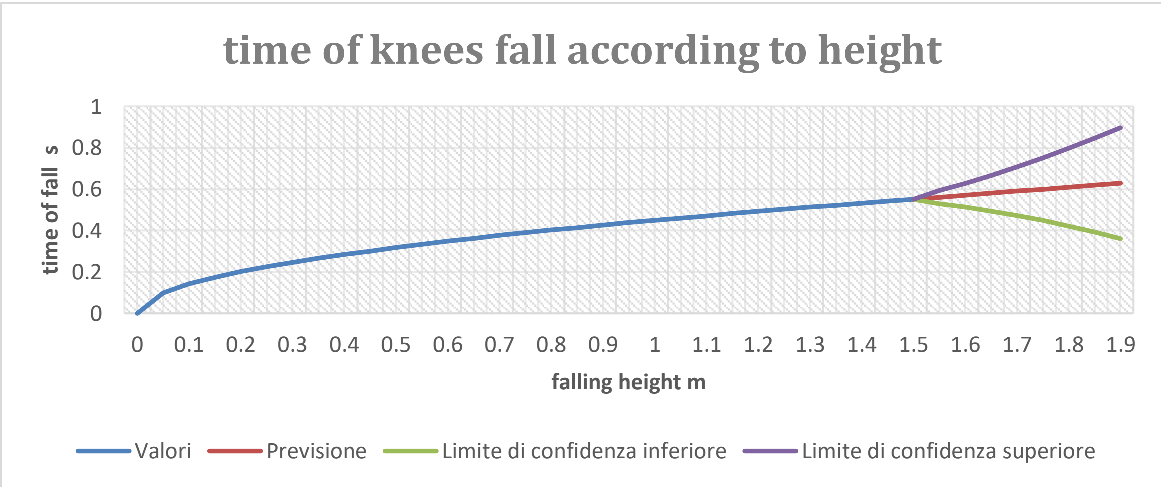
Tab11 Children Data

YEAR	H BODY	W	H Knee-heel	W+ J	DUBOIS	Dubois J
	m	kg	cm	kg	m^2	m^2
male						
1999	1,67	63	49	64,5	1,70827	1,72543
1998	1,69	63,8	51	66,5	1,73233	1,76312
1993	1,72	63,5	50	66,1	1,75107	1,78118
1993	1,69	71,6	48	74	1,81937	1,84505
1989	1,90	103,5	57	106,3	2,31639	2,34282
1991	1,87	104	58	106,7	2,29451	2,31964
1999	1,73	75	50	77	1,88734	1,90857
1998	1,7	70,8	50	73,2	1,81846	1,84442
1996	1,82	93	54	96,4	2,14547	2,17847
1990	1,9	110	55	115	2,37714	2,42248
1997	1,73	71,5	46	73	1,84939	1,86579
1998	1,76	75	51	78,2	1,91101	1,94525
Female						
1998	1,61	50,7	46	53	1,51685	1,54572
1999	1,6	50,1	47	52,8	1,50239	1,53629
1997	1,63	54	47	56,7	1,57206	1,60500
1998	1,49	48,2	47	50,3	1,40352	1,42919
1996	1,64	52	47	53,2	1,55392	1,56906
1995	1,58	59,1	45	61,9	1,59704	1,62876

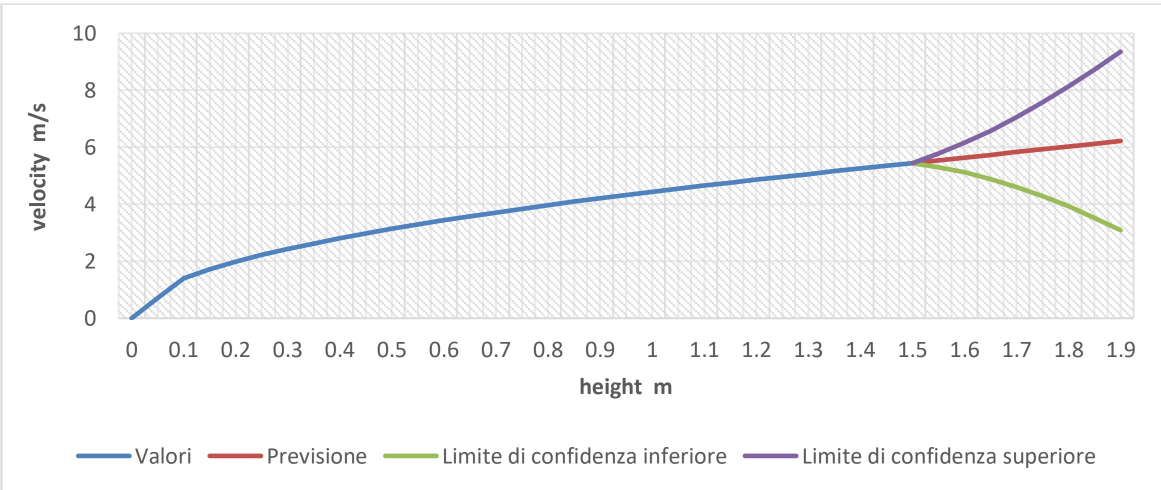
Tab 12 National Team data



Diag.6 Feet Pointed falling time variation according to leg height



Diag. 7 free fall time of fall according to falling height



Diag 8 free fall knees velocity according to height

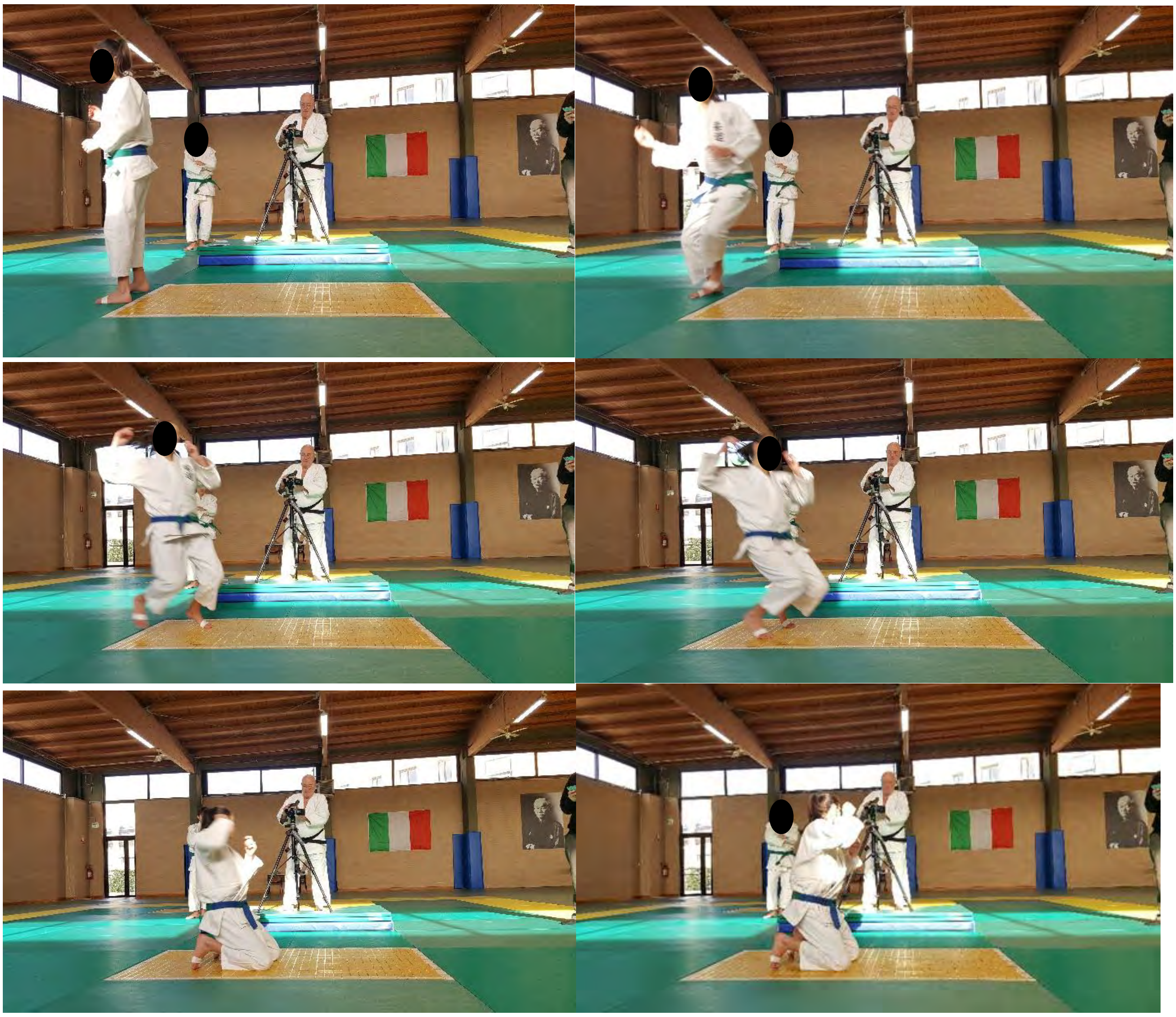


Fig49-58 Experimental Protocols: Suwari Seoi alone and with no throwing action

Fig. 59-64 Experimental Protocol: Suwari Seoi with throwing action

Fig 65-66 Thermal capture of athlete

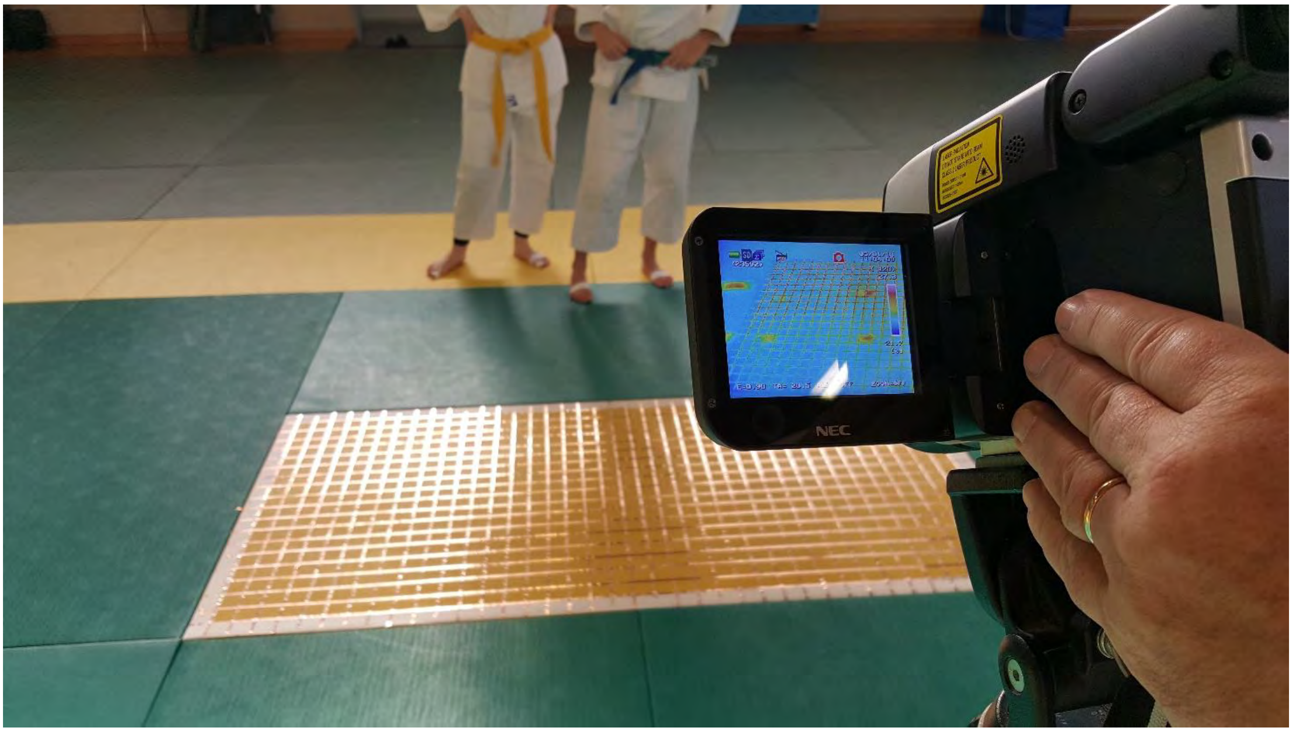


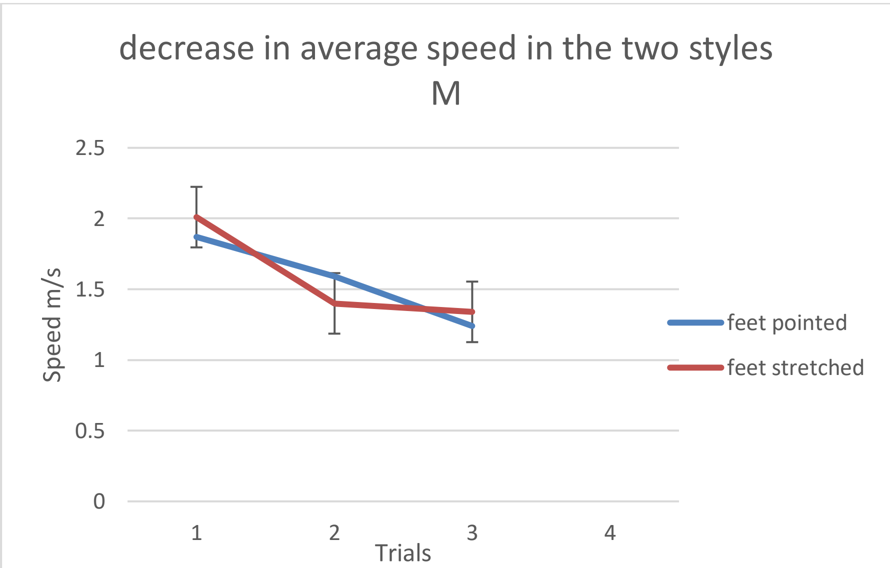
Fig 67-68 thermal capture of contact knees image

10. The experimental results

The in-depth work carried out on the techniques: analysis of 437 thermal films (223 of the children and 214 of the national Athletes), each of which averaged about 60 frames allowed to evaluate the average of the contact surfaces between the four tests performed for the children and the two performed for adults both in the case of execution with pointed feet and in the case with stretched feet.
The average contact surfaces obtained have been divided for the overall body surfaces, thus obtaining the surface contact percentage for each style. These percentages were compared between children and adults in order to obtain reference information on the greater or lesser danger of the style of the technique as a function of the age of Tori.
The average time of fall or flight (two measures) for each style made it possible to calculate the experimental fall velocity of Tori's knees.
This experimental speed was compared to the theoretical one, measured by the equations of the biomechanical model.
The biomechanical model made it possible also to calculate the impact force in the worst conditions (safety analysis), which resulted in the worst pressure, which weighs on Tori's knees for each style, and the ground reaction force of the mat that is received, assessing its dangerousness.
All measures are compared among children and adults to single out any difference.
This comparison in terms of safety is based on the SBA (Surface Body Area) calculation.
Normally for children, it is utilized the Costeff formula [99] more accurate than the well-known formula of Du Bois and Du Bois [pp] that overestimate the body surface for children.
However, we use the Du Bois and Du Bois formula applied for children, only in the case of the comparison with adults, because in this way, the measures of the overestimate surface increases (for safety) the pressure on the children knees and give us a more safe way to compare.
Some interesting safety evaluations are singled out from the specific experimental protocol.
At first, children show a constant decrement of the falling velocity in both two approaches: feet pointed, and feet stretched, starting from the exercise alone, ending with the projection exercise.
This behaviour is very important from the safety point of view.
It is easily explained, both: by the poor technical ability and by the dynamical equilibrium between Tori and Uke. In other words, the presence of the Uke Body slows down the knee speed of Tori, who is relented by the action of moving the body mass of Uke.
In this way, the final pressure will be less dangerous for the children knees.
In the following tables and diagrams, there are shown two examples of this decrease in speed averaged on five trials.
Equivalent results were found for 95% of the other children; the last 5% was almost equal to knees falling speed.

Average knees' speed in the trials of the two styles of suwari seoi, same boy M m/s		
Tori alone	***With Uke no throwing***	***Throwing Uke***
1,88	***1,38***	***1,23***
1,46	***1,56***	***1,34***
2,13	***1,56***	***1,42***
1,62	***1,95***	***1,17***
2,04	***1,04***	***1,27***
1,95	***1,51***	***1,23***
2,23	***1,42***	***1,51***
1,88	***1,62***	***1,17***
1,77	***1,61***	***1,29***
2.02	***1,39***	***1,29***

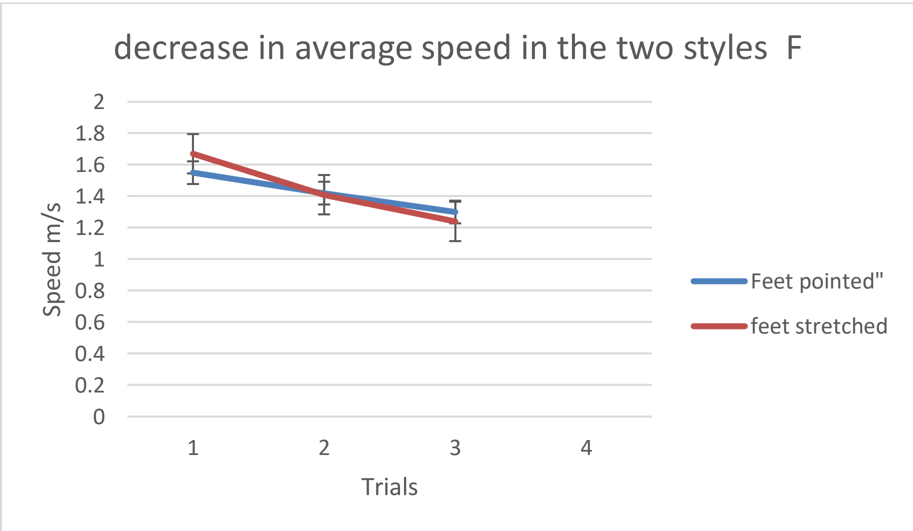
Tab13 average knees' falling speed (white Feet Pointed, Blue Feet stretched) Male



Diag. 9 Example of Children average speed decreasing M

Average knees' speed in the trials of the two styles of suwari seoi, same girl F m/s		
Tori alone	***With Uke no throwing***	***Throwing Uke***
1,28	***1,44***	***1,48***
1,58	***1,4***	***1,16***
1,75	***1,32***	***1,25***
1,96	***1,44***	***1,4***
1,48	***1,48***	***1,36***
1,36	***1,36***	***0,94***
1,63	***1,48***	***1,13***
1,88	***1,48***	***1,4***
1,64	***1,4***	***1,32***
1,58	***1,39***	***1,29***

Tab 14 average knees' falling speed (white Feet Pointed, Pink Feet stretched) Female



Diag,10 Example of Children average speed decreasing F

A more variable trend is found in the adults of the Italian National Team, that possess a greater technical ability and more accentuated automatisms.
This means that the skill ability is, at a high level, the discriminating factor between athlete and athlete.
Despite the small numerical sample, we give, in an indicative way, the percentage trends found between the athletes of the national team divided as males and females.
In fact, among males, about 63% has shown the expected decrease, while 7% more or less constant speed, and a 30% increase in speed in correspondence with the acquired competitive technique. Among females, 61% showed a decrease, 30% showed an increase and 9% more or less constant speed.

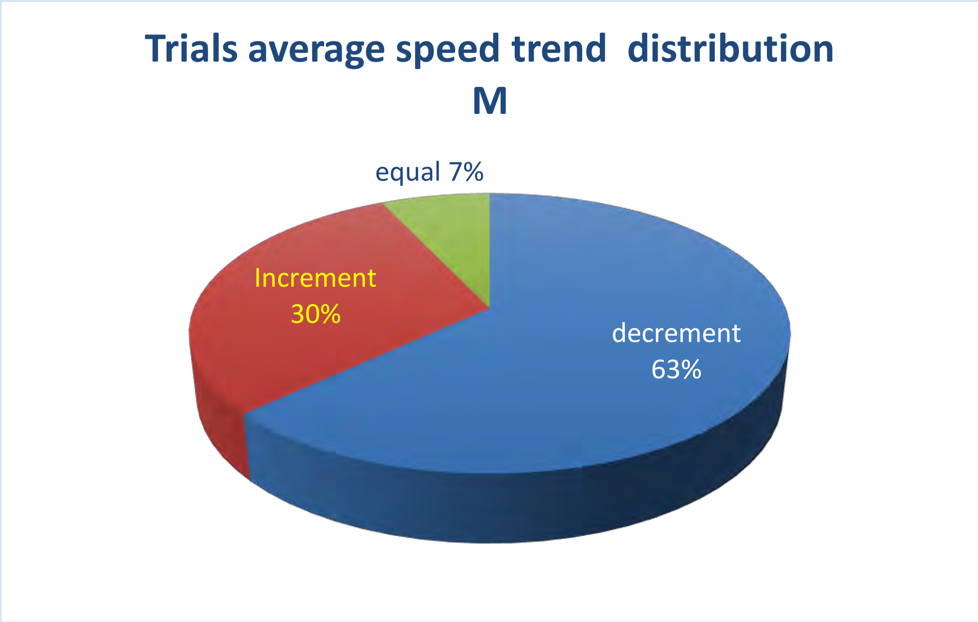


Fig69 Indicative average speed trend, National Team (Male)

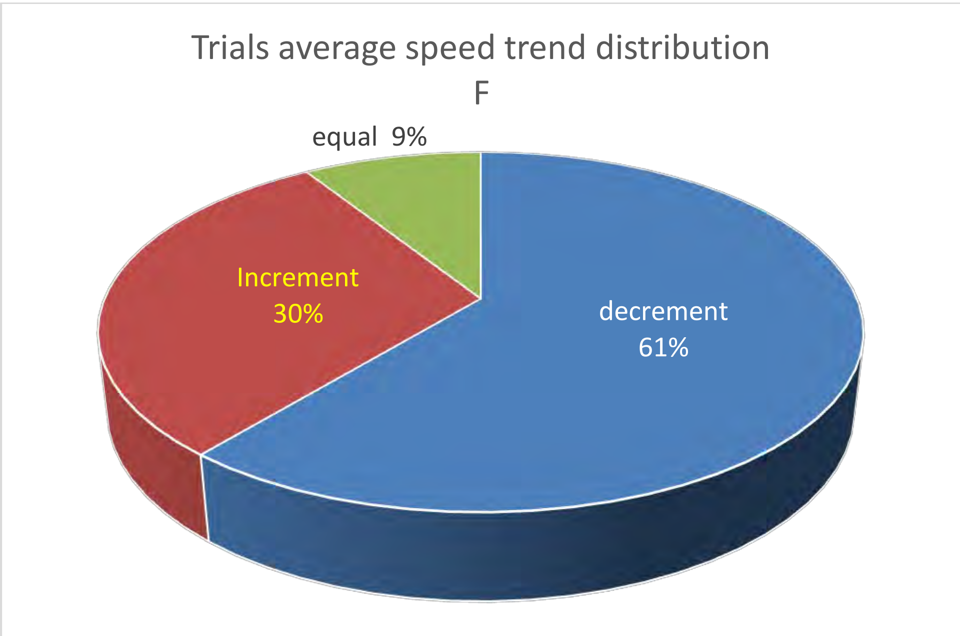
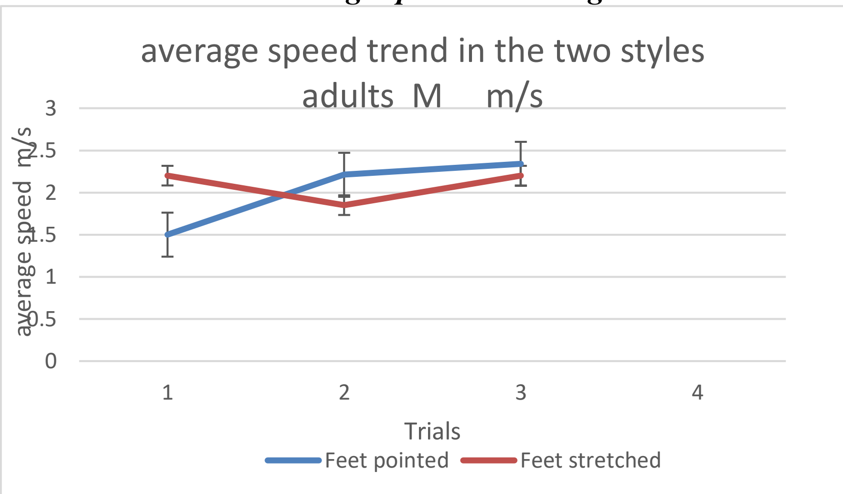


Fig 70 Indicative average speed trend, National Team (Female)

The connection between speed and skill of the athletes was also able to highlight, in which the fastest ever was a former world championship winner.

average speed in the trials of the two styles of suwari seoi, same Athlete M m/s		
Tori alone	***With Uke no throwing***	***Throwing Uke***
1,9	***2,31***	***2,31***
2,5	***1,3***	***2,04***
1,13	***2,12***	***2,37***
1,9	***2,31***	***2,31***

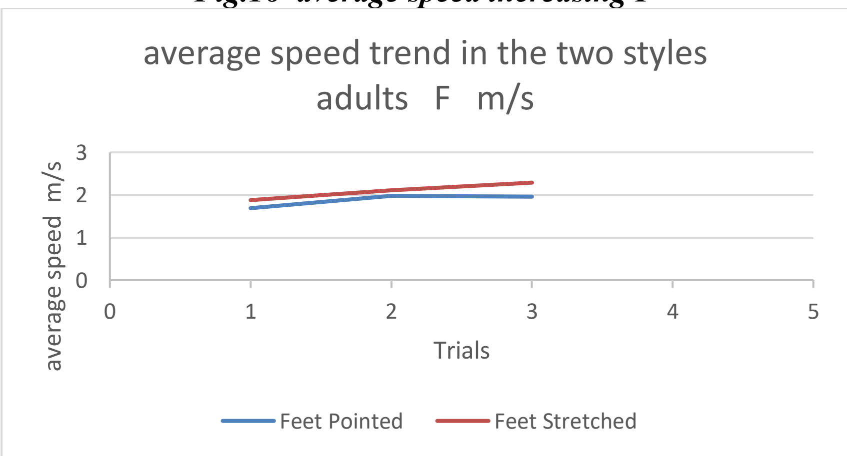
Tab 15 average speed increasing M



Diag. 11 speed trend

average speed in the trials of the two styles of suwari seoi, same girl F m/s		
Tori alone	***With Uke no throwing***	***Throwing Uke***
1,64	***2,13***	***1,95***
1,88	***2***	***2,24***
1,62	***1,84***	***1,95***
1,88	***2,23***	***2,35***

Fig.16 average speed increasing F



Diag.12 speed trend

The safety aspect of the throw for children and even for athletes, first of all, is guaranteed by the experimental data that for the majority of both boys and athletes, the average fall speed of the knees decreases when uke is projected. The next step will be to measure the average standard judoka child [63], the stress that is produced at the knees in the two styles at impact. [64]. In the end, we evaluate the AIS (***Abbreviated Injury Scale***) for the determined compression to see if there is danger in the application of the Suwari Seoi Family.

$$AIS = -3{,}78 + 19{,}56C$$

$$C = \Psi / E = F/A$$

The Compression factor is evaluated by the stress received divided by the Young Modulus of Tatami E= 0,44 GPa

In safety terms, considering the maximum available values of forces in the two cases, feet pointed and feet stretched, that is Respectively 3 BW and 7BW. We can evaluate the results in light of AIS,

	CHILDREN		ADULTS	
	MALES	FEMALES	MALES	FEMALES
MEAN S FEET POINTED	0,014 m^2	0,012 m^2	0,0167 m^2	0,0132 m^2
MEAN S FEET STRETCHED	0,022 m^2	0,017 m^2	0,047 m^2	0,029 m^2
BSA MEAN DUBOIS	1,5787 m^2	1,614 m^2	1,9456 m^2	1,5242 m^2
Category Es. A	1,36977			
Category Es. B	1,53498			
cadets	1,87469	1,59843		
juniors	1,53829	1,62961	1,811481	1,47425
seniors			2,07980	1,57434
MEAN WEIGHT	54,45 Kg	55,5 Kg	78,8 Kg	52,35 Kg
Category Es. A	45			
Category Es. B	54			
cadets	63,5	52,5		
juniors	55,3	58,6	69,52	49,6
seniors			88,08	55
MEAN WEIGHT WITH JUDOJI	55,7 Kg	56,5 Kg	81,3 Kg	54,45 Kg
Category Es. A	46			
Category Es. B	56,1			
cadets	64,6	53,4		
juniors	56,4	58,6	71,8	52
seniors			90.8	56,9
MEAN YEARS all subjects	2001	2001	1995	1997

Tab17 Comparison between children and Adult mean data

children	*Male f.p.s (m²)*	*Male f.s.s (m²)*	*Max force Fp 3BW (N)*	*Max force Fs 7BW (N)*	*Mass Kg*	*Stress Fp MPa*	*Stress Fs MPa*	*Compression Adimensional 10^{-3}*	
category Es. A	*0,010*	*0,02*	*1324,35*	*3090,15*	*45*	*0,13*	*0,15*	*0,29*	*0,34*
category Es. B	*0,014*	*0,022*	*1471,51*	*3433,5*	*50*	*0,10*	*0,15*	*0,22*	*0,34*
cadets	*0,017*	*0,024*	*2089,53*	*4875,57*	*71*	*0,12*	*0,19*	*0,27*	*0,43*
juniors	*0,016*	*0,021*	*1656,9*	*3866,12*	*56,3*	*0.1*	*0,18*	*0,22*	*0,4*
Medium standard Children	*0,014*	*0,022*	*1618,65*	*3776,85*	*55*	*0,11*	*0,17*	*0,25*	*0,38*
Athletes	*Male f.p.s (m²)*	*Male f.s.s (m²)*	*Max force Fp 3BW (N)*	*Max force Fs 7BW (N)*	*Mass Kg*	*Stress Fp MPa*	*Stress Fs MPa*	*Compression Adimensional 10^{-3}*	
juniors	*0,0158*	*0,04*	*2113,07*	*4930,5*	*71,8*	*0,13*	*0,12*	*0,29*	*0,27*
seniors	*0,0174*	*0,054*	*2672,2*	*6235,2*	*90,8*	*0,15*	*0,11*	*0,34*	*0,25*
Medium Standard Athletes	*0,0167*	*0,047*	*2392,6*	*5582,8*	*81,3*	*0,14*	*0,12*	*0,31*	*0,26*

Tab 18 Male Children -Athletes results comparison
fps =feet pointed surface; fss = feet stretched surface
Fp= Feet Pointed; Fs = Feet stretched

children	*Female f.p.s (m²)*	*Female f.s.s (m²)*	*Max force Fp 3BW (N)*	*Max force Fs 7BW (N)*	*Mass Kg*	*Stress Fp MPa*	*Stress Fs MPa*	*Compression Adimensional 10^{-3}*	
cadets	*0,011*	*0,014*	*1545*	*3605,1*	*52,5*	*0,14*	*0,25*	*0,31*	*0,57*
juniors	*0,013*	*0,020*	*1724,5*	*4024*	*58,6*	*0.13*	*0,20*	*0,29*	*0,44*
Medium standard Child	*0,012*	*0,017*	*1633,365*	*3811,185*	*55,5*	*0,135*	*0,22*	*0,30*	*0,49*
Athletes	*Female f.p.s (m²)*	*Female f.s.s (m²)*	*Max force Fp 3BW (N)*	*Max force Fs 7BW (N)*	*Mass Kg*	*Stress Fp MPa*	*Stress Fs MPa*	*Compression Adimensional 10^{-3}*	
juniors	*0,0122*	*0,023*	*1530,3*	*3570,8*	*52*	*0,12*	*0,14*	*0,27*	*0,34*
seniors	*0,0142*	*0,035*	*1674,5*	*3907,3*	*56,9*	*0,15*	*0,11*	*0,26*	*0,24*
Medium Standard Athlete	*0,0132*	*0,029*	*1602,46*	*3739,081*	*54,45*	*0,12*	*0,13*	*0,27*	*0,29*

Tab 19 Female Children -Athletes results comparison
fps =feet pointed surface; fss = feet stretched surface
Fp= Feet Pointed; Fs = Feet stretched

The AIS (0) values both for Children and Athletes are always negative. This means Extremely Lightweight Trauma.
Then there are no silent or evident trauma but only light contusion.
From that, we can evaluate that both applications of Suwari Seoi Family: (Feet Pointed and Feet Stretched), if right applied, are safe for all Judokas, from Children in Dojo to High Level Athletes in Competition in Term of sudden trauma.
Some doubts remain about the possible danger of the complementary movements carried out to perfect the result of the technique in competition, as previously indicated.

11. Discussion

The experimental part of this research, applied to the safety of the Suwari Seoi Family against the immediate trauma, was performed at the Italian Olympic Center “Matteo Pellicone” in Rome with eight children ranging from Es. Category A till to junior: 5 Male and 3 Female, and 18 Athletes are ranging from Junior to Senior: 12 Male and 6 Female.
There are evaluated two forms of Suwari Throws, one with feet pointed in which Tori is in a deep kneeling position, and another one in which Tori is in “seiza” position.
The experimental protocol has described the experiment and the lag of time used for safety (3 days for Children, two days for Athletes)
The first interesting result was that for children, the speed of knees dropping down decreased from alone till to throwing Uke.
This means in terms of safety that the presence of a body to throws slows down the speed of fall, making the knees’ impact on the Tatami less risky for the knee joint.
For the Adult, both males and females show the same interesting behaviour. 60% of subjects slowed down, 30% accelerated, and 10% showed no increase or decrease in speed.
This almost standard behaviour could be connected to the personal skill of athletes in perform this technique.
The Specific calculation of the compression of the tatami during the trials both for children and Athletes on IJF licensed Tatami in PU range between 0,88 mm to 2,28mm
We depend obviously on the mass and velocity involved.
It is well known in the biomechanics and orthopaedic world that the knee structure can absorb part of stress moving forward-backwards of about 5-10 mm [64].
Absurdly even in the case in which we no consider the decreasing stress received by knees (more or less15- 20% less of the stress given to the Tatami on the basis of the collision laws) but the total stress received by tatami, taking into account the elastic properties of the knee, anyway the final results, assure that if the technique is performed with no mistakes, on an IJF licensed Tatami, the impact received will be of negligible effect with respect to the target organ the Knee: the Posterior Cruciate Ligament (PCL).

12. Conclusions

Even we consider the worst stress on the knees or knees and tibia ranging: from 0,11 MPa till to 0,22 MPa. For a 12 cm thick knee in the sagittal plane, the relative strain, considering the young modulus of tibia bone 18,1 GPa [67], gives a very small compression which provides. As a result, negligible stress on the posterior cruciate ligament, which is able to resist at a force of 1500 N [68]. The final result, despite this small number of samples, assures that *if the technique is performed with no mistakes, on an IJF licensed Tatami, the impact received will be of negligible effect with respect, to sudden trauma, to the target ligament of the Knee: the Posterior Cruciate Ligament (PCL).*
A German paper on 260 athletes at a national level that deals with traumas related to techniques including those of the knee [15] shows that for Seoi, our target structure, PCL is connected to 0.05%, whereas ACL and Patella to 0.15%, MCL and LCL to 0.10%, then because the others knee’s target structures are much more connected with Seoi than PCL, it is possible to state that: *the deduction derived from the theoretical analysis carried out, indicating that, probably, most of the damage, that occur to the different knee ligaments, are almost certainly produced, during the complementary movements, made to refine the result in competition, it’s right.*
Although surely related both: too low number of samples and to safety assumption made on the impact forces, the experimental results on standard children show that slightly larger stress is associated with the style of feet stretched towards pointed feet, males (0.17 vs 0.11) MPa; females (0.22 vs 0.13) MPa.
In male Standard Adult Athletes, this tendency seems to be slightly reversed (0.12 vs 0.14) MPa, while in female Standard Adult Athletes, it appears to be conserved (0.13 vs 0.12) MPa.

However, it is correct to say that for both standard adult athletes, it seems that there are no substantial differences regarding their safety between the two performance styles analyzed.
As already underlined in this paper, we start with this new methodology, applied for the first time on Tori safety. Indeed, the result of the proven methodology in use is limited by the small number of samples analyzed. Of course, more data will be collected. The best estimation will be made to evaluate the standard athletes**,** and consequently, to obtain more precise evaluations about the safety of the technique.
In light of the above, this work must be considered substantially, as the right master working track to conduct more and even more precise researches on Tori's safety in Suwari Seoi execution

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