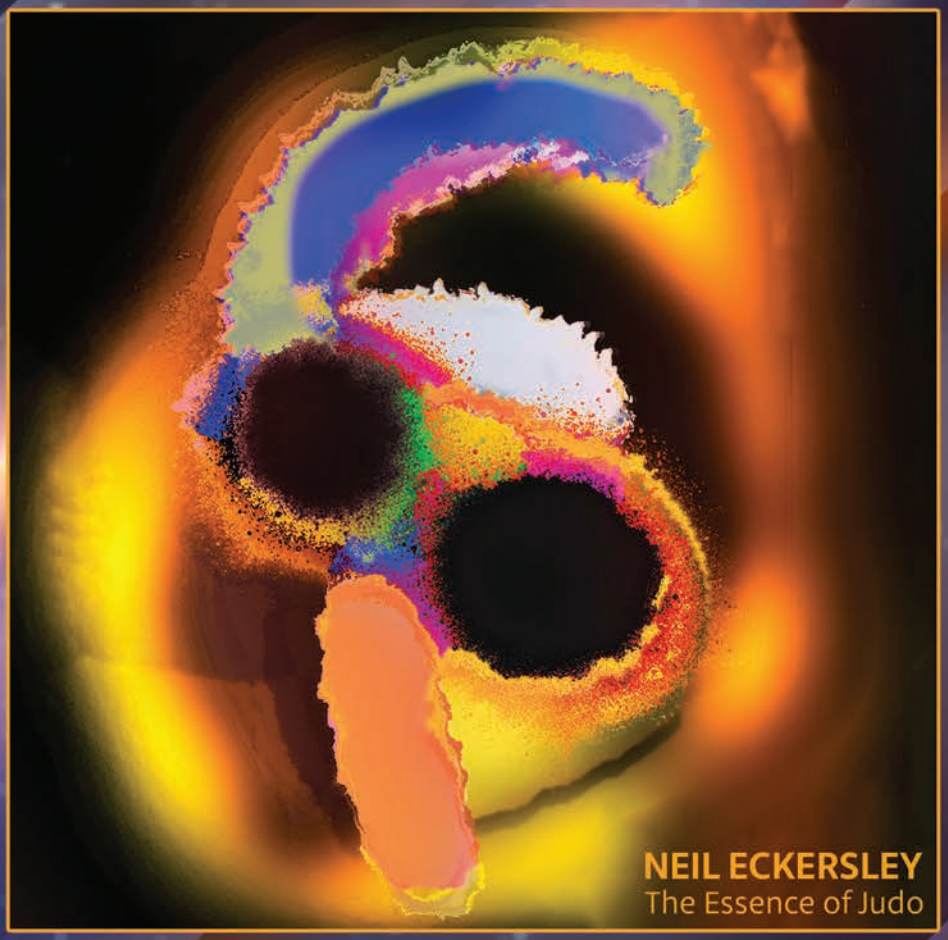
IJF ACADEMY

THE ARTS AND SCIENCES OF JUDO



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AIMS AND SCOPE: “The Arts and Sciences of Judo” (ASJ) is a newly established international interdisciplinary journal of the IJF Academy and the International Judo Federation (IJF). It is a research journal that welcomes submissions related to all aspects of judo – kinesiology, psychology, economy, marketing and management, history, arts, technology, communication sciences and all other related fields. It is an international platform for presentation of innovative research and scholarly works and for expressing opinions and views on the development of judo, giving a significant contribution to an understanding of the theory and practice of judo. In that way “The Arts and Sciences of Judo” serves as a reference source for education, but it also offers possibilities for exchange of ideas and keeping up with the latest developments in judo. ASJ publishes academic papers (original scientific papers, preliminary communications, and review papers) and research notes, professional papers and critical reviews on relevant topics. All submitted manuscripts are subject to initial appraisal by the Editor, and, if found suitable for further consideration, to peer review by at least two anonymous expert reviewers.

PUBLICATION POLICY: The IJF Academy and the International Judo Federation (IJF) support open access policy that enables everyone to access the knowledge on judo and all its aspects through published research papers and other contributions. As costs of publishing are covered by the publisher (IJF Academy and IJF), ASJ does not charge any fees to authors for submission or publishing their papers. Full texts is available free of charge on IJF website and IJF Academy website. The ASJ editorial policy strongly encourages research integrity, respect of human rights, respect of personal data and supports ethics in conducting research and academic communication. The ASJ is committed to peer-review integrity and upholding the highest standards of review. .

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Foreword

Marius VIZER
IJF President

We often say that judo is more than a sport. It is also an artful way to live, just as much as a scientific approach to life.

Since judo was created by Jigoro Kano Shihan in 1882 in Japan, our sport has been evolving to constantly adapt to the changes of our society, while keeping rooted deep in its genome, values that make it more modern today than ever.

This first edition of 'The Arts and Sciences of Judo' is a perfect illustration of this double anchoring in the tradition of an ancestral art and in contemporary modernity. Thanks to the meticulous and patient work of Sanda Čorak, Editor-in-Chief, under the umbrella of the IJF Scientific Committee and IJF Academy, this journal has come to life. I would like to thank her and all those who contributed to this achievement.

I would also like to congratulate all the researchers, whose scientific work inside and outside the dojo contributes to giving meaning to our quest for a better society. I am sure that reading this first issue will provide many answers to some of your questions and that it will allow you to raise new ones, which will, without a doubt, open up new fields of investigation.

Being able to offer a documented approach to judo is essential, as the sectors covered by the development of our sport are vast. We can be proud of the work we have in hand and proud of the values that judo conveys.

Sanda Čorak
Editor-in-Chief

As a former judoka, involved in judo for many years and working as a scientific researcher, I have always been fascinated by Jigoro Kano. He founded judo as a modern Olympic sport, at the end of the 19th century, through a detailed process of research around traditional combat forms. From a very young age he decided to use and study all available sources of knowledge and that process led him to create an innovative sport system and philosophy of judo.

In more recent times, researchers in judo, as academic scholars, have skills, knowledge and opportunities to conduct research in different aspects of judo, aiming to contribute to improvement in all fields. Their work, in the form of scholarly works (scientific papers) are published in numerous kinesiology journals but not often available to many judoka.

My intention when establishing the 'Arts and Sciences of Judo' (ASJ) is to bring together research from the judo community and collate their results and suggested practical implications. The aim of the ASJ journal is to become an important source of information for all those that would like to learn more about judo: judo students at the kinesiology faculties, those attending IJF Academy courses and seminars or simply to all judo fans.

As it is multidisciplinary, the journal can initiate judo research networks, conferences and project partnerships in specific research fields. In the contemporary, competitive world of sports, judo has to make an effort to build upon its traditional values and pave ways to always progress and strive for excellence. The ASJ is offering plenty of possibilities for everyone to express and share opinion and make the judo world even more prominent within the wider sporting community.

I would like to take the opportunity to thank the IJF President, Mr. Vizer, for always supporting my work, IJF Academy head, Mr. Galea, who recognised the values of the journal and many colleagues at the Editorial board who helped me and advised me in the process of establishing the journal. My gratitude also goes to Ms. Grace Goulding and Ms. Jo Crowley for prooreading all the articles and Mr. Messner who gave the final touch in designing the journal layout as well as Mr. Eckersley whose art work is just perfect for presenting the complexity and beauty of judo.

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Gender and Perspectives on Training and Techniques: Analyses of the System of Attacks in Standing up Position

By Michel Calmet[1*], Emanuela Pierantozzi[2]

Abstract: *The concept of a system of attacks explains how a judoka throws opponents during a contest; it integrates favorite throws, organized with specific kumi-kata (gripping) and can evolve throughout practice. Criteria defining it are: type of kumi-kata, time of triggered attack, name of throw, direction of attack, number of points of contact with the ground during the throw, scored attack. Calculated criteria are: sum of contest duration, rate of attacks, use of kumi-kata, linked attacks, efficient sectors.*

28 high-level judoka, from 9 countries, who did at least 4 contests in the same high-level competition were analyzed. Results show no difference between women and men concerning: number of contests, sum of contest duration, number of kumi-kata used, total number of attacks, number of directions of attacks, number of attacks with either one foot, two feet or back-side in contact with the mat, rate of attacks for 30s, percentage of linked attacks, percentage of attacks with kumi-kata corresponding to the direction of attack, percentage of attacks with kumi-kata opposed to the direction of attack, percentage of attacks with mixed kumi-kata, number of attacks scored. There was a difference between women and men concerning efficient sectors of attacks (2.2±1.1 vs 2.8±0.9 respectively, p=0.004).

ANOVA confirms sample cohesion; shows champions' organization and highlights different profiles.

Rules suggest that number of contests, sum of contest duration and total number of attacks can be identical for women and men respectively. However, number of kumi-katas, number of directions of attacks, rate of attacks, use of kumi-kata and efficiency, show that women and men practice judo with the same efficiency.

Key words: *systems modeling, system of attacks, gender, gender equality of results, judo*

During a judo contest (in training or competition), the major uncertainty resides in the actions and behaviors of the opponent. These contests take place standing up and can be continued to the ground in a kind of continuum: *tachi-waza* (standing up), transition, *ne-waza* (groundwork). In *tachi-waza*, the control of several throws in different directions is necessary for this uncertainty to allow the success of these throws. Authors Baudot, Urvoy and Pelletier (1975) defined an important skill that a judoka must acquire in the capability to execute an attack, with several others being complementary. In other words, a "judoka has to be able to move from the right towards the left, from forward to backward or conversely." When it happens, it is a sign that the judoka has begun to assimilate principles of judo and that the judoka is really progressing. By adding, "When the judoka can move [while gripping the opponent's *judo-gi* with the same *kumi-kata* (gripping)]…" we almost get the definition of a system of attacks in *tachi-waza* in judo. These recommendations appear in various publications of the French judo Federation (FFJ, 1983, 1985, 1989). Roux (2019) wrote, "The system of attacks is an individual construction that allows the judoka to appropriate [...] a full panoply of techniques [...] allowing him to take the initiative against his opponent, whatever his attitude." Scientific papers deal with this subject (Calmet, Ahmaidi 2004; Calmet, Trezel, Ahmaidi 2006; Calmet, Miarka, Franchini 2010a).

In this paper we analyzed the system of attack in *tachi-waza* of 28 high-level judoka. The aims were: [1] To improve the previous investigations giving results on the rate of use concerning throws, gender, level. [2] Modeling a high-level judoka's system of attacks. [3] To test two hypotheses: there is no gender difference in the system of attacks and the system of attacks does not depend on the competition rules currently. Although the purpose of this study was to specifically analyses judoka in *tachi-waza*, we will suggest a few lines of work regarding the transition into *ne-waza*.

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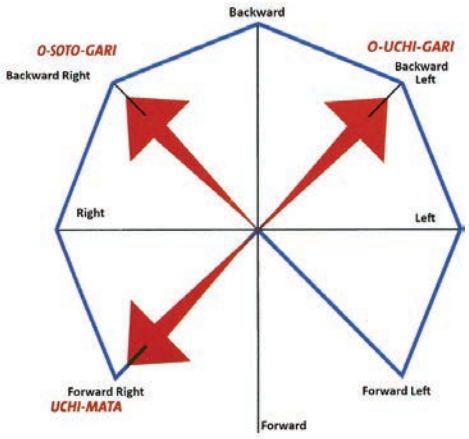
Definition of System of Attacks in *Tachi-waza*

A system of attack is composed of a least one *kumi-kata* that can allow an opponent to be thrown in different directions, using different judo throwing techniques.

Table 1: Riner's *kumi-kata* and throws at the 2013 Rio World Championships

At the 2013 Rio World Championships, Teddy Riner attacked and scored in three directions with the same right-high *kumi-kata* (Calmet, Franchini, 2013). The attacks were: *o soto gari* (backward right) *o uchi gari* (backward left) *uchi mata* (forward right)	 **Figure 01 : Rinner's directions of attacks**

The scientific papers cited above have shown that a high-level athlete uses several *kumi-kata* (a preferred one and two or more that are complementary), allowing 5 to 6 directions of attack, using different throwing techniques. The directions of attack are the eight angular sectors of the rose of *kuzushi* (cf. Fig. 01): backward, backward left, left, forward left, forward, forward right, right, backward right (i.e. 8 directions of *kuzushi*). The *kuzushi* (Kodokan, 2018) is one of the three parts of the throw: *kuzushi* = unbalancing *uke*, *tsukuri* = how *tori* places, positions his/her body, *kake* = execution of the throw.

Sample Studied

The sample consists of 28 high-level judoka. 10 female (F) and 18 male (M) were analyzed. Distribution of these 28 judoka regarding gender, weight categories, years of competition, countries and number of contests were analyzed (Table 2 and Table 3).

Table 2: Distribution of the 28 judoka regarding the weight categories

Categories	Women		Men	
Extra-lightweight	-48kg	0	-60kg	3
Half-lightweight	-52kg	1	-66kg	1
Lightweight	-57kg	2	-73kg	2
Half-middleweight	-63kg	5	-81kg	4
Middleweight	-70kg	2	-90kg	3
Half-heavyweight	-78kg	0	-100kg	2
Heavyweight	+78kg	0	+100kg	3

Table 3: Distribution of the 28 judoka concerning the year of competition

Year of competition	Number of judoka
2011	3
2012	5
2013	7
2014	7
2015	3
2017	3

Methodology

For each judoka, at least 4 complete contests (from the start to the end) during the same competition were analyzed via video. Videos were downloaded from Judobase.org, YouTube, ipponTV, judotv.fr, judoinside.com, alljudo.net, judo-snijders.nl

21 judoka completed 4 contests, 4 judoka completed 5 contests, 3 judoka completed 6 contests. 122 complete contests were obtained, and 973 attacks were analyzed. All the contests were verified by a specialist in judo; a 5th dan judo teacher. For each contest an attack was recorded when the referee gave a score or if we could consider an attack effective enough that the referee could take it into account and not give a penalty. Without score the attack was considered a single attack. Each attack was recorded using 6 criteria to determine a judoka's system of attacks in *tachi-waza*:

1. The time of the triggered attack (hh: mm: ss)
2. The name of the technique performed on the left or on the right (execution side of the technique) in reference to the International judo federation (2019).
3. The *kumi-kata* (cf. Fig. 02)
4. The score (1 = Single Attack [ki], 3 = *yuko* [Yu], 4 = *waza-ari* [Wa], 5 = *ippon* [I]) (cf. Fig. 03).
5. The direction of the attack (cf. Fig. 01, Fig. 03 and Fig. 04).
6. The number of supports (1 foot or 2 feet or back-side).

The criteria (*kumi-kata*, scores, directions of attack and number of supports) are detailed below. *Kumi-kata*, a global localization was done in figure 02; ★ left hand; ★ right hand:

According to the position of the hands on the judogi it was necessary to note different *kumi-kata* (**Figure 02**).

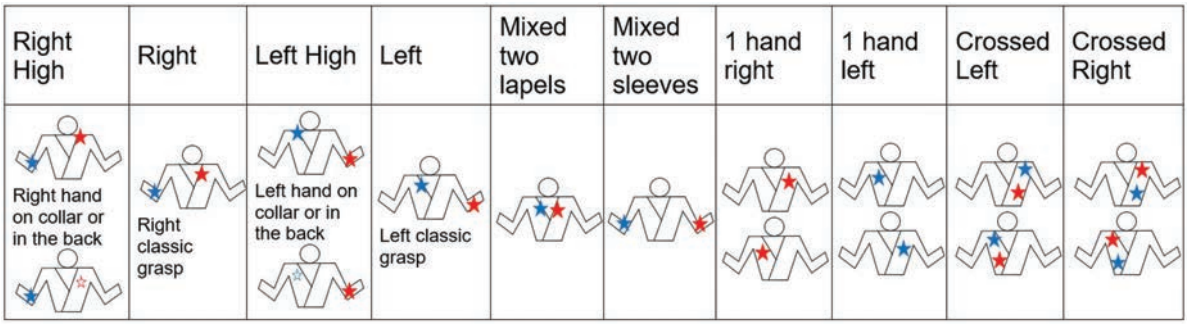


Figure 02: different *kumi-kata*

• The scores, efficient sectors, and the directions of attacks regarding the rose of *kuzushi*:

Table 4: Efficient sectors and directions of attacks

Scores and efficient sectors	Directions of attacks

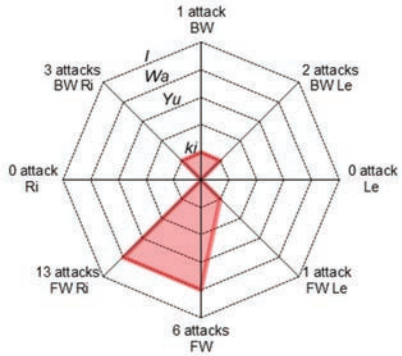
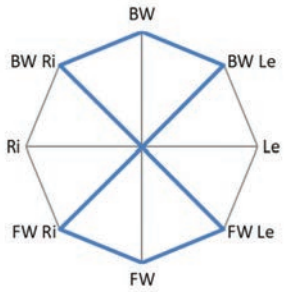

	

Figure 03: Example of data collected. The efficient sectors of attack (pink area) are built from the directions in which the judoka scored. In this example, the judoka attacked in 6 directions (BW RI; BW; BW Le; FW Le; FW; FW Ri) and scored in 2 directions (FW; FW Ri). The maximum score obtained was *waza-ari*. During the contest, one can imagine some attacks in backward directions to create opportunities to throw in forward directions. This is the efficient skills plan.	**Figure 04**: with data collected in Fig. 03, one can connect the points of the 6 directions (BW RI; BW; BW Le; FW Le; FW; FW Ri) to draw this chart (blue area). This allow us to perceive the unbalancing that can be created by the judoka, better (backward-forward and left-right). This is the technical skills plan.
Legend: BW=Backward, FW=Forward, Ri=Right, Le=Left, I=Ippon, Wa=*waza-ari*, Yu=*yuko*, ki=single attack	

• The number of supports on the mat, (depending of the technique used), examples:
    • *O-soto gari, uchi-mata, o-uchi gari, de-ashi harai*: 1 support
    • *Morote seoi-nage, tsuri goshi, o-soto otoshi*: 2 supports
    • *Tomoe nage, yoko tomoe nage, yoko otoshi, ura nage, tani otoshi*: Back-side

With the data collected, we calculated for each judoka: number of *kumi-kata*, number of directions of attacks, number of attacks, number of attacks with score, number of contests, number of efficient sectors (in which judoka scored), sum of duration of contests, mean attacks for 30s, number of attacks with 1 support, number of attacks with 2 supports, number of attacks with back-side support, number of attacks with kumi-kata in relation to direction of attack, number of linked attacks.

XLSTAT software was used to analyses data (ver. 2018.4.51670; Addinsoft (2019). XLSTAT statistical and data analysis solution. Long Island, NY, USA. https://www.xlstat.com). Mann-Whitney analyses, with significant level set at 0.05, were used to compare our samples and determine if there were differences between women and men, linked to the criteria. A principal component analysis (PCA) was used to study the correlation between these criteria.

Results

Globally, high-level female judoka competed in 4 to 5 contests (4.4 ± 0.7). The total duration of these contests was 15 minutes (14:44 ± 6.32); They used 5 *kumi-kata* (4.9 ± 2.1) and realized 33 attacks (33.1 ± 13.5) in 6 different directions (5.6 ± 1.2). They succeeded around 11% in their attacks (total number of attacks with score / number of attacks = 10.6%). They attacked identically on one support or two supports, with 16 attacks on one support (16.3 ± 10.4) and 16 attacks on two supports (15.8 ± 15), but few attacks from the back-side (1 ± 1.6). Their rate of attacks was one attack for 30s (1.2 ± 0.4) and less than 10% of attacks were linked (6% ± 3.7%). 62% of attacks were in the direction of the *kumi-kata* (61.6% ± 19.6%) whereas 29% of attacks were in the opposite direction of the *kumi-kata* (28.8% ± 19.4%). 10% of attacks were realized with mixed *kumi-kata* (9.6% ± 13.7%). There were two efficient sectors, i.e. scores in two different directions (2.2 ± 1.1).

Globally, a high-level male judoka competed in 4 to 5 contests (4.3 ± 0.7). The total duration of these contests was 15 minutes (14:13 ± 5.29). They used 6 *kumi-kata* (5.8 ± 2.1) and realized 36 attacks (35.7 ± 18) in 6 different directions (6.1 ± 1.2). They succeeded around 12% in their attacks (total number of attacks with score / number of attacks = 12%). They attacked more on one support than on two supports, with 22 attacks on one support (22.4 ± 9.2) and 11 attacks were on two supports (11.2 ± 10.4), but few attacks from the back-side (2.1 ± 4.6). Their rate of attacks was one attack for 30s (1.3 ± 0.5) and less than 10% of attacks were linked (9.2% ± 6.9%). 70% of their attacks were in the direction of the *kumi-kata* (68.6% ± 15.6%) whereas 26% of attacks were in the opposite direction of the *kumi-kata* (26.3% ± 15.6%). 5% of attacks were realized with mixed *kumi-kata* (5.1% ± 6.6%). There were three efficient sectors, i.e. scores in three different directions (2.8 ± 0.9).

Statistical analysis shows a difference in the last criterion: women had fewer efficient sectors than men (2.2 ± 1.1 vs 2.8 ± 0.9 respectively, p=0.004). More detailed data shown below in Table 5.

Table 5: results and corresponding p-values

Criteria	Women Mean ± SD	Men Mean ± SD	p-values
Number of combats	4.4 ± 0.7	4.3 ± 0.69	p=0.926
Sum of duration of combats (mm:ss)	14:44 ± 06:32	14:13 ± 05:29	p=0.915
Number of *kumi-kata* used	4.9 ± 2.1	5.8 ± 2.1	p=0.226
Number total of attacks	33.1 ± 13.5	35.7 ± 18	p=0.999
Number of directions of attacks	5.6 ± 1.2	6.1 ± 1.2	p=0.346
Number of attacks with one support	16.3 ± 10.4	22.4 ± 9.2	p=0.123
Number of attacks with two supports	15.8 ± 15	11.2 ± 10.4	p=0.506
Number of attacks with back side on the ground	1 ± 1.6	2.1 ± 4.6	p=0.399
Rate of attacks for 30 s	1.2 ± 0.4	1.3 ± 0.5	p=0.832
Percentage of linked attacks	6.0% ± 3.7%	9.2% ± 6.9%	p=0.269
Percentage of attacks with kumi-kata corresponding to the direction of attack	61.6% ± 19.6%	68.6% ± 15.8%	p=0.204
Percentage of attacks with *kumi-kata* opposed to the direction of attack	28.8% ± 19.4%	26.3% ± 15.6%	p=0.517
Percentage of attacks with mixed *kumi-kata*	9.6% ± 13.7%	5.1% ± 6.6%	p=0.646
Number of attacks scored	3.5 ± 2	4.3 ± 2.1	P=0.359
Number of efficient sectors of attacks	2.2 ± 1.1	2.8 ± 0.9	p=0.004

These results highlight specific uncertainties inherent in judo, requiring the need to attack in different directions, to move from right to left, from front to back or vice versa, to throw the opponent.

Concerning these 28 high level judoka:

- 100% have at least 2 kumi-katas, 80% have at least 4 *kumi-kata*
- 100% have attacked in at least 4 directions
- 61% of the attacks are done with a *kumi-kata* corresponding to the direction of attack
- 27% of the attacks are done with a *kumi-kata* opposed to the direction of attack
- 7% of the attacks are done with a mixed *kumi-kata*
- 10% of the attacks are linked attacks, but we must moderate this data. Currently we cannot detect all feints, e.g. within the video sequence, we cannot see all the fine wrist movements during the gripping phases.

The PCA analyses have put into evidence:

4 eigenvalues (Nb. total of attacks, Nb. efficient sectors, Nb. of attacks scored and Nb. of directions of attacks) explain 75.4% of the map. In these analyses, the active variables were criteria and values computed, the active observations were judoka.

Table 6: Eigenvalues and cumulative percentage

	F1	F2	F3	F4
Eigenvalue	4.581	3.608	1.830	1.284
Variability (%)	30.5	24.1	12.2	8.6
Cumulative %	30.5	54.6	66.8	75.4

The first two (Nb. total of attacks and Nb. efficient sectors) explain 54.6% of the analysis. The corresponding chart, with only the active observations (judoka), shows a concentration of 24 judoka (blue area) and 4 judoka on the periphery of the map. These four are all world champions (not in the same weight categories) and with different profiles as to the map of their efficient sectors.

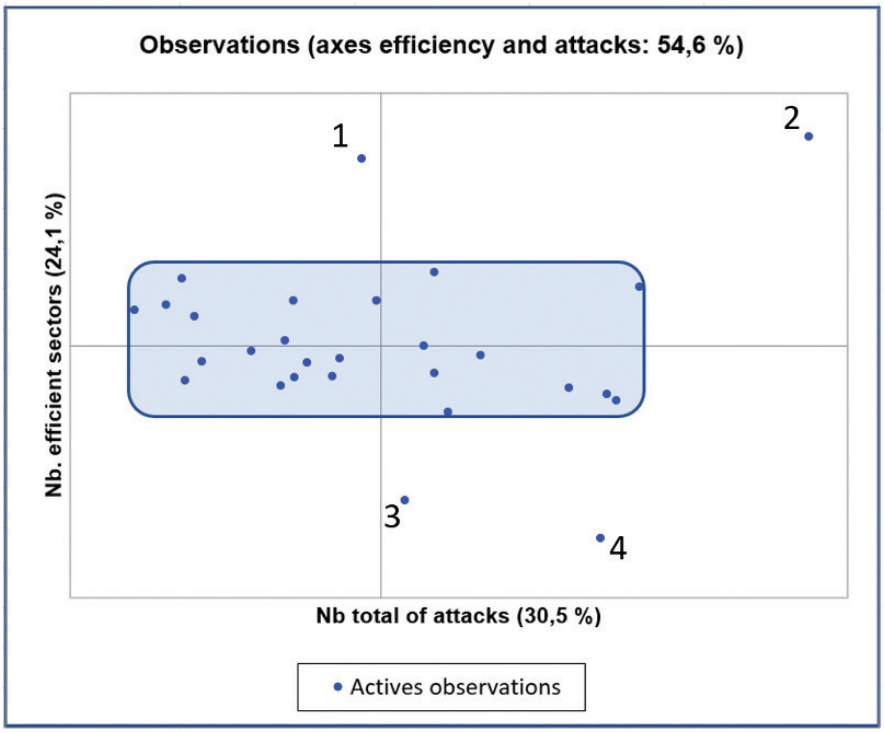
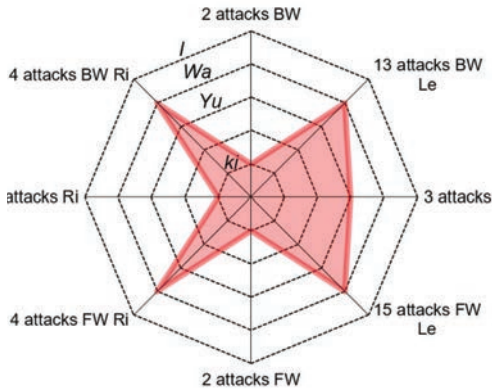
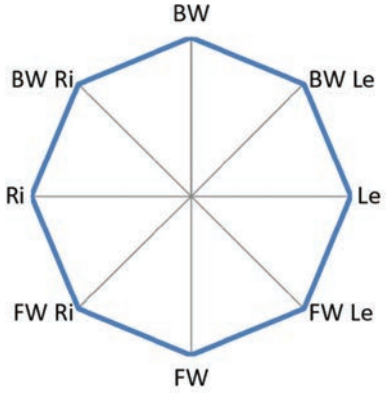
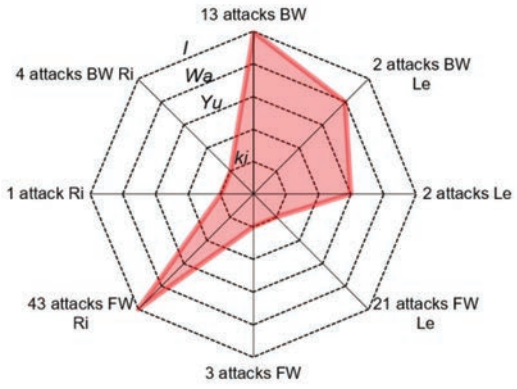
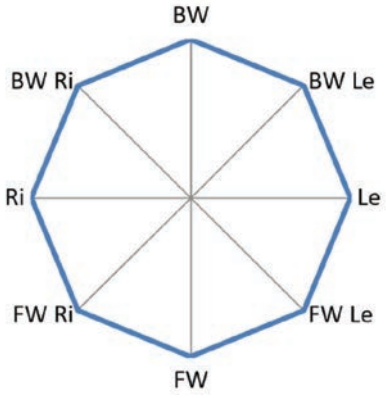
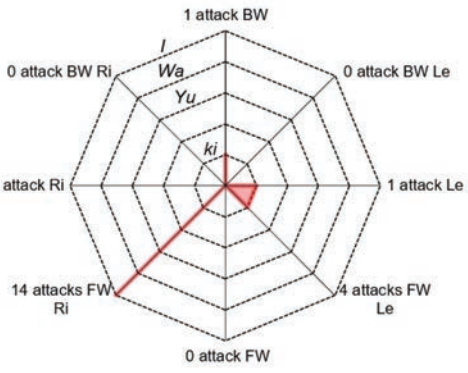
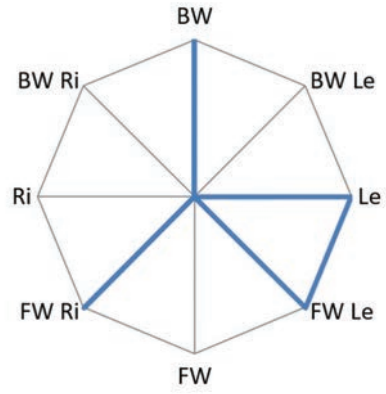
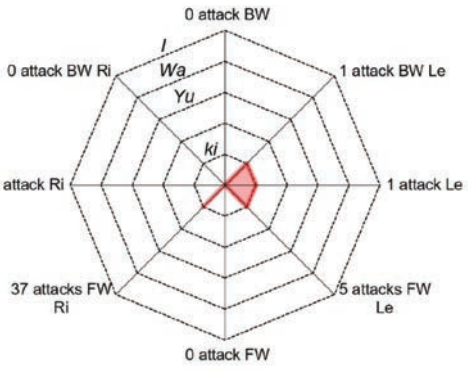
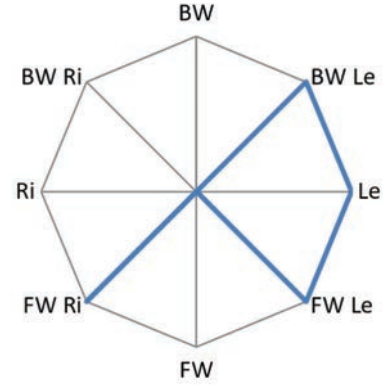


Figure 05: PCA regarding two first eigenvalues: Nb. total of attacks and Nb. efficient sectors

The four profiles below are examples of world champions. The most important findings are the commonalities in these 4 profiles: 4 directions of attack, possibilities to unbalance opponents forward-backward and left-right.

Example	Efficient sectors	Directions of attacks
1	 **Figure 06: 5 efficient sectors (all with waza-ari)**	 **Figure 07: 8 directions of attacks**
2	 **Figure 08: 4 efficient sectors**	 **Figure 09: 8 directions of attacks**
3	 **Figure 10: 1 efficient sector**	 **Figure 11: 4 directions of attacks**
4	 **Figure 12: 0 efficient sector**	 **Figure 13: 4 directions of attacks**

Conclusion

One can understand that the number of contests, the sum of the duration of the contests and the total number of attacks can be identical for women and men, respectively, because they follow the same rules. However, the number of *kumi-kata*, the number of directions of attack, the rate of attacks, the use of *kumi-kata* and the efficiency show that women and men practice the same efficient judo.

The main result of this study is that there was no significant difference in behavior between women and men when practicing judo in competition, relating to the 7 stated criteria (*kumi-kata*, directions of attacks, number of contests, total number of attacks, average of the sum of duration of contests, rate of attacks for 30s, number of supports used to attack).

There was a significant difference concerning the number of efficient sectors, with men seeming more efficient. The average ratio (number of efficient sectors / number of directions of attacks) was 39% for women and 46% for men. PCA confirms the cohesion of the behaviors of the judoka studied.

Our observations concern a small sample of women (10) in 4 weight categories out of 7. The contests were analyzed through a single camera and therefore from a single angle of view. 28 judoka were studied; 12 from France and 8 from Georgia. If one can remain cautious in a broad generalization of these conclusions, they correspond to the analyses of the experts, especially Roux (2019). These results do not confirm the physiological results found in Almansba et al. (2015) but refine those of S. Sterkowicz, A. Sacripanti, K. Sterkowicz - Przybycien (2013); more than a male style, this study shows an efficient judo style.

Regarding the hypotheses, the concept of the system of attacks is not dependent on gender; results show that women and men practice the same efficient judo. Skills do not depend on gender. Rules have changed a lot since 2003, but in our study, the system of attacks seems be more dependent on training and technical aspects than rules.

This study shows, from another perspective, that judoka can win in competition with different styles.

The above examples highlight that strategies and tactics are used in different ways but can lead to a world champion title; efficiency, strategy and tactic are partners and complementary.

Perspectives

Transitions into *ne-waza* were not studied here, but this does not mean that we consider these behaviors as less important. We could develop the standing up system of attacks by adding some other research concerning transitions from *tachi-waza* to *ne-waza*. In 1990, Patrick Roux analyzed 211 transitions relating to 29 judoka from 8 countries between 1982 and 1988 and suggested (Calmet, 2010b) that a high-level judoka should master 2 or 3 transition techniques, at least 2 favorite organizations/positions and at least 2 possibilities to obtain *ippon* in *ne-waza*.

Nagai et al. (2019) suggested that concerning the transitions scored, 67.3% were performed by the athlete who attacked in *tachi-waza* and 31.1% were performed by the judoka who were attacked in *tachi-waza*. The techniques to score in *ne-waza* were mainly *osaekomi-waza* (74.8%), followed by *kansetsu-waza* (13.7%) and *shime-waza* (11.5%).

We can suggest a model of system of attacks, not dependent on gender, for judoka and professors to train young judoka to develop systems of attack. A high-level judoka has and should master for use:

• *Kumi-kata:*
- 6 different *kumi-kata* among which these *kumi-kata* allow throws in a way:
- corresponding to the direction of attack (60%)
- opposed to the direction of attack (30%)
- mixed *kumi-kata* (lapels or sleeves) (10%)
- these *kumi-kata* allow fighting against any opponent using any *kumi-kata*

• Throwing techniques:
- 6 different directions of attack, 80% are direct attacks, 20% are linked attacks

• Number of supports regarding the throwing techniques:
- Balance (50% vs 50%) between the throwing techniques requiring 1 or 2 supports

• Physiology:
- This judoka can fight for 4 or 5 contests (i.e.: around 20 min, with rest between contests), and can do 1.5 attacks per 30s.

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Importance of Neck Muscle Strength in Resisting Neck Extension During Backwards *Ukemi*

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Abstract: *Serious head injuries in judo occur due to the inability of the athlete to prevent excessive extension of the neck when thrown backwards. Neck and trunk extension during backwards ukemi (a technique for breaking a fall) was investigated, with the aim of clarifying the challenges faced by judo novices. Using descriptive laboratory study, a total of 12 novices (mean age ± standard deviation, 27.3 ± 6.1 years) and 13 judoka (27.8 ± 8.6 years) participated. Neck flexor muscle strength was assessed using a handheld dynamometer. Kinematic analyses and surface electromyography on the right and left sternocleidomastoids were performed during backwards ukemi. Comparisons of kinematic variables and neck flexor strength between novices and judoka were performed with the independent t-test. The neck flexor muscle strength per body weight of judoka (1.2 ± 0.2 N/kg) was significantly greater than that of novices (0.6 ± 0.1 N/kg; p < 0.001). The angular change from maximum neck flexion during ukemi to maximum extension immediately after ukemi was significantly greater in novices (33.8 ± 16.8º) than in judoka (19.7 ± 8.4º; p = 0.046). Moreover, the average percentage of maximum voluntary contraction just after the backward ukemi was significantly greater in novices (81.9 ± 23.7 %) than in judoka (45.2 ± 13.8%; p < 0.001). Novices were less able to oppose neck extension during ukemi than judoka, potentially owing to their comparatively weaker neck muscle strength.*

Key words: *judo, acute subdural haematoma, ukemi (breakfall), motion analysis, injury prevention*

Various problems are associated with sports-related head injuries, including: concussion at the time of injury, second-impact syndrome developing if a second impact occurs during the acute phase of concussion and potentially resulting in life-threatening brain damage, mild traumatic brain injury which can lead to reduced cognitive function if repeated. Recently, several reports have highlighted the significance of serious judo-related head injuries in Japan. As judo includes the essential elements of the martial art *jūjutsu*, numerous injuries can occur despite it being regulated as a formal sport. A high proportion of cases result in death or severe neurological sequelae, therefore causing a considerable problem. Effective prevention of such injuries is therefore an immediate and pressing issue in judo.

In this paper we analyzed the system of attack in *tachi-waza* of 28 high-level judoka. The aims

Judo-related serious head injuries in Japan have the following characteristics:

1. In 90% or more of cases, acute subdural haematoma is involved,
2. Individuals who sustain injuries are most often in their first year at junior high school or high school and have therefore only recently started the sport,
3. The *waza* (judo technique) that most commonly results in injury is *o-soto-gari*, which is a type of *ushiro waza* (a technique involving falling on the back). It was the cause of 42% of the serious judo head injuries,
4. Approximately 50% of cases hit the occipital region of the head.

The mechanism by which injuries generally occur involves the individual falling backwards, contacting the mat with the back and subsequently striking the mat with the back of the head, because of forceful neck extension. On impact, the skull recoils from the mat, rapidly decelerating, while the brain continues to move backwards, resulting in the relative movement between the skull and the brain. This relative motion, generated by the rapid extension-flexion of the neck, can damage the bridging veins between the skull and the brain, resulting in acute subdu-

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ral haematoma. Therefore, restricting neck extension is key for preventing acute subdural haematoma.

Few previous studies on the biomechanics of *ukemi* (a technique in judo for falling safely by breaking the fall) have been reported. To the best of our knowledge, no studies have been conducted specifically investigating neck and trunk extension during *ukemi*. The aim of the present study was to explore factors relating to neck-trunk extension during backwards *ukemi* by comparing the kinematics of *ukemi*, neck strength and muscular activation in the neck during *ukemi* between novices and experienced judo practitioners (judoka) and to elucidate the potential challenges faced by those inexperienced in the sport.

METHODS

Participants

A total of 12 novices (mean age ± standard deviation [SD], 27.3 ± 6.1 years) and 13 judoka (27.8 ± 8.6 years; mean age ± SD) completed the study. A judoka was defined as a certified black belt holder of a dan (judo rank). The judoka included eight international athletes (two Olympic gold medallists, one Olympic silver medallist, and one World Championship bronze medallist), with the other five being members of the university judo team.

This study was approved by the Ethics Committee at Keio University's Faculty of Science and Technology. Details of the study were explained to each participant and informed consent was obtained prior to their participation in the study.

Measurement of maximum neck flexor muscle strength

The strength of neck flexor muscles was measured using a handheld dynamometer (Mobie; Sakai Medical Co., Ltd., Tokyo, Japan). According to the manual muscle test, as described by Daniels and Worthingham (2007), isometric muscle strength during maximal neck flexion in the supine position was measured three times, with the mean then used for the analyses.

Procedure of *ukemi*

Prior to assessment, novices were given instructions about correct backwards *ukemi*, by a judoka, for 15 min. During the experiment, a sixth-dan judoka was asked to push participants, with a consistent force, from the *sonkyo* (initial crouching) position. The participants were then required to perform backwards *ukemi* with their eyes closed (to prevent anticipatory muscle contraction).

Kinematic assessment

A high-speed camera (Memrecam GX-1; NAC Image Technology Inc., Tokyo, Japan), at a shutter speed of 1000 fps and a resolution of 1280 × 1024 pixel, was used for the kinematic assessment. Reflective markers were attached to different body parts of the participant. Nine reflective markers were attached to the following body parts: 1) lateral part of the head, 2) anterior auricular position, 3) basicervical region, 4) middle of the lateral trunk, 5) iliac crest, 6) greater trochanter, 7) fibular head, 8) ankle lateral malleolus, 9) fifth metatarsal head (Figure 1). The positions of the markers were tracked using PV Studio 2D, version 2 (OA Science Co. Ltd., Miyazaki, Japan). In addition, an accelerometer (myoMOTIONTM; Noraxon USA Inc., Scottsdale, AZ, USA) attached at the lateral head was used to identify the initiation of *ukemi*.

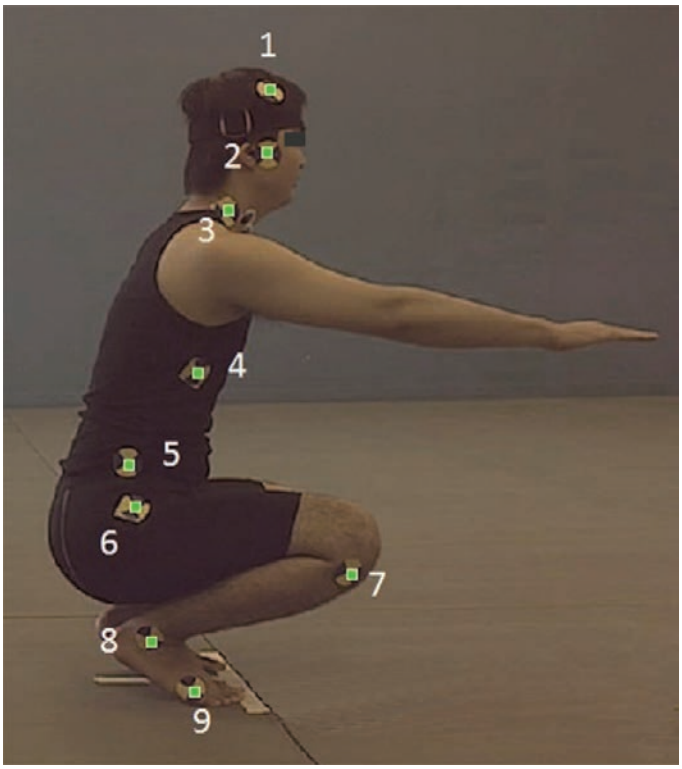

Figure 1

Surface electromyography

After shaving the relevant area of the skin and cleaning with an alcohol wipe, surface electrodes were attached at the right and left sternocleidomastoid muscles. Electromyography (EMG) signals were recorded using a TelemyoDTS Telemetry system (Noraxon USA Inc.) at 1500 Hz and bandpass filtered at 10–500 Hz. Surface EMG signals were measured during *ukemi* and the assessment of neck muscle strength.

Data processing

Baseline head acceleration was determined by averaging the head acceleration for 1 s in the stationary state during *sonkyo*, before *ukemi* initiation. The starting point of *ukemi* was defined as the first instance of acceleration change greater than the mean + 3SD of the baseline. *Ukemi* completion time was defined as the time when a horizontal line between the basicervical marker (marker 3) and the greater

trochanteric maker (marker 6) became parallel to the mat. As explained earlier, the mechanism by which acute subdural haematoma develops as a result of judo is that, when the judoka falls backwards, after the trunk makes contact with the mat, the neck extends, and the head rotates through a large angle, so that the occipital region strikes the mat. Therefore, to evaluate the degree of overall extension of the upper body and neck, the neck-trunk angle was measured; this being defined as the angle between a line between the anterior auricular and basicervical markers (markers 2 and 3) and a line between the basicervical and iliac-crest markers (markers 3 and 5) (Figure 1). The flexion of the angle was defined as positive. Head speed was also calculated using the marker at the lateral head.

The EMG data were rectified and smoothed using the root-mean-square algorithm with a 100-ms window. In addition, the maximum of the averaged EMG amplitude for 1 s in the right and left sternocleidomastoid muscles was determined during the neck flexor muscle strength measurement. The mean value of three measurements was taken to be the maximum voluntary contraction (MVC), and the percentage of MVC (%MVC) was assessed during *ukemi*. The mean value of the right and left sternocleidomastoid muscles was used for the analyses.

As each participant's *ukemi* duration was different, kinematic and EMG indices were normalised to the *ukemi* duration. The total *ukemi* period (0–100%) and the subsequent time period (100–120%) were used for this normalisation. This resulted in 121 data points per trial. Data processing was conducted using MatlabR2016b (MathWorks Inc., Natick, MA, USA).

Statistical analyse

Independent t-tests were used to compare basic characteristics (age, height, bodyweight) between the novice and judoka groups. Independent t-tests were also used for between-group comparison of neck flexor muscle strength, neck muscle strength per unit of bodyweight and kinematic indices of *ukemi* (*ukemi* duration, timing of the initial contact of the upper limbs with the mat [uchite], maximum head speed and head speed at *ukemi* completion). With regard to the neck-trunk angle, between-group comparisons using independent t-tests were performed for the following parameters: baseline angle (during sonkyo), maximum flexion during *ukemi*, maximum extension angle after *ukemi* completion, angular difference between maximum flexion and subsequent maximum extension, time of the maximum flexion during *ukemi* and time of maximum extension after *ukemi* completion. Pearson's correlation coefficient was used to assess the relationship between the angular change from maximum flexion to maximum extension and neck muscle strength per unit body weight. The averaged %MVC just before the completion of *ukemi* (80%–100% of *ukemi* duration) and just after the completion of *ukemi* (100%–120% of *ukemi* duration) were calculated and compared between groups. All statistical analyses were performed using STATA/SE, version 13.1 (Stata Corp., College Station, Texas, USA). Any p-values < 0.05 were considered statistically significant.

RESULTS

Participants' Characteristics and Neck Muscle Strength

The participants' characteristics are shown in Table 1. The bodyweight of judoka was significantly greater than that of novices, although there was no significant between-group difference in age or height. The mean ± SD neck flexor muscle strength of judoka was more than twice that of novices (judoka, 212.3 ± 39.0 N; novices, 101.8 ± 22.7 N; $p < 0.001$). In addition, the mean ± SD neck flexor muscle strength per unit of bodyweight of judoka was significantly greater than that of novices (judoka, 1.2 ± 0.2 N/kg; novices, 0.6 ± 0.1 N/kg; $p < 0.001$).

Table 1. Characteristics of the participants

	Novice (n = 12)	Judoka (n = 13)	p Value
Age, y	27.3 ± 6.1	27.8 ± 8.6	0.845
Height, cm	173.7 ± 4.4	174.5 ± 7.5	0.751
Weight, kg	66.0 ± 10.2	83.2 ± 13.1	0.001
Neck flexion strength, N	101.8 ± 22.7	212.3 ± 39.0	<0.001
Neck flexion strength per body weight, N/kg	0.6 ± 0.1	1.2 ± 0.2	<0.001
Judo rank	-	2nd dan, 5 3rd dan, 1 5th dan, 3 6th dan, 4	-

Values are presented as the number or mean ± standard deviation.

Kinematic indices

No significant between-group differences were found in *ukemi* duration, uchite time, maximum head speed, or head speed at the completion of *ukemi* (Table 2). In addition, no significant between-group differences were found in the following parameters of the neck-trunk angle: baseline angle, maximum flexion angle during *ukemi*, and maximum extension angle after *ukemi* completion (Table 2). Peak changes in the neck-trunk flexion angle relative to the baseline, which was normalised to the duration of *ukemi*, were similarly observed between 80% and 100% of *ukemi* duration in both groups. However, the angular change from maximum flexion during *ukemi* to maximum extension after *ukemi* completion was significantly greater in novices than in judoka (judoka, 19.7 ± 8.4º; novices, 33.8 ± 16.8º; $p = 0.046$; Figure. 2A, C). Although the time of maximum flexion was not significantly different between groups, the time of maximum extension tended to be delayed in novices compared with that of judoka (Figure. 2A and Table 2). In addition, a weak correlation between the angular change from maximum flexion to maximum extension and neck muscle strength was found with marginal significance ($r = -0.35$; $p = 0.091$) (Figure 3).

Table 2. Comparison of basic kinematic parameters and neck-trunk angle parameters of *ukemi* between groups

		Novice (n = 12)	Judoka (n = 13)	p Value
Duration of *ukemi*, s		0.79 ± 0.09	0.78 ± 0.06	0.591
Time of uchite, s (%*ukemi*)		0.77 ± 0.13	0.73 ± 0.07	0.369
		(97.5 ± 17.3)	(94.0 ± 7.1)	(0.504)
Maximal head speed, m/s		3.84±0.45	3.81 ± 0.40	0.849
Head speed at the end of *ukemi*, m/s		2.57 ± 0.55	2.40 ± 0.43	0.412
Neck-trunk angle	Baseline angle (during sonkyo), deg	25.6 ± 12.3	25.0 ± 9.3	0.899
	Maximum flexion angle during *ukemi*, deg	63.9 ± 13.1	61.6 ± 9.6	0.621
	Maximum extension angle after *ukemi* completion, deg	33.1 ± 12.3	41.9 ± 15.7	0.136
	Time of maximum flexion during *ukemi*, s (%*ukemi*)	0.69 ± 0.11	0.70 ± 0.05	0.800
	Time of maximum extension after *ukemi* completion, s (%*ukemi*)	(77.9 ± 25.3)	(82.6 ± 10.6)	(0.548)
	Time of maximum extension after *ukemi* completion, s (%*ukemi*)	0.90 ± 0.10	0.85 ± 0.06	0.110
		(113.2 ± 4.9)	(108.8 ± 5.8)	(0.052)

Values are presented as mean ± standard deviation. %*ukemi*: percentage of times relative to the duration of *ukemi*.

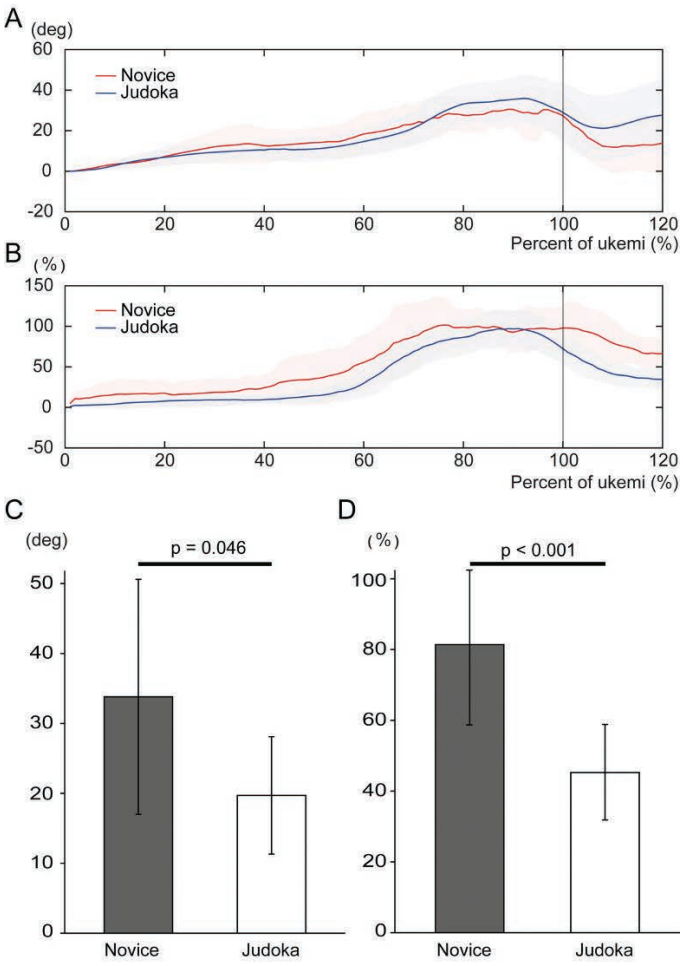

Figure 2

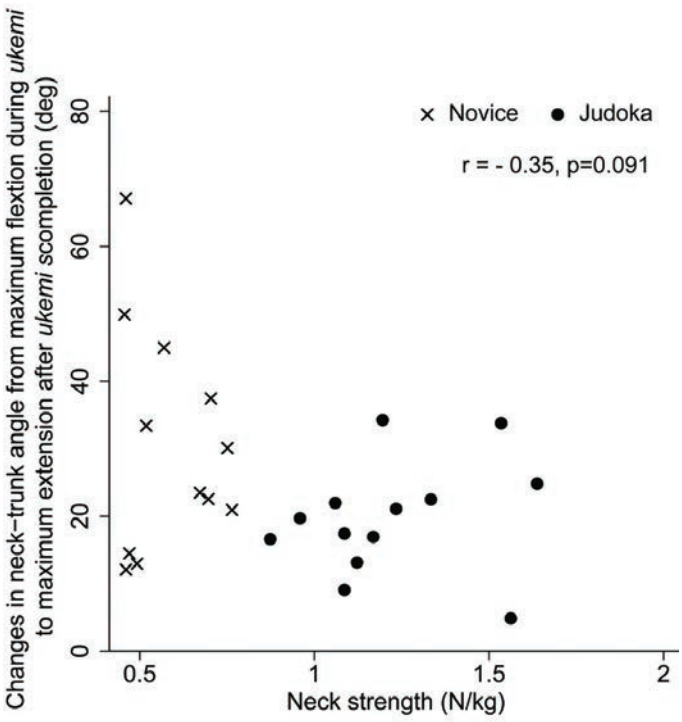

Figure 3

Figure 4 shows representative examples of a novice and a judoka. The images illustrate the moment of initial contact of the trunk with the mat (% of *ukemi* = 100%; A, C) and the period after touching the mat (% of *ukemi* = 120%; B, D). In the novice, after the initial contact of the trunk with the mat, the neck extended and the back of the head struck the mat (Figure 4B). Conversely, the judoka was able to maintain neck flexion after the initial contact of the trunk with the mat (Figure 4D).

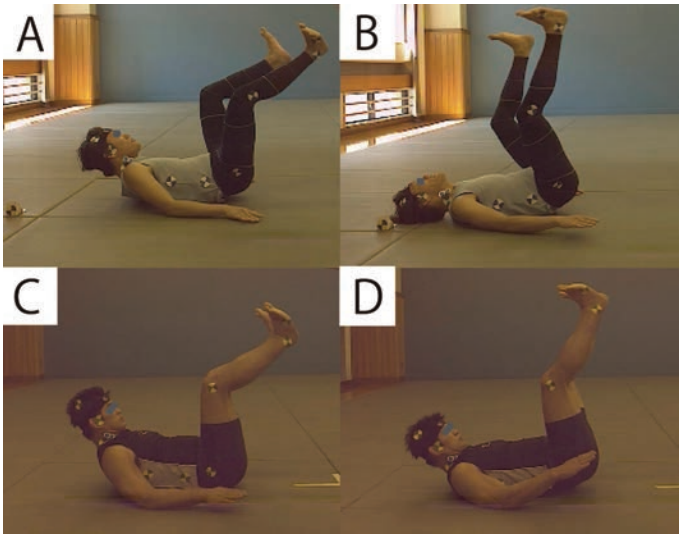

Figure 4

Surface EMG

The distinct peak of %MVC was observed at approximately 90% of *ukemi* duration in judoka. However, in novices, the peak of %MVC was relatively dull and observed before 80% of *ukemi* duration and was maintained after the *ukemi* completion (Figure 2B). The average %MVC during 80–100% of *ukemi* was not significantly different between novices and judoka (judoka, 90.8 ± 21.4%; novices, 97.5 ± 21.1%; $p = 0.439$). On the other hand, the average %MVC during 100–120% of *ukemi* was significantly greater in novices than in judoka (judoka, 45.2 ± 13.8%; novices, 81.9 ± 23.7%; $p < 0.001$; Figure 2D).

DISCUSSION

To elucidate the challenges that novices face with backwards *ukemi*, 12 novices and 13 judoka, in *sonkyo* positions and with their eyes closed, were pushed by a sixth-dan judoka and the following backwards *ukemi* was kinematically and electromyographically analysed.

No statistically significant differences in kinematic indices, including *ukemi* duration and head speed, were found between novices and judoka. This finding was consistent with that previously reported, suggesting that there were no major differences in the fundamental kinematics of *ukemi*. On the other hand, the angular change from maximum neck-trunk flexion during *ukemi* to extension after *ukemi* completion was significantly greater in novices than in judoka. In addition, this flexion-extension difference in neck-trunk angle tended to increase with decreasing neck muscle strength. Considering that neck flexor strength was significantly weaker in novices than in judoka, the novices were unable to fully restrict neck extension after *ukemi*. This was also supported by the finding that the time of maximum extension in neck-trunk angle tended to be later in novices than in judoka.

Surface EMG just after *ukemi* completion showed that the peak %MVC was approximately 80% in novices but approximately 45% in judoka. This difference is considered to be due to the major difference in the maximum neck muscle strength between the groups. The neck muscle strength of judoka was approximately twice that of novices, and thus the %MVC needed to suppress neck extension after *ukemi* was maintained at a relatively low level in judoka.

The timing of muscular contraction during *ukemi* in the two groups also highlights important differences between novices and judoka. Judoka showed a clear peak in muscular contraction immediately before contact between the back and the mat, whereas novices showed a dull peak from 80% of the *ukemi* duration, with contraction persisting even after the mat contact (*ukemi* completion). It could be suggested that because novices had considerably lower neck muscle strength, a larger voluntary effort, for a longer duration, was required to try preventing excessive neck extension. Furthermore, the absence of a clear peak in muscular contraction in novices, followed by an extended plateau, likely reflects the fact that novices were unable to resist neck extension successfully and prevent the back of the head from contacting the mat.

Suggestions for the Practice of Judo

In judo, guidance on *ukemi* is initially given to mitigate the effect of impact when one is thrown. For example, it has been shown that sideways *ukemi* can reduce the impact of falling on the hip joint by 17%. *Ukemi* is classified as either forward, sideways, backwards, or forward-roll *ukemi*, depending on the direction. Among them, backwards *ukemi* is the most important for reducing head injuries. The Judo Manual includes the following statement, “The main points to bear in mind when falling are to strike the mat hard with one or both arms, to curve the back, and to tuck in the chin so that your head does not hit the mat.”

The present research clearly shows, however, that even if a novice is capable of performing the correct *ukemi* technique in form, insufficient neck muscle strength makes it difficult to resist head rotation during backwards *ukemi*, which leads to a considerable risk of impact to the back of the head. This is especially important when planning judo training for young people in schools. When instructing novices, it may be beneficial to provide neck muscle strength training in addition to repeated practice of backwards *ukemi*. Substantial consideration must therefore be given before subjecting novices to ōsotogari, while also

encouraging the use of protective head gear in novices until their neck muscles are strong enough to cope with serious falls.

Limitations

This study has several limitations. Firstly, in addition to the major physical differences between novices and judoka, the force with which they were pushed was not controlled and so the possibility that results were affected by this variable cannot be ruled out. However, the observed results showed no major between-group differences in primary kinematic indices such as head speed. Therefore, we can be reasonably confident that the differences in neck-trunk extension between the groups were not due to increased relative force during the initial push. Secondly, the *ukemi* used in this study had differences from the *ukemi* utilised in situations in which a judoka is thrown with *o-soto-gari*. *Ukemi* is likely to be more difficult with *o-soto-gari* and therefore we assume that an even greater neck muscle strength than that observed in this study would be required. Finally, it is possible that the novices improved their *ukemi* technique during the study, through training before the experiment. Therefore, we could have underestimated the neck-trunk extension during *ukemi* in real novices. However, the primary objective of this study was to elucidate the challenges faced by athletes at the early stages of judo practice when compared with judoka and therefore the results should still accurately reflect those.

CONCLUSIONS

The primary conclusions of this study are as follows:

- In comparison with judoka, novices have less ability to resist neck extension immediately after *ukemi* completion. This is likely due to the insufficient neck muscle strength of novices.
- If neck muscle strength is inadequate, learning the correct *ukemi* technique in form alone may not be sufficient to prevent excessive neck extension during *o-soto-gari*, making it difficult to avoid head impact with the mat.
- Substantial consideration must therefore be given before subjecting novices to *o-soto-gari*.

Acknowledgments

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Figure legends

Figure 1. Reflective markers and neck-trunk flexion angle

The neck-trunk angle was defined as the angle of the line between the anterior auricular and basicervical markers (markers 2 and 3), and the line between the basicervical and iliac crest markers (markers 3 and 5). Flexion was defined as positive.

Figure 2. Neck-trunk angle and percentage of maximum voluntary contraction (%MVC) during *ukemi*

Transition of neck-trunk angle (A) and %MVC (B) normalised to total *ukemi* duration (including the immediate period after *ukemi* completion; 0–120%). The shaded area indicates between negative standard deviation (-SD) to +SD. Comparisons of neck-trunk angular change from maximum flexion to maximum extension (C) and mean %MVC during 100–120% of *ukemi* (D) between novices and judoka. The neck-trunk angular extension change and the mean %MVC during 100–120% of *ukemi* were significantly greater in novices than in judoka.

Figure 3. Correlation between neck flexor strength and neck-trunk angular change from maximum flexion during *ukemi* to maximum extension after *ukemi* completion

A weak correlation between neck strength per unit of bodyweight and neck-trunk extension changes was found with marginal significance.

Figure 4. Representative participants

A, B. Novice. C, D. Judoka. In novices, head impact was observed after contact between the back and the mat with neck extension (B). Judoka maintained neck flexion even after contact between the back and the mat (D).

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The Judo Moral Code or the Western "Re-Japanisation" of Modern Judo

By Michel Brousse

Abstract: *Nowadays, in many dojos around the world, posters of the judo moral code promote judo as a powerful means to build people and transmit educational values. This article questions the roots of the judo moral code, presented as a French invention and a western rewrite of the philosophy of Jigoro Kano.*

Cultural history enlightens us on the turning points in judo history which mark out the evolution of the Japanese art. It helps us to comprehend the impact of the 'sportisation' process that has induced a 'de-sacralisation' of Kano's method.

Since today's practice revolves around the two main nuclei of professional sport and socio-motor education for children, our purpose is to demonstrate that the primary function of the moral code is the re-enchantment and 're-Japanisation' of modern judo

Key words*: judo; cultural history; moral code; sacralisation; sportization; Westernisation*

Today, judo practice is universal. The vast majority of dojos in the world display the effigy of the founder and the maxims that illustrate the pedagogical dimension of an activity that is defined as a sport and a means of building people. The mastery of the Japanese man-to-man fight appears as a way of affirming one's personality and acquiring civic values. It is at the heart of the collective imagery, whatever the place or country. In each continent, the emblematic figure of the judo champion perpetuates the idea of a personal balance, of a wisdom and a power, putting calmness of thought and strength of acts together, in harmony. The Japanese method is defined as much by the technical prowess it encourages as by the educational principles it carries. The moral code of judo is omnipresent. Composed of eight values, it legitimises the discourse of those who consider that judo is 'more than a sport.' The posters that adorn the walls of dojos are translated into many languages. Recalled recurrently in official speeches, the moral code is often referred to in administrative texts as the document defining the current goals and missions of the International Judo Federation (IJF). From both a cultural and institutional point of view, the moral code seems rooted in judo history, but the dates can be questioned. The formulation of the moral code dates back to the mid-1980s, a century after the founding of Kodokan judo. Can we consider such a list of values a mirror to the ideas of the founder of judo? Should they be seen as a faithful reflection of the philosophy of Jigoro Kano or should we regard them as a recent rewrite, translating the export from Japan, of a cultural product adopted and adapted by the west? Can we identify historical sources in Kano's writings or should we reveal an invention of the tradition whose causes and functions should be defined?

What matters in judo history are not continuities but the turning points. Shun Inoue pointed out the first one when he studied what he calls the 'invention of the martial arts' by Jigoro Kano. In *Mirror of Modernity*, the sociologist states,

"*Kodokan judo is the first example of the invention of budo, specifically the transformation of jujutsu, a martial art of the Tokugawa era, into a 'national sport' (kokugi) and a body culture, which came to symbolise Japan's modern national identity. Budo, of which Kodokan judo was the prototype, was originally conceived as a hybrid cultural form produced by a modernised 'traditional' practice. With the rise of militarism and ultranationalism, budo was reinvented as a counter to western values and to infuse Japan's modern sport-culture with Japanese spirit*" (Inoue, 1998, p. 163).

Judo is a cultural mirror. It reflects the evolution of the society that welcomes it and, at the same time, integrates it as an original educational way and a new social use of the body. To take the moral code of judo as an object of history is to study the legacy of the values, symbols and heroic figures that today constitute the culture and spirit of judo. It is to try to define the motivations, the hopes and the disappointments of the disciples of the Japanese method. It is to delve into the cultural and social history of the discipline. It is to identify the impact of culture and society on the execution of gestures, what the French sociologist Marcel Mauss (1950) defines as a social idiosyncrasy, i.e. to show how much the form of the techniques of the Japanese art goes beyond their mere function and to reveal to what extent judo practice reflects a class affiliation and a vision of the world. It is also to understand the context that generated the judo moral code and then allowed its wide dissemination. To establish that the moral code has a French origin, that it is a western rewrite of Kano's thoughts, implies that particular attention must be given to the evolution of judo in this country. However, it cannot be ignored that the international influence of France is such that its organisation and functioning have often served as a model on different continents. The questions raised by the changes are to be found everywhere in the judo world.

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From *Jujutsu* to Judo in the West

The values one lends to today's judo are anchored in the history of the discipline and its spreading outside of Japan. In the early 1900's, the first followers found, in the Japanese art of combat, the codes and the usages of excellence that suited their social class. The link between judo manners and techniques and those of samurai warriors are central to the public image of the Japanese combat arts. This gave Kano a real advantage to promote his method. At the beginning of the 20th century, the war between Japan and Russia attracted attention. After the battles of Mukden and Tsushima, the caricature of the 'little yellow man flooring the Russian ogre' knew no borders. Immediately, the press seized the victories and the mysterious techniques of the Mikado soldiers. The idea of a Japanese know-how allowing the weak to defeat the strong began to be anchored in collective representations. *Jujutsu* and judo experts were invited worldwide to teach in military and police institutions, adding legitimacy to the superior efficiency of the Japanese art. These experts also taught in the private clubs of the well-renowned apostles of physical culture like Mc Fadden in the USA, Sandow in Great-Britain or Desbonnet in France. In 1905, the Japanese art became trendy for members of high society. Edmond Desbonnet, who introduced *jujutsu* to the French capital remembers, "*Immediately all the Paris high-life came to register: Prince of Caraman-Chimay, Duke of Broglie, Prince Murat, Count Grëhfulle, artists, doctors, the most eminent men of letters, arts, industry, etc.*" (Brousse, 2005, p. 112).

Professor Ré-Nié, Paris, 1905

The values associated with the Japanese method were imbued with a fascination triggered by the discovery of a country and culture largely ignored by the general public until the end of the 19th century. In an interview given to the American magazine *The Oriental Review*, Kano declared, "I would say that it is an art that makes use of both the mind and body to the best possible advantage. It must be considered from three different points: mental and moral training, physical training and self-protection" (Kano, 1913, p. 246). Claiming so, Kano confirmed the central place of self-defence in the western image of the art. In the years 1920-1930, these gymnasia and clubs were not in insignificant numbers. They constituted the base on which Kano relied to progressively transform *jujutsu* into judo outside Japan, but the members of the elite social class involved in physical activities in those days also added an aristocratic background to Japanese manners, courtesy and self-control. Doctor Pagès, one of the early admirers of the new art of self-defence declared, "*In short, one must know jiujitsu, and the more so because one is less tall, less heavy and more distinguished*" (Pagès, 1911).

Kano, a Theoretician for the Elite

Kano is a theoretician for the elite. His method advocates the perfection of the individual in the service of society. It imposes abnegation and the surpassing of oneself. He was a visionary. Seen from the west, his humanist and international perspective offered a vision of society that suited the ruling classes. When Brian Goodger (1981) analysed the social composition of the first members of the London Budokwai, he highlighted the high status of the adepts of the first European club. In the 1930s, the members of the Jiu-Jitsu Club de France founded by Moshe Feldenkrais were scientists and students of the École Spéciale des Travaux Publics de la Ville de Paris, the Sorbonne University, the Collège de France or the Radium Institute.

The choice of judo was the choice of a social class. In the years 1950-1960, numerous dojos around the world, like the club run by Haku Michigami in Bordeaux, saw attendance on the *tatami* from a large number of the notables of the city, including doctors, dentists, psychiatrists, bankers, lawyers, politicians and many more. Judo was then an elitist pastime which, by its implicit rules and its uses, translated into behaviours, offered a set of values fitting for the upper classes of society: the requirement of effort, courtesy, excellence and self-control included. Pierre Bourdieu draws a parallel between sport practice and social status. In La Distinction, the French sociologist affirms,

"*A sport is in a way predisposed to bourgeois use when the use of the body it calls does not offend the sense of high dignity of the person which excludes the possibility of throwing the body into obscure battles [...] and which demands that, anxious to impose the indispensable representation of its authority, of its dignity or of its distinction, the body is treated as an end, that one makes of the body a sign and a sign of its own ease*" (Bourdieu, 1979, p. 240).

In the dojo, practice is not aimed at winning medals but at surpassing oneself and respecting Japanese culture. The decoration of the dojo, disciple-master relationships and practitioner behaviours reflect the weight of the symbols. Jean-Lucien Jazarin, who was president of the Collège des ceintures noires for many years, remembers his beginnings in the 1940s under the leadership of Professor Kawaishi,

"*Behaviour on the tatami, silence, dignity, strict and immediate obedience to the Master, the respect of our comrades, our superiors, the dojo, etc., all this was for us Judo as much and perhaps more than the 1st leg throw or the 10th hip throw. Add to this that the master from time to time blamed us, for faults or errors of conduct of which we were not aware, with the epithet of 'bad mental'. This comment plunged us into abysses of reflections, examinations of conscience, and we were thus subjected to a perpetual self-observation*" (Jazarin, 1974, p. 26).

In their diversity, the judokas had a great interest in the many facets of the mysterious and unknown Orient. They were curious about aikido and karate, about *kuatsu*, acupuncture and zen philosophy. Many people then read, for instance, Lily Adams Beck's novel *Zenn Amours Mystiques*. In it, the author defined judo as "*a powerful discipline to prepare the way for satori, which is the name we give to enlightenment, and which constitutes the very essence of the Zenn*" (Adams-Beck, 1938, p. 80).

The Advent of Kodokan Judo in Europe

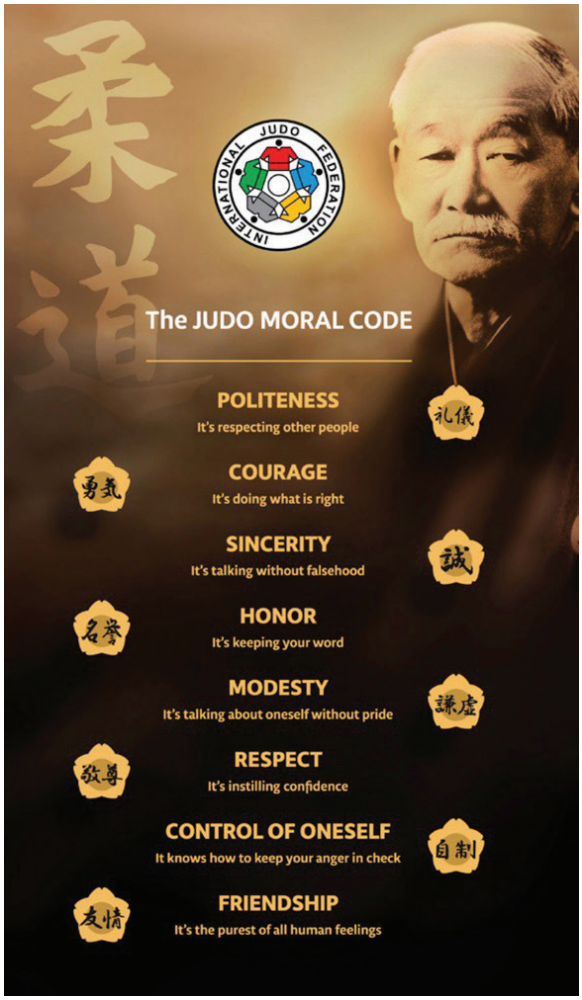
It was only in the early 1950s that Kodokan judo and Kano's educational message became accessible to a larger audience. If the thought of the founder of judo was better known in the USA and Great Britain before the Second World War (WWII), it has remained confidential in France until the early 1950s. In November 1951, Ichiro Abe, then 29, was invited to Toulouse by a club reluctant to accept the authoritarian system implemented by Kawaishi and his group. The judo demonstrated by Abe was airier, more flexible, more aesthetic. It favoured movement and freed the body. The dynamism of the forms, the creation and exploitation of the *kuzushi*, the search for sensations departed from the previous static work, taught that only exceptional judoka could reach his level. But above all, the Kodokan envoy transmitted a philosophy still unknown, even forbidden. Kawaishi even demanded, without success, the withdrawal of the black belt from two of his students, Jean Beaujean and Roger Duchêne, who, despite his ban, went to study judo at the Kodokan, following the advice of Minoru Mochizuki (Brousse, 2005, p. 302). The break was almost immediate. Several French teachers were seduced by the new technical style. They were also eager to escape Kawaishi's authoritarianism and federal dirigisme. In 1954, they left the FFJ to create the Federal Union of Judo Kodokan Amateurs. Forced to leave France, it was from Belgium that the Japanese expert continued his missionary work. Thanks to Abe's contribution and to the strong international influence of French judo, Kano's educational ideas disseminated rapidly in Europe.

The post-WWII was also a period of development by means of information and transnational exchanges. The first judo journals were issued during that period. In Paris, Henry Plée published a bilingual English-French magazine, *Ju-Do, the official translation of the magazine of the Kodokan*. The first issue was launched for Christmas 1950 (for six issues, a yearly subscription cost the current equivalent of 120€). Over the first decade, the summary of the articles of the review, i.e. 585 articles, shows the proportions of the collective centres of interest for the readers: cultural domain, 48.7%; technical field, 38.3%; competition area, 8.1%; miscellaneous 4.9%. Significantly, almost half of the content is related to Japanese culture i.e. to stories about Kano's life, Kodokan judo history, winter and summer training camps, the opinion of the great masters, the epic epoch of the inter-school contests. Readers also had a passion for the novels of *quaterly bulletin of the Budokwai*. The novel, The Story of a Dream at Bizan by Shiro Saigo gives an idea of the values at stake,

"*The true samurai never loses his mind in any event, he feels no terror when facing the shining blade of a hostile sword. No matter how great his suffering may be, he will remain impassive as well in the ordeal, in the fire or in the water, impassive even if he is the object of the worst insults, and he does not pride himself on any action so brilliant as it is. The reason for his power lies in the fact that he has been able to understand the true nature of martial arts*" (Saigo, 1953, p. 144).

JU-DO, first issue, December 1950

This narrative was not unique. Similar contributions could be found in Judo, *quaterly bulletin of the Budokwai*, for instance in the writings of the famous British judo expert, Trevor Leggett. They revealed the 'spirit of the times'. The clothing of the judoka that erased the physical and social differences and the scrupulously observed rituals reinforced the idea that only the initiate can achieve the mastery of the body and the space, the control of his actions and emotions. Through his presence, the sensei appropriated the 'place where one studies the way'. He guided and, without enslaving, he imposed his will. Everything was hierarchical, ritualised, sacred. In the immediate post-war period, in many countries, *bushido* and Japanese culture were an important component of the zeitgeist.



IJF Poster

The Moral Code of French Judo

This was the context when Bernard Midan (1917-1994) was introduced to judo. Once a shepherd in the Pyrenees, later a student of a former army member of the military school of Joinville, he attended Kawaishi's lessons. French Military champion in 1947, he was awarded his black belt in August 1948. In Toulouse, he discovered the Kodokan judo demonstrated by Ichiro Abe. A new future was then revealed to him, all in elegance and body movements. It was a shock that directed him definitively towards a more aesthetic judo, a judo giving a larger part to the education of the person. A professional teacher, not indifferent to the economic aspects of judo teaching and a technical advisor of the French Judo Federation (FFJ), Midan was a significant actor of his time, at the local and national level. The 8th *dan* was awarded to him in December 1990.

Bernard Midan was at the origin of what must be called the 'invention' of a tradition: the French judo moral code. As British historian Eric Hobsbawm states,

"*Invented tradition is taken to mean a set of practices, normally governed by overtly or tacitly accepted rules and of a ritual or symbolic nature, which seek to inculcate certain values' norms of behaviour by repetition, which automatically implies continuity with the past*" (Hobsbawm & Ranger, 1983).

A simple leaflet published a while ago by the French Judo Federation on '*Bushido, the Code of the Samurai*' came to be Midan's first source of inspiration. Surrounded by a group of judo teachers, he then decided to launch an awareness campaign on education by judo, in the form of a poster composed of a list in a table format, gathering eight values and eight definitions, in an order which varied according to successive editions. Since the beginning, the layout of the poster has anchored the moral code in the history of judo. Still today, the official IJF poster uses Kano's portrait as a background on the right. On the left, the word judo is written in large *kanji*. Under the IJF logo a title states, "The Judo Moral Code." The list reads the eight values and the translations of their French definitions: Politeness", it's respect for others; Courage, it's doing what is right; Sincerity, this is to speak truthfully; Honor, this is to be true to your word; Modesty, this is to talk about yourself without arrogance or impatience; Respect, without respect there is no trust; Self-control, this is to remain silent when negative feelings rise; Friendship, this is the purest of human feelings."

The judo moral code programme was officially launched in October 1985. Initially, the initiative was regional but since it was promoted by a French newspaper *Nice-Matin* and thanks to the active participation of the Côte-d'Azur judo league, it spread rapidly. It was taken over by the FFJ at the national level and presented during the Paris Open in 1986. The comic strip, a privileged means of communication with young people, offered a relay of great efficiency. An agreement was made between the FFJ and the company that manages the image of a typically French hero, Asterix the Gaul. A new character with a Japanese physiognomy was created: Waza-Arix. The eight values illustrated by the various characters of the series were high quality creations. Promptly, a diploma and stickers were available for the children of the 5,000 French dojos. The adult version, mostly in a kakemono format, was simply decorated by adding to definitions the *kanji* translations of the set of values.

The rapid success of the moral code also revealed the

profound crisis that disturbed French and world judo i.e. the shift from a martial discipline to an Olympic sport. Using the words of Max Weber, we can consider that, for Bernard Midan and many judo pioneers, 'sportisation' has disenchanted their judo. Rationalisation and bureaucratisation added an increasing stress to competition and its corollary, the race for medals. Feelings were strong on both sides, debates long and intense. They caused deep divisions. For traditionalists, judo was then secularised, 'desacralised': a judoka could not be a sportsman.

The definition of judo had been centrally accepted since the early days of the founding of international institutions. The roots of the sports movement appeared as early as August 1932 with the founding of the European Judo Union, whose statutes already set the goal of introducing judo into the Olympic programme. This text was long forgotten but the question surfaced again with the foundation of the IJF. In 1952 at the Zurich Congress, Aldo Torti, the first IJF president, presented a long report of activities. He started by regretting the biased attitude of France, whose president Paul Bonét-Maury had offered the presidency to Japan while the country was not even a member of the IJF. Then Torti asked, "Is judo a sport?" The Japanese answer came, "It is even a sport." He expressed all his dissatisfaction for a formula he considered too vague,

"*Judo is not the creature of their creators. The creature has grown, it moves, it walks alone, it abandons its parents. It recalls them, loves them, venerates them, listens obediently to them, but it walks by itself. It is entitled to it, because, by the merit of its creators, it has in itself something universal. That's why judo has to enter the field of world sports*" (Torti, 1952, p. 14).

The acceptance of the IJF presidency by Risei Kano, a year later, did not solve the question. It was not until 12th November 1963 that an issue could emerge. An IJF meeting was held in Tokyo to revise the statutes as the Olympic championship was approaching. After five days of work, the wording of article 1 was still deadlocked. What should be the purpose of the IJF? Is it the development of Kano's judo or of the sport of judo? In a diplomatic move, André Ertel, the French European Judo Union president, who chaired the meeting in the absence of Great Britain's Charles Palmer, convinced the Japanese clan and their supporters that a negotiated solution would be more favourable to them than a vote. All the articles of the revised IJF statutes were completed within the last day (Ertel, 1986). The 'sportisation' of judo had become definitive.

Massification, Quest for Medals and Disenchantment of Judo

The transformation of judo as a method of intellectual, physical and mental education into a competitive sport illustrates the analyses made by sports historians like Allen Guttmann, Melvin Adelman and Steven Reiss. It is linked to a process of institutionalisation and of the multiplication of regulations and contests. Judo was born in the city. It was the fruit of the industrial revolution in Meiji, Japan. This is why it cannot be called a martial art. In choosing a sporting orientation, the post WWII judo leaders opted for a system that departed from the Japanese model of schools, under the tutelage of the Kodokan Judo Institute. Kano did not particularly adhere to the federalist model in use in the West. It is indeed important to note that the founder of judo did not seek to promote independent national institutions but branches of his Tokyo school. His action on the American continent and his attempted annexation, in 1933, of the club led by Gunji Koizumi in London, provides the evidence (Bowen, 2011, p. 192). In Britain, the project failed mainly because of the refusal of English judokas to abandon the name of 'The Budokwai' for 'The Kodokan, London branch'. Independence vis-à-vis Japan, although it remained variable, gave each nation a real potential for autonomy in the use of sport as a means of developmen.

In France, between 1946 and 1956, data shows the total number of people practising a sport was multiplied by 10. Within the same time-slot, the French judo organisation membership was multiplied by 100! In a period of economic growth, the media, press and television, proved to be a decisive propaganda tool at the service of sport in general and of judo in particular, relaying as much the national and international championships as the esoteric culture and the sensationalist facets of the Japanese art. Championships, once occasional, came to punctuate the life of judokas. Sporting events, multiplied by an increasing number of weight and age classes, became a driving force for judo development, but it also changed the landscape profoundly. In many countries, the dojo became a training room. The traditional warm-up turned into a hard workout session. Rituals lost their formalism and utility. Kata practice became obsolete. Admiration moved from the master to the champion, whether or not his behaviour reflected judo culture and traditions.

The 'sportisation' of judo led to a double break, the democratisation and the 'de-sacralisation' of Kano's method. For traditionalists, the champion, especially when he was not Japanese, was considered a heretic. Comments on the victories of Anton Geesink demonstrate how criticism was biased, partisan and unfounded. Ignoring the exceptional technical and tactical qualities of the Dutchman, French devotees to pure judo condescendingly described a giant, a colossus, only superior in strength and weight. In 1961, in the *Encyclopédie des Sports*, Paul de Rocca Serra, former FFJ president and then president of the French College of Black Belts, accused, "When we see in European Championships, the stone cutter Geesink, a force of nature, crushing his opponent under his 103 kilograms, we can ask where is zen in this fight?" He went on to say,

"*Already the 'championnite' is rife, with all that it entails in material interests and possible combinations. [...] We are already regretting, in France, that there are championships. We create weight classes, which is the very antithesis of the spirit of judo. [...] Will youth understand [...] that a title is nothing compared to the smallest individual progress?*" (Rocca Serra, 1961, p. 303).

The technical knowledge, that seemed immutable and even more sacred when Japanese, appeared also as a field of transgressions. In 1972, in Munich, Takao Kawaguchi won the title in the lightweight category. In the final match, he met for the second time an opponent hardly beaten in the preliminaries. During their first fight, he was caught in *osae komi*. He managed to free himself. In the effort, the future winner seriously damaged his ribs. It was an intense, harsh, restless confrontation. His fierce opponent imposed a frantic pace. When his belt dropped on the mat, since he was anxious to beat the Japanese champion, he rapidly wrapped it around his waist, doing it only once. The referee stopped him. It was too late. His gesture was an admission. It betrayed the shift of cultures. In the eyes of a keen observer, the fighter who did not tie his belt in a proper way was a defector from another form of wrestling. As the Soviet Union competitors who owed their selection to their expertise in sambo and who could face their opponents in preliminaries wearing a coloured belt and changed for a black belt for the final block, his technical knowledge, even though efficient, did not fit in with the traditions of judo. At the turn of the 1970s, the contrast was great between elite fighters brought up in a classical judo model and those selected on the basis of their expertise in other folk wrestling styles. The question came to be crucial in the 1990s with the fall of the Iron Curtain and the dissolution of the Soviet Union. Only drastic changes to the IJF refereeing rules could limit the resulting hybridisation of classical judo techniques. Less intensely displayed nowadays, the cleavage between traditionalists and modernists has not disappeared. In Japan, some fundamentalists reserve the use of *kanji* to refer to Kodokan judo. When it comes to modern judo, they write the word in *romaji* i.e. in Roman letters. These examples illustrate the extent of the disenchantment.

The ‘Re-enchantment’ of Judo

Between 1955 and 1985, the membership of the French judo organisation rose from 22,259 to 382,544. This exceptional growth was linked to the inclusion of younger practitioners, an important lowering of the age of its members. A new attendance meant new goals, new methods and new behaviours. It also widened the generation gap. The other element that fundamentally changed the atmosphere of the dojo was the loss of the cultural and social mix which previously reigned there, putting together experts and novices. Judo lessons came to be organised by classes of age and level. Competitors deserted the *tatami* of the club for those of regional or national training centres. Peer-to-peer exchanges that were generally educational and humane became less common. In addition to this, parents who are also customers and consumers expected more for their children from a discipline presenting itself as the champion of education and civic values. Bernard Midan actively lived this period of passions and conflicts of ideas as well as interests. In a document he left in a form of legacy to future generations, he looked back at his life as a judoka. Mentioning what he defined as the golden age of French judo, Midan evoked a balance of “exemplary proportions between tradition, education and sportsmanship.” Turning to the next sporting period, he denounced “the influence of the leisure society,” the “loss of faith and hope of teachers […who…] no longer participate in the building of people.” He blamed championships, “once a way, today the only goal” (Midan, 1992).

The ‘sportisation’ of judo made a difficulty apparent. By becoming the centre of gravity of modern judo, the massive quantity of contests had generated a moral code in return. It does not matter that there was no historical anchorage, that the inspiration came mainly from a fantasised code of the samurai, from the analogy with French chivalry or other dreamt zen stories, that from Kano’s texts only his two most famous mottos and his 1932 Los Angeles speech were referred to. Midan was an autodidact. His humanism bore the mark of the Masonic ideas to which he adhered, like many FFJ leaders. His idea of a moral code was shaped by experience, by philosophical influences and by resentments. He held an idealistic discourse to preserve a time running away from him, to recover a judo from which he felt dispossessed. By writing a moral code he was calling for the ‘re-enchanting’ of judo. For Rudolf Otto, the sacred is an ambivalent force that imposes both fear and respect, dread and admiration for something that goes beyond the individual and overwhelms him (Otto, 1949, 19). For Midan, judo had glided into the profane but the profane space did not offer men a model of behaviour. As an experience of the body and the mind, judo is not just reality but a feeling, an inner and intimate feeling Midan wanted to share with new generations. What would be a judo without morality, without value, without culture?

Jita kyoei

Seiryoku zenyo

The judo moral code has eight values, some of which are obviously redundant. Is it really harmless? The number 8 has a symbolic meaning. It is the vertical figure of the infinite. It represents the completion, the perfect balance between the human and the cosmic, the spiritual and the sensible. Offered to a new population of children and teenagers, the philosophy of judo invented in France and promoted by the FFJ bears the marks of its time. The values chosen, their order and the definitions given to them reflect both the nostalgia and the social needs of an era aimed at satisfying a specific population of pupils entrusted to judo teachers by their parents, who are often in search of further education. Self-assertiveness, the acquisition and respect of civic values pose social problems in the daily life that the practice of judo offers to solve by building the body and the mind of a new generation of youngsters, confronted with the modification of family structures and the inadequacies of educational systems.

At the turn of the 21st century, judo has been aligned on the model of professional and spectator sports. In the same period, the teaching of the Japanese art has been turned into a consumer product. Yesterday unified, the facets of judo are today sold separately in order to meet consumers' expectations: self-defence and taiso for adults, socio-motor education for children. For a long period of time, judo has had no rivals on the field of educating the youth through sports, but things have changed and it is obvious that the moral code, as a powerful marketing tool, serves the promotion of judo to target parents and their children. Besides its contents, its economic side effects appear as one of the most decisive factors of its global use.

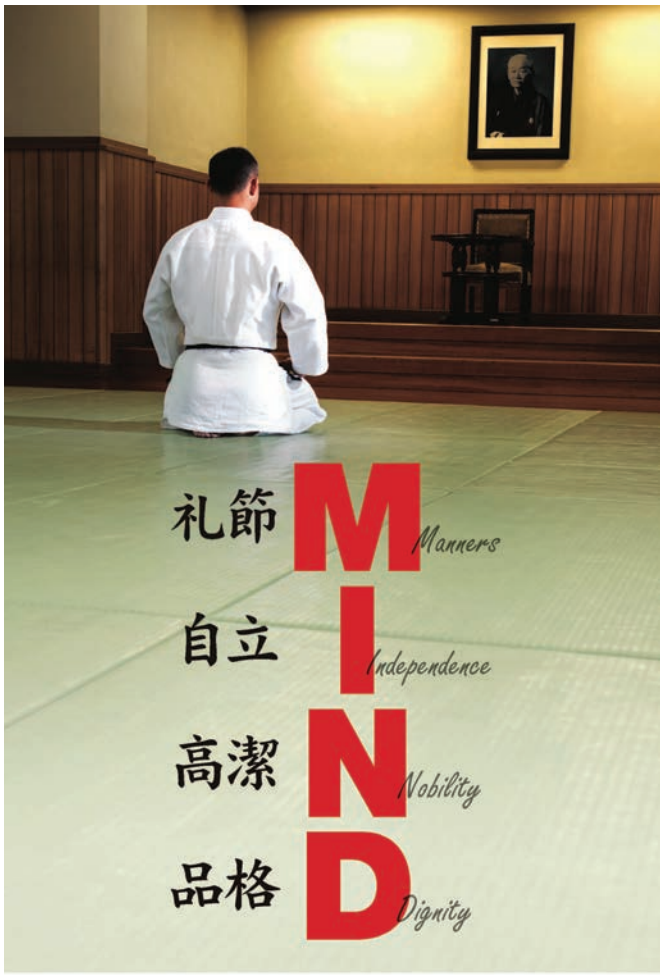
Westernisation of Judo Values

The home country of martial arts, Japan, was confronted with similar problems. Kano himself fought against the western influence and the use of his method from a strictly utilitarian perspective. In his continuous quest for education, he had always wanted to mark a clear distinction between *gedan judo* (judo in the 'narrow sense') and *jodan judo* (judo in the 'wide sense'). He refused judo techniques to be reduced to their efficiency in self-defence or competition (Kano, 2005). For these reasons, Kano never failed to put the stress on his misgivings about judo being a competitive sport. It proved to be a long process and we cannot ignore that the maxims, *jita kyoei* and *seiryoku zenyo*, dating from the founding of the *Kodokan Bunkakai* (Kodokan Cultural Society), on 1st January 1922, precisely forty years after the founding of the Kodokan Institute. Closer to us, in 1979, Shigeyoshi Matsumae was elected President of the IJF. Immediately, the founder of Tokai University faced an increased demand for experts in the development of judo and budo around the world. Thus, he proposed to create the International Budo University and a Budo Charter. The greatest experts were consulted, among them Shinichi Oimatsu and Kisshomaru Ueshiba. The goal was to preserve the expression of Japanese culture.

"*The study of budo encourages courteous behaviour, advances technical proficiency, strengthens the body and perfects the mind. […] budo has attracted strong interest internationally and it is studied around the world. However, a recent trend towards infatuation just with technical ability compounded by an excessive concern with winning is a severe threat to the essence of budo*" (Bennet, 2009, p. 18).

Published in 1987, the *Budo Charter* includes 6 articles:

"*Article (1) Objective of Budo. […] seek to build their character, […] become disciplined individuals capable of making contributions to society at large. Article (2) Keiko (training) […] act with respect and courtesy […], and resist the temptation to pursue mere technical skill rather than strive towards the perfect unity of mind, body and technique. Article (3) Shiai. […] do their best at all times, winning with modesty, accepting defeat gracefully and constantly exhibiting self-control. Article (4) Dojo. […] budo practitioners must maintain discipline, and show proper courtesies and respect […]. Article (5) Teaching. […] Teachers […] should not allow to focus on winning or losing in competition, or on technical ability alone. Above all, teachers have a responsibility to set an example as role models. Article (6) Promoting Budo. Persons promoting budo must maintain an open-minded and international perspective […].*"



AJJF poster

In the words of William Bodiford, the *Budo Charter* "gives a modern Japanese voice to ideals rooted in the 19th century efforts to promote group physical training as a means of transmitting national (and now international) moral values" (Bodiford, 2001). The Budo Charter, which is not a code but a set of precepts, sounds like a modernised vector of the culture and traditions of the classical martial arts. The same is true of the action implemented since 2013 by the Japanese Judo Federation. Following the Renaissance programme initiated by Yasuhiro Yamashita and to respond to the period of strong turmoil experienced by the Japanese federation before the election of Tokyo as host city of the 32nd Olympic Games, the MIND programme was launched. 'Manners, Independence, Nobility, Dignity' (MIND) highlights values that not only stem from Kano's teaching but are also a pure expression of Japanese cultural habits. However, instead of 精神 (seishin), the research group in charge of the MIND programme has preferred an English acronym, as brilliant as it is, not to spread judo culture worldwide but to reach younger generations of Japanese judo players more easily.

Body Control and 'Re-Japanisation' of Modern Judo

As a form of return to the roots, the judo moral code offers for reading, another facet of the evolution i.e. the inscription of the Kano method in what Norbert Elias defined as the social control of violence (Elias & Dunning, 1994.) The existence of a list of values dictating behaviours exercises a power over the bodies. It induces what the German sociologist defines as a generalisation of self-constraint that is both egalitarian, because shared by all, and all the more acceptable as a tradition rooted in the history and philosophy of Japanese judo. The control of bodies and emotions reinforces the hierarchy established by seniority and rank, especially as it is imposed in a system that favours mastery and not sport results.

Widely regarded as arising from Kano's thought, the judo moral code is another example of the 'invention of tradition'. More than its origin or its content, it is its existence, the functions it fulfils and its internationalisation that matter. The globalisation of the judo code inculcates the greatest number of beliefs and dictates modes of behaviour that reinforce the collective identity of the judokas of the world who, in fact, recognise each other and share the same symbols, the same values, the same legends. Simultaneously, the judo moral code reinforces the established hierarchical order of individuals and institutions that define themselves as the only legitimate ones. In *Discipline and Punish*, Michel Foucault shows how physical violence as a mode of repression of the state has regressed to make room for a generalisation of disciplines aimed at the efficiency and docility of subjects in all sectors of society, "*The classical age discovered the body as object and target of power. It is easy enough to find signs of the attention then paid to the body - to the body that is manipulated, shaped, trained, which obeys, responds, becomes skilful and increases its forces*" (Foucault, 1979, p. 136).

By developing a theory of 'biopower,' the French philosopher explains the role of the school, the hospital, the barracks or the factory in bringing under control the "least parcels of life and body". However, judo is not educational in itself. What makes it a powerful tool for building people is the way it is taught, but individual deviances are not exceptional. In the past decades, reports have shown that judo practice, when directed by coaches obsessed by results and ignorant of the values of judo, can lead to severe and even fatal accidents (Burke, 2010).

The origin of the international diffusion of the moral code expresses the political will of the IJF to balance the sporting aspect with the educational. Elected in 2007, Marius Vizer set up an IJF World Tour and established a world ranking list, used to determine Olympic selection. In parallel, decisions were taken to organise 'Judo for Peace' and 'Judo for Children' commissions to promote judo as an educational tool. More specifically, from 2011 onwards, actions such as the 'World Judo Day', an exhibition at the Olympic Museum in Lausanne for the 60th anniversary of the IJF, or the publication of an historical book, *Judo for the World*, were implemented (Brousse, 2015). In the same period, the IJF, with the agreement of the FFJ, sent an English version of the French judo moral code to all its member countries and gave them the opportunity to use it.

The 're-enchantment' of the method Kano expresses will strengthen the connection between today's judo and Japanese spirit and culture. By reinventing martial arts, Kano has helped to preserve the Japanese spirit of Meiji's modern Japanese sports culture. Today, the invention and the worldwide spreading of a judo moral code appears as a Western 're-Japanisation' of modern judo.

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Development of Judo Research
The History of the Scientific Method

By Mike Callan

Abstract: *Taking a chronological perspective, the main events and influences on the development of academic research in judo are explained. Jigoro Kano studied styles of jūjutsu and collected together jūjutsu literature, engaging in a process of discussion, exchanging texts and oral teachings, followed by reflection and analysis. This paper demonstrates that early judo developed through research.*

The Kōdōkan through the Judokai, produced a monthly journal 'Judo' which included a scholarly column on the arts and sciences. This was followed by a new publication, Taisei. Containing topics on strength training and injuries. It could be viewed as one of the first academic journals about judo. From 1922 the regional Kōdōkan Yudansha Association were established and were required to create a Research Division and a Council. The Research Division remit was to report findings and opinions centrally. Later the inaugural meeting of the Kōdōkan Judo Medical Research Group was attended by 9 doctors, the group still exists as the Kōdōkan Judo Scientific Research Group.

The creation of various judo related journals is charted. European research initiatives are outlined including the British Judo Association Technical Conferences, the founding of the European Society for the Scientific Study of Judo in France, the European Judo Union Science of Judo Poster Exhibitions, and the Scientific and Professional Conference on Judo created in Croatia. Further international initiatives outlined include; the first International Science of Judo Symposium in 1999, the International Association of Judo Researchers (IAJR) formation in 2007, and the IJF journal to be launched in 2020.

Key words*: judo, history, Jigoro Kano, research, science*

The founder of judo, Jigoro Kano was an academic. Initially taking a job as a teacher at the Gakushuin school for the sons of nobles, later serving as the Principal of Tokyo Higher Normal College (now Tsukuba University) for 25 years (Hoare, 2009; Waterhouse, 1982). Even as a child at the Seitatsusho Juku, the teacher saw that he was a bright child, and suggested to his father that he study the sciences (Watson, 2000). From the age of 14, as a schoolboy boarder at Ikuei Gijuku, he resolved to learn *jūjutsu* as a riposte to the culture of bullying in the school (Stevens, 2013). It wasn't until 1877 at the age of 17 whilst still a student himself at Tokyo Imperial University, he attempted to deal with his small frame starting his study of *Tenjin Shin'yō-ryū* at the dojo of Hachinotsuke Fukuda (Brousse & Matsumoto, 1999). After only two years, Fukuda sensei invited the young student to demonstrate *randori* at a display for United States President Ulysses S. Grant, who was making a state visit to Japan (Bennett, 2009). Shortly after this, Fukuda sensei passed away, and his widow invited Kano to lead the dojo, giving him the scrolls with the secrets of the *Tenjin Shin'yō-ryū* techniques (Brousse, 2015).

Kano did not feel ready to lead a school, he had much to learn. There is a chapter entitled "*Jujutsu* Research" in the biography "The father of judo" which explains the introduction to Tsunetoshi Iikubo, expert in the *Kito-ryū* style of *jūjutsu* (Watson, 2000). Iikubo sensei extended Kano's understanding of different techniques. Thus, the founder of judo developed expertise by making a detailed study of old forms of *jūjutsu*. Reading all the *jūjutsu* literature he could find, he scoured the old shops purchasing books and antique scrolls. Kano took every opportunity to discuss his extensive research of *jūjutsu* styles, and so he continued to learn through discussion, exchanging texts and oral teachings, followed by reflection and analysis (Callan & Bradić, 2018).

The Frascati definition of Applied research is; "original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective" (OECD, 2015). Therefore, we can see clearly that the very creation of judo is founded on a scientific research process. In fact, Kano refers to judo as "this science" in a lecture in 1889 advocating the introduction of judo into the school curriculum (Kanō & Lindsay, 1889).

What is well known is that on graduation from Tokyo Imperial University, and alongside his demanding job as a lecturer in politics and economics at the Gakushuin, Kano founded two institutions, the Kano Juku, a small private school, and the Kōdōkan "a place to study the way". It

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was with the early members of the Kōdōkan, that Kano was able to continue his practical research and continue to refine judo (Callan, 2017; Onda, 1994). Kano often explained the concept of *jū-no-ri* in biomechanical terms and in many of his explanations about judo he referred to forces, balance and the centre of mass (Kano, 1986; Kano 2005).

In 1899 Kano was sent on a research visit to Europe by the Imperial Household to investigate educational practices (Bennett, 2009). On his return he was appointed as principal at Kumamoto Government College. It was there that Lafcadio Hearn became impressed with Kano and his way of judo. Hearn wrote about this in the chapter 'Jiu-jutsu' in his book 'Out of the East', thus helping to popularise judo in the West (Hearn, 1903). He notes that in the dojo at the Kumamoto Government College, Kano had placed calligraphy written by Count Katsu with the saying "Profound knowledge is the best of possessions". Kano travelled overseas a total of 13 times in his lifetime, taking opportunities to engage in fact-finding, to give lectures, and to disseminate information about judo (Mataruna-Dos-Santos, Alencar de Carvalho, Callan, & Nauright, 2020; Sato, 2013).

In June 1908 as part of the efforts to establish judo in the school curriculum, the Kōdōkan established the Secondary School Judo Research Panel (Watson, 2000). Then in 1914 the Kōdōkan formed the Judokai, which produced a monthly journal "Judo", later renamed in 1919 to "*Yukō no Katsudō*". Kano stated that the new publication would include a scholarly column on the arts and sciences for reference, especially for judo trainees and instructors (Bennett, 2009; Callan & Bradić, 2018). Brousse (2015) explains how Kano met the famous American educator John Dewey in 1919, and Dewey was very impressed with the blend of Zen Buddhist teachings with the laws of physics to create a method of physical, mental and moral development superior to gymnastics (Brousse, 2015; Dewey, 1997).

1922 was an important year in the development of judo. Kano himself joined the House of Peers (Kizoku-in), one of the two houses in the Japanese Parliament and also the Privy Council. The Kōdōkan renamed the Judokai as the Cultural Council (Kōdōkan Bunkakai) on January 1st, and Kano presented the concepts of *Seiryoku Zen'yō* and *Jita Kyōei* for the first time, some 40 years after the founding of the Kōdōkan (Callan, 2008; Callan, 2018a). Two of the prescribed tasks of the Bunkakai were to publish journals and books, and to hold lectures and seminars. A new publication was launched, "Taisei". Containing topics including 'How can we train to strengthen our bodies?' and 'What kind of injuries occur in judo?' and could be viewed as one of the first academic journals about judo (Bennett, 2009; Callan & Bradić, 2018). Also, in 1922, Kano developed a system of regional *yudansha*, the Kōdōkan Yudansha Association (KYA). Article 6 of the regulations states: "Each regional KYA must create a Research Division and a Council. The Research Division is charged with researching judo and must report findings and opinions to the Central KYA" (Bennett, 2009). So, in the same year, Kano had created a regionalised research infrastructure, and a journal in which to publish the outcomes of that research.

In 1926 Kano established The Kōdōkan Koenkai (Support Society) in order to build a sponsorship base for the Kōdōkan. President Go Seinosuke wrote to potential donors, the letter includes the fact that "there are scholars in physical education departments at universities fervently researching the benefits of judo training" (Bennett, 2009). The Kōdōkan continued its research activities and in 1932, the inaugural meeting of the Kōdōkan Judo Medical Research Group was held in the Gakushi Kaikan in Kanda (Bennett, 2009). Attended by 9 doctors, they were tasked to investigate 12 research areas including:

1. Warming-up and cooling-down exercises
2. Instruction for youth during the period of physical development
3. The medical effects of *kan-geiko* and *shochū-geiko*
4. Influence of judo on physiological development
5. *Seiryoku Zen'yō Kokumin Taiiku no Kata*
6. Bone and joint stress from each technique
7. Medical effects of unconsciousness
8. *Atemi*
9. Judo injuries
10. Statistical analysis of life expectancy of judo students
11. *Dōjō* hygiene
12. Medical considerations of women's judo.

The group still exists as the Kōdōkan Association for the Scientific Studies on Judo. They continue to publish research in the Bulletin of the Association for the Scientific Studies on Judo (Kodokan, 1958).

Following the Second World War, The Americans established the General Headquarters (GHQ) to run Japan, and they banned the use of the term "*budō*", and the practice of all *budō* including judo in schools and community clubs in November 1945 (Guttmann & Thompson, 2001). However, as a private institution, rather than a public school, the Kōdōkan was allowed to continue to operate (Hoare, 2009). GHQ finally officially lifted the ban on judo in schools on 13 October 1950. Although the term "*budō*" was not officially accepted again until 1989, the Japanese government established the Nippon Budokan Foundation, for the study of traditional *budō* arts in 1961 (Nippon-Budōkan, 2009).

There are many examples of academic explanations of judo appearing in the literature. Notably, Douglas Mann (London Budokwai) introduced the topic of "Judo and Science" in the 1949 Budokwai bulletin (Mann, 1949). Moshe Feldenkrais was one of the early researchers based in Europe. In the same bulletin he published "Research work at the Budokwai", about transfer of training, and

correct actions of techniques (Feldenkrais, 1949, 1950). The “Annuaire Officiel du Judo International” (International Judo Official Yearbook) was first published in 1948 by Henri Pleé. Chapter 1 deals with the history of sciences, arts and philosophies related to judo (Pleé, 1948). In the 1950’s authors published research papers with the affiliation ‘Kodokan, Society for Scientific Research of Judo’ (Igai, Masuda, & Ogawa, 1956a, 1956b). In 1960 Kato published a review of the development of Japanese Physical Education research (Kato, 1960).

Judo research in Europe continued apace. Having only been established in 1948, in the 1950s the British Judo Association held Technical Conferences with scientific topics including physiology and mechanics. In 1957, Robert Smith published “Notes of Judo Research” (Smith, 1957). In France, the European Society for the Scientific Study of Judo (ESSSJ) was founded by Professor Michel Brousse in 1989 (Goodger, 1989). The Bulletin of the Association for the Scientific Studies on Judo was first published by the Kōdōkan in 1958. Nine studies were presented on the topics:

1. Physiological Studies on choking in Judo - Part I Studies in General
2. Physiological Studies on choking in Judo - Part II X-ray Observations on the Heart
3. Medical Studies on choking in Judo, with Special Reference to Electro-encephalographic Investigation
4. The Kinetics of Judo
5. Studies on Reflex Action in Judo
6. Energy Metabolism in the Fundamental Throwing Techniques of Judo
7. Survey on Public Interest in Judo with Consideration to Age
8. The Effect of Judo on Blood Pressure
9. Various Forms of Injury Caused by Judo

Authors were drawn from 8 universities (Tokyo University, Tokyo University of Education, Tokyo Jikei-kai Medical School, Nihon Medical School, Tokyo, Ochanomizu University Tokyo, Department of Orthopaedic Surgery, Nippon Medical School, Tokyo University of Education, Tokyo Medical-Dental University), all in the Tokyo area, and is indicative of the amount of judo research that was prevalent in Japan at that time. In the preface, Risei Kano explains that the research brief had widened to psychological and educational matters from a narrower medical focus.

The Japanese Academy of Budo was established in 1968 and continues to lead the organisation of academic research in judo within Japan. The 50th Anniversary Conference of the Japanese Academy of Budo was held in Osaka in 2017, in partnership with the International Association of Judo Researchers and the International Martial Arts and Combat Sports Scientific Society (Itoh & Takahashi, 2018). Online academic journal Archives of Budo was first published in 2005 and the Journal of Combat Sports and Martial Arts was first published in 2010, both of these are published in Poland, where there is an active judo research community. A scientific literature analysis published in Archives of Budo in 2013 retrieved 383 judo related scientific reviews and original papers from 162 journals across 78 Web of Science categories (Peset Mancebo et al., 2013). Canadian Wayland Pulkkinen published “The sport science of elite judo athletes” in 2001, presented as a comprehensive literature review on judo training, performance and athletes, it focusses on medical, physiological, biochemical and psychological adaptations related to judo (Pulkkinen, 2001). Worthy of note is the significant contribution to judo research by Professor Attilio Sacripanti from Italy, since 1989 when his work on the biomechanics of judo was published (Sacripanti, 1989, 2010).

In 1999 the IJF held the first International Science of Judo Symposium, alongside the Senior World Championships in Birmingham, having appointed two IJF Research Commissioners, Professor Michel Brousse and Dr David Matsumoto (Brousse & Matsumoto, 1999). There were further IJF Research Commission led Symposia at the Senior World Championships in Munich 2001, Osaka 2003, Cairo 2005 and Rio de Janeiro 2007 (Del Vecchio & Franchini, 2007; Sikorski, 2005). In 2007 in Rio de Janeiro, the International Association of Judo Researchers (IAJR) was formed via the initiative of Professor David Matsumoto with support from Professor Yasuhiro Yamashita. Professor Matsumoto’s research into match outcomes for the wearer of the blue judogi led him to create an independent research organisation for judo. The founding officials were: Dr Mike Callan (Great Britain) President, Professor Emerson Franchini (Brazil) General Secretary, Professor Takeshi Nakajima (Japan) Treasurer, Professor Michel Brousse (France) and Professor Taketo Sasaki (Japan) were Executive Officers. Dr David Matsumoto (USA) was elected as Honorary Vice President. The International Association of Judo Researchers, with the support of the International Judo Federation, organised symposia alongside the Senior World Championships in Rotterdam 2009, Tokyo 2010, Paris 2011 and Rio de Janeiro 2013.

In 2010 the European Judo Union instigated the EJU Science of Judo Poster Exhibition. The Iberian Association of Researchers in Judo (AIBIJ) was founded around 2013 by eminent professors Jose Manuel Garcia Garcia (University of Castilla-La Mancha), Vincent Carratala (University of Valencia) and Luis Monteiro (Lusófona University of Sciences and Technology). The Scientific and Professional Conference on Judo: “Applicable Research in Judo” was created in Croatia in 2014 hosted jointly by the Faculty of Kinesiology University of Zagreb, and the Croatian Judo Federation and supported by the European Judo Union, the conference continues to make a significant contribution to judo research and is led by Professor Hrvoje Sertic (Callan, 2018b; Simenko, 2019).

In 2016 Professor Emerson Franchini from the University of São Paulo’s School of Physical Education & Sports

(EEFE-USP) was recognised as the leading judo-related researcher in the world by publications (Franchini, Brito, Fukuda, & Artioli, 2014; Franchini & Julio, 2015; Franchini et al., 2017). He was awarded a symbolic bronze medal due to ranking third worldwide by authorship of scientific articles on Olympic sports published in indexed journals, according to the Olympic Research Medals Dashboard. An analysis of Olympic Research was carried out by Wizdom.ai, in judo they claimed 1186 researchers from 53 countries had published 729 publications between 1934 and 2018 indexed by PubMed and CrossRef (wizdomai, 2018).

As the 2020 Olympic Games returns to Tokyo, the judo competition will once again be held in the iconic Nippon Budokan (Nippon-Budōkan, 2009). At the initiative of the IJF President Mr Marius Vizer, and through the tireless efforts of Croatian Judo Federation President Dr Sanda Čorak, the IJF will use the occasion to launch the academic journal "The Arts and Sciences of Judo". This global publication will bring together the leading judo research from across the world in a format accessible for academics, coaches, officials, athletes and the whole judo family.

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High-Intensity Interval Training in Judo *Uchi-komi* Fundamentals and Practical Recommendations

By Emerson Franchini

Abstract: *Judo is characterised by high-intensity actions (e.g., attacks, defensive actions and counter-attacks, in both standing and ground positions), interspersed with low-intensity actions (e.g., displacement without contact) or pause (e.g., referee stoppage), resulting in an intermittent activity. Thus, high-intensity interval training (HIIT) is part of judo-specific training and used as complementary training. Consequently, a proper HIIT prescription can benefit high-level judo athletes. Indeed, a recent systematic review (Franchini et al., 2019a) reported that HIIT was able to improve the aerobic and anaerobic fitness of combat sport athletes, including judo athletes, while maintaining athletes' body mass. HIIT can be divided into four main protocols: HIIT short-intervals, HIIT long-intervals, repeated sprint training (RST) and sprint interval training (SIT) (Buchheit and Laursen, 2013a and b). The assessment of physiological indexes (intensity associated with the maximal blood lactate steady state, maximal oxygen consumption, and maximal sprint) or of time-motion variables (high-intensity actions, low-intensity actions, effort-pause ratio) are key elements for a better prescription of each of these four HIIT protocols and to a better individualisation of the training loads imposed on the athletes (Buchheit and Laursen, 2013a and b; Julio et al., 2019). During judo training sessions, uchi-komi (technique repetition without throwing the opponent) is one of the most-executed exercises by high-level judo athletes (Franchini & Takito, 2014). Thus, this article presents a proposal for HIIT prescription for judo athletes, exemplifying with different HIIT protocols (HIIT short-intervals, HIIT long-intervals, RST, SIT, and based on judo-specific time-motion), using uchi-komi as the exercise mode and the parameters for the individualisation of these protocols.*

Key words: *specificity; physiology; intermittent; exercise prescription*

Judo is a high-intensity, intermittent, grappling, combat sport, in which performance is determined by technical-tactical skills (Franchini et al., 2008), physical fitness (Franchini et al., 2011; Torres-Luque et al., 2016), psychological aspects (Ziv & Lidor, 2013) and nutritional and body management support (Pettersson et al., 2012). To better understand the physiological demands of competitive judo, several approaches have been used, but the main strategies to increase knowledge concerning the physiological needs of top level athletes include: (1) To investigate the physiological profile of elite athletes and to compare them with lower level athletes (Franchini et al., 2005). (2) To determine the time-motion analysis of top level competitions (Miarka et al., 2016). (3) To conduct physiological measurements in simulated or official competitions (Franchini et al., 2019b).

Moreover, the number of publications reporting the time-motion analysis of judo competitions also increased considerably and now it is possible to retrieve information about the time-motion of different levels of competition and from different phases of combats, including the displacement without contact (Miarka et al., 2012), grip dispute (Calmet et al., 2010), direction of attacks (Camargo et al., 2019), type of throwing techniques executed (Martins et al., 2019), transition from standing (*tachi-waza*) to the ground combat (*ne-waza*) and the techniques used in *ne-waza* (Nagai et al., 2019). In general, nearly 50% of valid combat time is spent in grip dispute and the work-to-rest ratio is around 2:1 to 3:1 (around 20 to 30s of effort and 7 to 10s of pause) (Franchini et al., 2013a). Due to instrumentation characteristics, judo energy systems contributions were determined in simulated matches only and described as being predominantly oxidative, although the scoring actions rely heavily on anaerobic sources: ATP-PCr = 21%; Glycolytic = 8%; Oxidative = 70% (Julio et al., 2017).

Thus, to achieve success in judo, athletes need to develop both aerobic and anaerobic pathways to cope with the demands of the action during the matches. High-intensity interval training (HIIT) has been reported to be able to develop the different energy systems in a time-efficient approach (Buchheit & Laursen, 2013a and 2013b). Indeed, the use of HIIT in Olympic combat sports, including judo, was recently reported to be efficient at improving both aerobic and anaerobic fitness of judo athletes (Franchini et al., 2019a). The understanding of physiological responses to judo-specific HIIT sessions, is a key element needed to improve the training prescription, while guaranteeing that the specificity principle is assured (Baudry & Roux, 2009). In the present review, the main HIIT protocols, its acute and chronic physiological responses and performance responses, are summarised and indications on how to prescribe them using *uchi-komi* (technique repetition without throwing the partner) are reported. The *uchi-komi* was chosen because this is one of the most used judo-specific exercises executed by high level judo athletes (Franchini et al., 2014; Franchini & Takito, 2014).

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High-Intensity Interval Training Protocols

Although there are different classifications of HIIT protocols, the one proposed by Buchheit & Laursen (2013a) has gained popularity among researchers and coaches due to its scientific basis and practical applications. Table 1 presents a synthesis of the four protocols suggested by these authors and the main variables that can be manipulated to organise a HIIT session.

Table 1: Variables and physiological parameters used as references during different types of high-intensity interval training (based on Buchheit & Laursen, 2013a,b).

Variable	HIIT long intervals	HIIT short intervals	RST	SIT
Effort duration	1 to 3 min	15 to 60 s	3 to 8 s	20 to 30 s
Effort intensity	90-100% $iVO2_{max}$	100-120% $iVO2_{max}$	120-170% $iVO2_{max}$	All-out (~120-180% $iVO2_{max}$)
Pause duration	< 2 min (if passive) ~ 4 min (if active)	< 15 s (if passive) 15 to 60 s (if active)	20 to 60s	2 to 4 min
Pause intensity	Passive Active (40-60% $iVO2_{max}$)	Passive Active (30-40% $iVO2_{max}$)	Passive Active (30-40% $iVO2_{max}$)	Passive Active (30-40% $iVO2_{max}$)
Sets	4 to 10	10 to 20	10 to 20	4 to 8
Effort-pause ratio	1:1 up to 4:1	1:1 up to 2:1	> 1:8	> 1:8

$iVO2_{max}$ = intensity associated with maximal oxygen consumption; HIIT = high-intensity interval training; RST = repeated sprint training; SIT = sprint interval training; ~ = approximately.

Briefly, the protocols proposed are:

(1) High-intensity interval training using long intervals, with intensities equivalent to or just below maximal aerobic power, applying effort duration longer than one minute and work-to-rest ratios of 1:1, 1:2 or 1:3, mainly focusing on aerobic power and the anaerobic systems development.

(2) High-intensity interval training using short intervals, with intensities equivalent to or just above maximal aerobic power (up to approximately 120-130%), applying effort duration shorter than 1 minute and work-to-rest ratios of 1:1, 2:1 or 3:1, mainly directed to develop aerobic power and the anaerobic systems.

(3) Repeated sprint training (RST), using very short actions (5–8 s) at intensities around 120–160% $VO2_{max}$, with very long recovery periods (40-60s) and directed to neuromuscular and metabolic development frequently needed in team sports, but also in some combat sports.

(4) Sprint interval training (SIT), using four to six 30-second all-out efforts separated by 3 to 4-minute intervals, allowing for a full recovery, but resulting in very high aerobic and anaerobic demands

Ideally, to properly prescribe the first three protocols above, strength and conditioning professionals should have the following parameters in the exercise mode chosen for the training sessions: (1) maximal sprint speed or power, (2) maximal aerobic speed or power, (3) maximal lactate steady state speed or power or other submaximal index (e.g., critical power or velocity, ventilatory thresholds, lactate thresholds, onset of blood lactate accumulation, respiratory compensation point) and its associated intensity in terms of velocity or power.

It is important to consider that in the last decades, many combat-sport-specific tests were created and validated (Chaabene et al., 2018) and these tests can be used to prescribe sport-specific protocols, which is extremely important given that specificity is a key training principle (Issurin, 2010). For the HIIT long intervals, it has been reported that using deltas between the submaximal index and the maximal aerobic power can result in better training individualisation (Lansley et al., 2011), another key training principle (Issurin, 2010). For example, during cycling, Lansley et al. (2011) reported that the use of delta between the gas exchange threshold and $VO2_{max}$ (either the delta 40% or the delta 80%) reduced the inter-subject variability in physiological responses, therefore resulting in a better individualisation than using a fixed percentage of $VO2_{max}$ (i.e., either 50%, 70% or 90%). Thus, a similar approach is recommended when using judo-specific tasks. Additionally, a recent study (Julio et al., 2019) utilised the concept of anaerobic speed reserve during running, i.e., the difference between maximal sprint speed and maximal aerobic speed, to determine individualised running velocities to be used in supramaximal sprints. These authors demonstrated that the use of delta intervals using the anaerobic speed reserve resulted in lower variation in time limit (41% to 55% less variation) and blood lactate (51% to 53%), compared to the traditional use of supramaximal loads calculated using solely the maximal aerobic speed. Therefore, it is important to determine the anaerobic speed reserve using judo-specific tasks to prescribe HIIT short intervals and RST properly (Franchini, 2020).

As the SIT protocol is based on all-out efforts, no previous tests are needed, but the strength and conditioning professionals should consider that this protocol is not similar to the time-motion analysis of judo matches (Franchini et al., 2013a; Miarka et al., 2012) and should be used only when a high metabolic stress is desired.

Another approach frequently used in combat sports is to organise the HIIT protocol using the time-motion structure as the reference (Franchini et al., 2016a and b), which cannot ever be allocated easily to one of the four classifications proposed by Buchheit & Laursen (2013a).

Acute Physiological and Performance Responses to Judo-specific High-Intensity Interval Protocols

Uchi-komi is one of the main judo-specific exercises used for both athlete's conditioning and technical development (Franchini et al., 2014; Franchini & Takito, 2014). Athletes normally perform *uchi-komi* in several sets, using basic entry repetition (*hikidashi*) or using their favorite technique (*tokui-waza*), frequently changing roles as *tori* (the one executing the technique) and *uke* (the one receiving the technique), which normally results in a 1:1.5 work-to-rest-ratio (Franchini et al., 2014; Franchini & Takito, 2014). Despite its frequent use, only two studies were found that investigated the performance and physiological responses to high-intensity interval *uchi-komi* (Baudry & Roux, 2009; Franchini et al., 2013b).

Baudry & Roux (2009) engaged ten adolescent judo athletes to a judo-specific circuit, mainly comprising uchi-komi. The athletes performed 6 x 40s of all-out effort with 40s, 120s or 200s rest interval, i.e., 1:1, 1:3 and 1:5 work-to-rest ratio. The following exercises were executed in each set: (1) *hikidashi*, (2) *hikidashi* + *seoi-nage uchi-komi*, (3) *seoi-nage uchi-komi*, (4) *hikidashi* + *seoi-nage nage-komi* (technique entrance throwing the opponent), (5) *seoi-nage nage-komi*, (6) *seoi-nage uchi-komi* + *nage-komi*. The authors measured blood lactate and heart rate during each protocol. The final heart rate did not differ significantly between the protocols (1:1 = 179 ± 8 bpm; 1:3 = 184 ± 6 bpm; 1:5 = 177 ± 11 bpm), indicating a similar overall cardiovascular stress during the sessions, even though the heart rate was lower in the 1:5 protocol during the circuit session when compared with the other two protocols, due to the longer recovery time, which resulted in lower heart rate values at the end of the intervals. Thus, those coaches who would like to keep a lower heart rate variation and a higher overall heart rate during this kind of circuit are advised to use the 1:1 work-to-rest ratio. For the blood lactate concentration, the 1:1 and 1:3 protocols did not differ concerning the peak value (10.3 ± 2.6 and 10.3 ± 2.5 $mmol.L^{-1}$, respectively), but were higher than the peak value for the 1:5 protocol (7.1 ± 3.3 $mmol.L^{-1}$). Indeed, these differences started to be significant from the second set to the end of the circuit. Due to the physiological demands of the 1:1 protocol (i.e., higher overall heart rate and blood lactate), a lower number of repetitions was observed from the third set, compared to the 1:5 protocol. Additionally, 1:3 also resulted in a lower number of repetitions, compared to the 1:5 protocol in the fifth and sixth sets. These results suggest that the longer interval likely allowed a higher phosphocreatine resynthesis and blood lactate removal, decreasing the subsequent glycolytic and oxidative activation, while the short interval protocol may have increased the oxidative participation as a consequence of an accelerated oxygen uptake kinetics. Thus, coaches can use the 1:1 and 1:3 protocols when a higher glycolytic and oxidative activation is desired, whereas the

1:5 protocol can be used when a less glycolytic activation is warranted and a higher phosphagen system activation and a higher number of repetitions are the goals.

The other study (Franchini et al., 2013b) used *uchi-komi* exclusively, using three different techniques: one leg technique (*ashi-waza*, *o-uchi-gari*), one hip technique (*koshi-waza*, *harai-goshi*) and one arm technique (*te-waza*, *seoi-nage*). Additionally to the different classifications, these techniques were chosen because the *o-uchi-gari* requires only a frontal displacement, whereas both *harai-goshi* and *seoi-nage* require a rotational displacement and these later techniques differ from each other in terms of the supporting leg (one foot for the *harai-goshi* and two feet for the *seoi-nage*) and the knee flexion (higher in the *seoi-nage*, when compared with the *harai-goshi*). Three different time structures were used: 18 x 10s:10s, 9 x 20s:20s and 6 x 30s:30s, totaling the mean duration of judo match duration in international competitions (i.e 3min, considering that many matches finish before the time limit due to *ippon* occurrences) and a work-to-rest ratio of 1:1 in all protocols. Efforts were performed with maximum effort and passive recovery was used in the intervals. Thus, ten adult judo athletes were tested across nine different protocols. Heart rate, blood lactate and oxygen consumption were the physiological measurements recorded, whereas the energy expenditure was estimated, based on oxygen consumption during the exercise, intervals and post-exercise phase and blood lactate, and number of repetitions per set and the total were used as performance indicators. As expected, athletes executed a higher number of repetitions in the *o-uchi-gari* exercise, when compared with the *seoi-nage* and *harai-goshi* conditions, with a higher number of repetitions in the first minute than in the second and third minutes and higher in the second compared to the third minutes independently of technique and time structure. However, there was no difference concerning the number of repetitions in the different time structures adopted. Heart rate increased from the first to the second minute and from the second to the third minute independently of technique and time structure adopted, but did not differ between techniques and time structures. Oxygen uptake also increased from the first to the second minute and from the second to the third minute in all conditions. Moreover, higher oxygen uptake values were achieved in the 10s:10s protocol when compared with the 30s:30s protocol. Blood lactate only differed between minutes, i.e. lower values in the first minute than in the second and lower values in the second when compared with the third minute. Absolute, total energy expenditure was not influenced by technique or time structure. However, when energy expenditure was expressed relative to the number of repetitions, *o-uchi-gari* resulted in lower values than the *seoi-nage* technique. The decrease in the number of repetitions across the minutes of exercise is likely to be due to a decrease in the anaerobic pathways contributions (i.e. a decrease in the glycolytic participation due to the hydrogen ions and inorganic phosphate accumulation and an inability to restore, during the intervals, all the phosphocreatine degraded during the effort period) and an increase in the oxidative contribution. As the effort was all-out, the physiological responses were similar across techniques, which may be a result of a compensatory effect concerning the number of repetitions, i.e. as *o-uchi-gari* was performed a higher number of times during each protocol, a similar physiological demand was achieved between techniques. The shorter intervals in the 10s:10s condition allowed the oxygen uptake to remain elevated and resulted in an overall higher oxygen uptake during the effort phases of this condition when compared with the 30s:30s, suggesting that this approach can be useful when coaches would like to provide a higher maximal aerobic power stimulus to their judo athletes. A higher relative energy expenditure (kJ/rep) in the *seoi-nage* condition compared with the *o-uchi-gari* condition indicates that when a fixed number of repetitions is established and the coach would like to induce a higher energy expenditure, a more complex technique, like the *seoi-nage*, could be used. However, when the all-out approach is used, no difference is observed in the total absolute energy expenditure, due to the compensatory effect described above. Another important aspect to be considered is that heart rate did not differ between techniques, whereas the relative energy expenditure did, suggesting that heart rate cannot be as useful a variable to prescribe HIIT using *uchi-komi* as exercise mode. Moreover, these *uchi-komi* protocols induced heart rate and oxygen uptake values similar to those observed in judo match simulations and official matches (Franchini et al., 2013a; Julio et al., 2017), but with lower blood lactate values compared to judo matches, indicating that the inclusion of grip dispute would be needed to increase the glycolytic participation.

Chronic Physiological and Performance Responses to High-Intensity Interval Protocols in Judo Athletes

Despite the intermittent nature of judo, few studies have investigated the effects of HIIT on judo athletes physiological and performance responses (Bonato et al., 2015; Borowiak et al., 2014; Franchini et al., 2016a and b; Kim et al., 2011; Lee et al., 2015; Norkowski et al., 2014) and among these investigations, some did not include a control group of athletes performing judo-only training (Bonato et al., 2015; Borowiak et al., 2014) and most used non-specific training modes or tests (Bonato et al., 2015; Borowiak et al., 2014; Kim et al., 2011; Lee et al., 2015; Norkowski et al., 2014), which makes it difficult to apply their findings to judo-specific performance.

Kim et al. (2011) compared a resistance training plus judo training group (resistance training) with a HIIT plus judo training group (HIIT group), during 8 weeks. The judo training involved traditional sessions 5 times per week, totaling 10h per week. The resistance training was conducted 4 times per week, totaling 7 h per week, but no details about the loads, sets and exercises were provided. The

HIIT was composed of 30s efforts separated by 4 minute intervals, performed 4 times per week. They performed 6 sprints at 80% of the maximal aerobic velocity in the first two weeks and at 90% of the maximal aerobic velocity thereafter, executing 8 sprints between weeks 3 and 4 and 10 sprints in weeks 5-8. Kim et al. (2011) did not find any change in the maximal oxygen consumption, suggesting that for high level judo athletes, this protocol seems to be effective only when more than 8 weeks of training is executed. However, they observed an increase in peak (pre = 12.84 ± 1.33 W.kg-1; post = 15.46 ± 1.68 W.kg-1) and mean power (pre = 9.43 ± 1.10 W.kg-1; post = 12.14 ± 2.12 W.kg-1) during the Wingate test for the HIIT group but not for the resistance training group (peak power pre = 12.86 ± 1.93 W.kg-1; post = 13.88 ± 2.27 W.kg-1; mean power pre = 9.19 ± 1.67 W.kg-1; post = 9.65 ± 3.15 W.kg-1), indicating that 8 weeks of this protocol was effective to improve judo athletes anaerobic power and capacity when the HIIT was added to the usual judo training. These authors also analysed the heart rate response to a 5-min judo match simulation but did not find any change for any group.

Using a similar approach, Lee et al. (2015) compared three judo athletes groups engaged in judo training only (control group), resistance training added to judo training (resistance training group) and HIIT plus judo training (HIIT group) for 12 weeks. The judo training involved traditional sessions 5 times per week, totaling 10h per week. The resistance training consisted of 2 x 12 reps at 70% one-repetition maximum (1RM) during the first two weeks, 3 x 12 reps at 80% 1RM in weeks 3-8 and 4 x 12 reps at 80% 1RM in weeks 9-12, for the leg curls, leg deadlift and cable one-leg curl exercises on Mondays and Tuesdays, with squat, leg extension, leg press and lunge exercise on Thursdays and Fridays. The HIIT comprised of 30s efforts separated by 4 minute intervals, performed 4 times per week. They performed 6 sprints at 80% of the maximal aerobic velocity in the first two weeks and at 90% of the maximal aerobic velocity thereafter, executing 8 sprints between weeks 3 and 8 and 10 sprints in the weeks 9-12. The authors found a higher increase in the maximal oxygen consumption for the HIIT group (from 49.88 ± 4.30 mL.kg-1.min-1 to 54.39 ± 4.32 mL.kg-1.min-1) when compared with the control group (from 46.56 ± 2.62 mL.kg-1.min-1 to 48.74 ± 2.61 mL.kg-1.min-1), indicating that the high-intensity interval training programme was effective for increase the athletes' aerobic power.

Bonato et al. (2015) submitted 9 judo athletes to 12 weeks of training; six weeks comprised judo and resistance training, whereas the other six weeks were for judo and aerobic training. The initial six weeks of training involved 4 hours per week of resistance training and 14 hours of judo training, while the last six weeks kept this training protocol and added three aerobic training sessions per week. The aerobic training lasted 30 min, with two continuous exercises at 60% of the maximal aerobic speed and one HIIT session, comprising fifteen 1-min sets at 90% of the maximal aerobic speed, with 1 minute intervals at 60% of the maximal aerobic speed. The main limitations of this study were the absence of evaluation after the initial six weeks and the fact that no control group was used. However, this study included a judo-specific test, i.e. the Special Judo Fitness Test (SJFT). They found no change in maximal oxygen uptake, although increases (4.6%) in the maximal aerobic speed and in the ventilatory threshold (6.6%) and fast recovery of both oxygen uptake (22%) and heart rate (17.3%) were observed in the treadmill test. Additionally, the SJFT improved by 12%, which was mediated by lower heart rate (7%) and faster heart rate recovery (7%) after this test. Thus, this study suggests that the inclusion of HIIT, together with traditional judo training, may affect judo-specific performance positively.

Taken together, these studies indicate that even submaximal, short and long interval, HIIT can improve aerobic power (when four such training sessions per week during a 12 week period are completed), anaerobic power and capacity (after 8 training weeks) and judo-specific performance (after 12 weeks).

Norkowski et al. (2014) and Borowiak et al. (2014) investigated the effects of repeated sprint training in aerobic and anaerobic physiological and performance responses of judo athletes. Norkowski et al. (2014) used a control group (25 standard judo training sessions) and RST plus judo training sessions (6 x 10s all-out efforts with 45s rest intervals on a cycle ergometer, RST group) to verify the effects of five weeks of these training conditions on peak power and total work during the 6 x 10s:45s protocol. They found a higher improvement in both peak power and total work for the RST group (peak power pre = 11.26 ± 0.41 W.kg-1; post = 12.54 ± 0.72 W.kg-1; total work pre = 96.83 ± 4.70 J.kg-1; post = 106.32 ± 5.05 J.kg-1), compared with the control group (peak power pre = 11.02 ± 1.07 W.kg-1; post = 11.21 ± 0.64 W.kg-1; total work pre = 90.20 ± 3.43 J.kg-1; post = 93.44 ± ± 4.56 J.kg-1). Borowiak et al. (2014) investigated the effects of five weeks of RST, comprising 6 x 10-13s (i.e., all-out 4 x 14 m running performed six times), five times per week on the same days as the usual judo training sessions. This study did not have a control group, which limits its findings. However, they noticed an improvement in the velocity at the anaerobic threshold (pre = 12.25 ± 1.40 km.h-1; post = 13.98 ± 0.90 km.h-1) in a graded treadmill test, peak power (11.42 ± 0.63 W.kg-1; post = 12.51 ± 1.08 W.kg-1) and total work (91.10 ± 11.39 J.kg-1; post = 103.54 ± 11.29 J.kg-1) in the 10s Quebec cycle ergometer test.

Taken together, these studies indicate that RST added to traditional judo training can improve peak power, total work and the anaerobic threshold speed in only five weeks, if the training is performed five times per week.

No study was found using the SIT in judo athletes, as defined by Buchheit & Laursen (2013a). Additionally, it is important to note that the HIIT studies with judo athletes only used running and cycling as exercise modes (Bonato et al., 2015; Borowiak et al., 2014; Kim et al.,

2011; Lee et al., 2015; Norowski et al., 2014) and only one study (Bonato et al., 2015) included a judo-specific test. However, two studies (Franchini et al., 2016a and b) used the judo time structure to create the HIIT for these athletes. One study (Franchini et al., 2016b) presented the aerobic and anaerobic physiological and performance responses, whereas the other (Franchini et al., 2016a) reported the judo-specific physiological and performance responses to HIIT protocols. In these studies (Franchini et al., 2016a and b) four groups were investigated: a control group in which judo athletes performed their usual judo training only, upper-body HIIT in which judo athletes performed two upper-body cycle ergometer training sessions per week plus the usual judo training, lower-body HIIT in which judo athletes performed two lower-body cycle ergometer training sessions per week plus the usual judo training, *uchi-komi* HIIT in which judo athletes performed two *uchi-komi* training sessions per week plus the usual judo training. For all HIIT groups, athletes were required to perform 2 sets of 10 x 20s all-out efforts interspersed with 10s rest intervals, with 5 minute passive recovery between sets. In the *uchi-komi* training, athletes performed a hip technique and threw their partner at the end of each 20s period. Athletes executed these training protocols for only four weeks.

When general tests were used, Franchini et al. (2016b) did not find any change in the maximal oxygen uptake for any group, but the intensity associated with the onset of blood lactate accumulation during the upper-body graded cycle ergometer test increased in judo athletes who performed the lower-body high intensity interval training (from 68 ± 22 W to 83 ± 14 W) and the upper-body maximal aerobic power increased for the upper-body high intensity interval training group (pre = 146 ± 18 W; post = 164 ± 15 W). The authors also found an increase in upper and lower body Wingate test peak power for the *uchi-komi* group (upper-body pre = 8.18 ± 1.33 W.kg-^{1}; post = 9.40 ± 1.06 W.kg-^{1}; lower-body pre = 10.48 ± 1.31 W.kg-^{1}; post = 10.91 ± 1.26 W.kg-^{1}). Moreover, these authors reported increased mean power in the fourth bout of lower-body Wingate test (3-min intervals between bouts) when all HIIT groups were pooled. Typically, the improvement in aerobic power variables is attributed to increases in oxygen delivery (i.e., improved cardiac output) and to oxygen utilisation by active muscles (i.e., arteriovenous difference), which may explain the improvement in the upper-body training group, although no change was observed in maximal oxygen uptake for any group. This may have occurred only for the upper-body training group due to the high upper-body solicitation during judo training, which may have interacted with the HIIT and resulted in such improvement. Conversely, the increase in the upper-body intensity associated with the onset of blood lactate accumulation for the lower-body training group is harder to explain. The interaction between judo training and the *uchi-komi* HIIT could have resulted in an optimal combination to improve the upper-body peak power, whereas the lower stimulus directed to the upper-body in the case of the lower-body training group and an excessive stimulus directed to the upper-body in the case of the upper-body training group may have compromised the adaptation. Similarly, as judo training does not demand an elevated lower-body solicitation, the interaction between the typical judo training and the HIIT directed to the lower-body for the lower-body training group resulted in increased lower-body mean power during the four Wingate tests. The anaerobic adaptations are muscle-specific because many key enzymes' activity are increased as a consequence of this training stimulus (MacDougall et al., 1998).

Concerning judo-specific performance, Franchini et al. (2016a) found an increased number of throws during the SJFT for the upper-body HIIT group (pre = 25 ± 2 rep; post = 27 ± 2 rep), decreased heart rate immediately after the SJFT for the lower-body training group (pre = 181 ± 9 bpm; post = 174 ± 9 bpm), whereas the SJFT index improved for the *uchi-komi* training group (pre = 12.84 ± 1.47 bpm.throw-^{1}; post = 12.07 ± 1.36 bpm.throw-^{1}). These authors also submitted the athletes to a 5 minute judo simulation, but they did not find any change in heart rate, rating of perceived exertion, blood lactate or technical actions for any of the groups. However, the upper-body HIIT group presented a decreased creatine kinase response to the simulated judo match after the training period (pre-training = before the match, 505.6 ± 210.2 U.L-^{1}; after the match = 592.4 ± 248.9 U.L-^{1}; post-training = before the match, 219.8 ± 105.8 U.L-^{1}; after the match, 291.8 ± 170.5 U.L-^{1}), which is likely to be due to the lower muscle mass involvement in this training group. The testosterone-cortisol ratio response to the match was lower pre-training than post-training, when all groups were pooled, suggesting that the HIIT protocols were able to induce a more anabolic state. For the time structure, the lower-body HIIT group presented a decrease in the number of standing combat sequences (pre = 13 ± 2 rep; post = 10 ± 3 rep), which was likely to be due to the aerobic and anaerobic fitness improvements also observed, allowing that more intense techniques could be executed, despite a shorter time in this combat phase (where more scores are achieved). These results suggest that all training groups improved performance, but the adaptations to HIIT differed between exercise modes. For example, the adaptation to the SJFT was different for each group, suggesting that distinct muscle and cardiovascular adjustments occurred for each group. Specifically, the increased number of throws for the upper-body training group may have been a consequence of a better adaptation to the balance-breaking (*kuzushi*) and throwing phase (*kake*) during the *seoi-nage* technique execution, as the phases of this arm technique are mainly influenced by upper-body actions. The decreased heart rate immediately after the SJFT for the lower-body training group was likely to be a result of improved aerobic fitness, due to the higher muscle mass involvement in this exercise mode, which induced a lower cardiovascular demand during the test execution. As the *uchi-komi* training involves large muscle activation using a judo-specific action, the most desirable adaptation occurred for this

group, i.e. a decreased SJFT index, which is a variable related to both aerobic and anaerobic fitness.

Thus, when the typical judo match time structure (approximately 20s effort by 10s intervals) is used to organise the HIIT protocol, it was found that upper-body aerobic performance was affected positively, lower and upper body peak power was increased, judo-specific aerobic and anaerobic fitness were improved and a more anabolic state was induced. However, each exercise mode resulted in slightly different adaptations, which suggests that coaches should pay attention to the exercise mode choice, depending on the adaptation they would like to induce in their athletes.

High-Intensity Interval Training Prescription Using *Uchi-komi* as an Example

Judo athletes perform many different exercises in their training routine, including general and judo-specific exercises (Franchini et al., 2014). However, *uchi-komi* is one of the most used exercise modes, as this is specific, safe and can be used to improve athletes' technical skill, strength, muscle power, speed, strength-endurance, aerobic and anaerobic power and capacity, depending on the intensity and duration prescribed. Most Olympic level judo athletes have reported that they perform static (with a partner in a stationary position) and dynamic (with a partner moving) *uchi-komi* 5-7 times per week, 28 ± 18 minutes per session. Moreover, when asked to rate, using a 0-10 scale, the relevance, effort, pleasure and concentration during different *uchi-komi* modes (i.e., shadow, static, dynamic, strength, and speed), relevance mean values varied form 7 ± 3 a.u. (for the shadow *uchi-komi* for the non-medal winner group) to 10 ± 1 a.u. (for speed *uchi-komi* for the medal winner group), effort varied from 5 ± 3 a.u. (for the shadow *uchi-komi* for the medal winner group) to 9 ± 1 a.u. (for the speed *uchi-komi* for the medal winner group), pleasure varied from 7 ± 2 a.u. (for the shadow *uchi-komi* for the non-medal winner group) to 9 ± 2 a.u. (for the dynamic *uchi-komi* for the non-medal winner group) and concentration varied from 8 ± 2 a.u. (for the shadow *uchi-komi* for the non-medal winner group) to 10 ± 1 a.u. (for the speed *uchi-komi* for the medal winner group) (Franchini & Takito, 2014). Thus, due to its frequent use and relevance *uchi-komi* was used in this article as an exercise mode to exemplify HIIT protocols for judo athletes; specifically, the *hikidashi* version was used as an example because it is a basic movement for different techniques and some tests used it as an *uchi-komi* mode (Del Vecchio et al., 2014; Shiroma et al., 2019). Examples of the four categories of HIIT proposed by Buchheit & Laursen (2013a), as well as the use of the judo-specific time structure are presented below.

The use of mechanical or physiological parameters is paramount for a better HIIT prescription. Ideally, a submaximal (e.g. maximal lactate steady state, critical power or velocity, anaerobic threshold, ventilatory thresholds, respiratory compensation point, lactate minimum), a maximal (e.g. maximal oxygen uptake) and a supramaximal (e.g., maximal sprint speed or peak power) physiological and/or mechanical parameters are necessary for an individualised prescription (Buchheit & Laursen, 2013 a and b). For judo, different submaximal (Azevedo et al., 2007), one maximal (Shiroma et al., 2019) and supramaximal (Del Vecchio et al., 2014) *uchi-komi* tests are available.

The test to determine the lactate minimum intensity during *uchi-komi* used the *ippon-seoi-nage* technique (Azevedo et al., 2007). Briefly, for the lactate minimum intensity determination the athletes performed 40s all-out uchi-komi, then rested for 8 min and then started a graded exercise test composed of 1 minute stages, increments of one repetition each 8s, 7s, 6s, 5s, 4s, 3s, 2s and 1s, with 1 minute intervals for blood lactate measurements. The 40s all-out *uchi-komi* set resulted in elevated blood lactate accumulation and then the initial loads in the graded exercise protocol removed the blood lactate accumulated up to a point where the intensity was too high and blood lactate restarted accumulating; the intensity where the lowest blood lactate is achieved is the lactate minimum, which is a widely used submaximal index to infer the maximal lactate steady state intensity (Azevedo et al., 2007). Shiroma et al. (2019) proposed a graded exercise test to evaluate judo athletes' aerobic power during uchi-komi, using *hikidashi*. These authors demonstrated the test to be reliable and valid and can therefore be used to determine the maximal oxygen uptake and maximal aerobic speed in a judo-specific exercise. Briefly, this test involves 1 minute stages with increments of 3 rep.min^{-1}, with an initial speed of 32 rep.min^{-1}. The test ends by voluntary exhaustion, when the athlete is not able to keep the speed or when he/she cannot execute the repetitions properly. For maximal sprint speed, there is no published test using uchi-komi, but Del Vecchio et al. (2014) proposed the 20s all-out *hikidashi uchi-komi* test, which can be shortened (e.g. to determine the time for 5 all-out *hikidashi* executions).

It is likely that an adaptation from the original proposal of Azevedo et al. (2007), using the *hikidashi uchi-komi* instead of the *ippon-seoi-nage* technique, may not affect the possibility to identify the lactate minimum intensity. Thus, the examples below are based on one submaximal index (adapted from Azevedo et al., 2007), one maximal aerobic power variable (i.e. the maximal aerobic speed, Shiroma et al., 2019) and one maximal sprint speed variable (i.e. the speed in a 5 rep set, adapted from Del Vecchio et al., 2014). The *hikidashi* was chosen because judo athletes frequently execute this version when performing speed *uchi-komi* (Franchini & Takito, 2014), it is easy to execute and is used as a

preparatory movement for other techniques (especially *koshi-waza*) (Shiroma et al., 2019). Based on these variables it is possible to calculate the delta (e.g. 75%, 90%) to better individualise the submaximal training stimulus (Lansley et al., 2011), as well as to calculate the anaerobic speed reserve, which is a parameter recently demonstrated to be able to reduce the inter-athlete variability, therefore providing a better individualisation of high-intensity supramaximal interval training (Julio et al., 2019). The example used is based on results published in the literature, with a male athlete presenting the following performance for the *hikidashi* technique: maximal sprint speed = 95 rep.min-1, maximal aerobic speed = 60 rep.min-1, lactate minimum speed = 42 rep.min-1, anaerobic speed reserve = 35 rep.min-1.

Table 2: A synthesis of the proposed protocols for a hypothetical athlete.

Variable	HIIT long-intervals	HIIT short-intervals	RST	SIT	Judo time structure
Effort duration	1 min	15s	5 s	30 s	20s
Effort intensity	90% of MAS (54 rep.min-1) or delta 75% LM and MAS (~55 rep.min-1)	20% of ASR (67 rep.min-1)	50% of ASR (77.5 rep.min-1)	all-out	all-out
Pause duration	1 min	15 s	40s	4 min	10s
Pause intensity	Passive recovery	40% of MAS (24 rep.min-1)	Passive recovery	30 of MAS (18 rep.min-1)	Passive ecovery
Sets	Up to exhaustion	Up to exhaustion	20	4	12
Effort-pause ratio	1:1	1:1	1:8	1:8	2:1

ASR = anaerobic speed reserve; HIIT = high-intensity interval training; LM = lactate minimum; MAS = maximal aerobic speed; RST = repeated sprint training; SIT = sprint interval training; ~ = approximately.

Each protocol is briefly described below. For this hypothetical athlete, the HIIT using long intervals could be calculated using either the maximal aerobic speed (e.g. 90% of maximal aerobic speed; 54 rep.min-1 in our example) if blood lactate measurements are not available to determine the lactate minimum intensity, or the delta (e.g., delta 75% of the lactate minimum speed and the maximal aerobic speed; ~55 rep.min-1 in our example) if the lactate minimum test can be performed. For this kind of protocol, the athlete could exercise for 1 minute in each set using 1 minute passive recovery intervals. To maximise the time close to the maximal oxygen consumption, which is considered an important aspect for improving aerobic power (Buchheit & Laursen, 2013a and b), the athlete should perform the sets to exhaustion.

As shorter intervals are likely to keep the oxygen uptake elevated during the recovery phase (Baudry & Roux, 2009; Franchini et al., 2013b) and active recovery delays the oxygen uptake decay during the recovery phase (Buchheit & Laursen, 2012 a and b), a HIIT protocol using short intervals could be used, if the athlete desires to guarantee more time close to his maximal oxygen uptake while working at higher speeds, which may benefit them in terms of speed and anaerobic fitness (Franchini et al., 2014). Thus, 15s efforts at 20% of the anaerobic speed reserve (i.e. anaerobic speed reserve x 0.20 + maximal aerobic speed, in our example 67 rep.min-1, nearly 17 repetitions in the 15s effort period) with 15s intervals at 40% of maximal aerobic speed (24 rep.min-1 in our example) up to exhaustion.

The RST is more recommended when the focus is to develop speed and speed-endurance, which are important aspects for success in judo (Franchini et al., 2013a). The protocol proposed involves short burst, high-intensity actions, separated by the typical interval between successive attacks (approximately 40s) in a judo match, when the matte (referee interruption) is added to subsequent attacks performed during the valid time (Franchini et al., 2013a). Thus, the recommendation is to perform 20 sets of 5s at 50% of the anaerobic speed reserve (i.e. anaerobic speed reserve x 0.50 + maximal aerobic speed, in our example 77.5 rep.min-1, 6-7 repetitions every 5s effort period) interspersed by 40s passive recovery intervals, to allow an almost full recovery between sets.

Typical SIT comprises 4 sets of 30s all-out efforts, separated by 4 minute passive recovery or active recovery at 30% of maximal aerobic speed. Typically, there is a decrease in speed or power during this kind of protocol along the sets, as a consequence of the elevated metabolic stress (e.g. high glycolytic activation) generated already in the first set (Franchini et al., 2016c), but it is quite effective for improving both aerobic and anaerobic fitness (MacDougall et al., 1998). Therefore, an example of this protocol is to ask the athlete to perform four 30s all-out efforts and to recover at 18 rep.min-1 for 4 minutes to minimise the negative effects of the metabolites accumulation.

The judo-specific HIIT follows the typical time structure observed in an official judo match (Franchini et al., 2013a), i.e. 20s efforts and 10s pauses, generating a 2:1 work-to-rest ratio. During the effort period, the athlete is requested to perform an all-out effort and has only 10s to recover. The number of sets is 20, to result in 240s of effort, which is the time limit in official judo contests.

For the protocols where the intensity is not fixed (i.e. involving all-out efforts) it is important to register the speed achieved in each set, to allow the identification of the intensity relative to maximal aerobic speed, maximal sprint speed and anaerobic speed reserve, which is paramount to assess the evolution of the athlete along the training period.

Finally, it is important to consider that the studies that investigated the HIIT in judo athletes varied the number of sessions from 2 to 5 per week, but those using higher frequencies (Kim et al., 2011 and Lee et al., 2015) engaged the athletes in this training at the return to the season, for longer periods of training (i.e., 8-12 weeks) and not during the competitive period, while others (Franchini et al., 2016 a and b) used lower frequencies and a shorter period (i.e. 4 weeks of training) to simulate the interval between successive competitions in the international scenario (Franchini et al., 2017). Thus, coaches must consider all other judo athletes' training and competitive activities, allied to the physical fitness profile of a given athlete, before deciding which HIIT is more appropriate for their athlete. Additionally, a recent investigation (Franchini et al., 2019b) demonstrated that the use of HIIT using *hiki-dashi* uchi-komi, similar to that proposed in the present paper, resulted in reduced strength-endurance-related variables (grip dispute duration) and an increased time of low-intensity variables (displacement without contact) in three 4-min judo match simulations, performed 3 minutes after the high-intensity interval training protocol. Therefore, coaches should allocate the HIIT protocol away from the *randori* (match simulation) sessions, to avoid the intensity of relevant actions being affected negatively.

Final Considerations

After an initial analysis concerning the judo characteristics and the specific athlete's needs, HIIT protocols should be prescribed based on physiological and performance parameters, to increase the individualisation of the external and internal load for a given athlete. Additionally, the specificity principle must be considered and judo-specific tests should be used to provide the parameters for the prescription of a judo-specific HIIT protocol. Future research should be conducted to verify the effectiveness of different judo-specific HIIT protocols for different physical abilities and its impact on judo athletes' performance, as well as its effectiveness in different phases of the periodisation.

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Impact of Foot Deformation on Balance of Young Judoka

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Abstract: *Balance is one of the most important motor abilities for execution of throwing techniques in judo, especially among younger judoka in technique learning phase. Practice is pointing out the fact that today's children are more subjected to foot arches deformation for many different reasons. The main goal of this paper is to determine the connection between flat feet and balance among young judoka. 44 female and male judoka, born in the years of 2008. and 2011., were chosen for this research. Participants were assigned to two groups, depending on flat foot grade, which is specified with a clinical test. All participants were measured in three balance tests, on both right and left leg: Standing Stork Test (SST), Modified Standing Stork Test (MSST) and Dynamic Standing Stork Test (DSST). Results are showing significant differences between subject groups in Modified Standing Stork Test and Dynamic Standing Stork Test. There is no significant difference in Standing Stork Test because of the inadequacy of the test for these age categories. This paper proves significant connection between flat feet and balance in judo which has a great impact on application of throwing techniques.*

Key words: *flat feet, motor abilities, judo techniques*

Bones of the foot can be separated in three parts: tarsus (ossa tarsi), metatarsus (ossa metatarsi) and digiti pedis (ossa digitorum pedis), which form the front, side and back parts of the foot. It is the tarsus bones, mainly os naviculare, that are most affected by deformations in flat feet. Flat feet can be classified in three grades. First grade means feet with changes on a muscular level, in other words we refer to the stretching of the muscles on the medial side of the lower leg and deficits in *m. abductor hallucis, m. flexor hallucis brevis, m. flexor digitorum brevis, m. quadratus plantae and m. abductor digiti minimi*. In this stage of deformation, pressure on the surface is achieved with the lateral side of the metatarsal bones. Second grade of flat feet means feet with changes in connective tissues in which the pressure on the surface is achieved with the central part of the foot equally as with the front part of the foot. Third grade consists of feet with changes on a bone level, in other words we refer to the lowering of metatarsal bones and the navicular bone while the pressure on the surface is being achieved by the whole surface of the foot (Garcia-Rodriguez, Martin-Jimenez, Carnero-Varo, Gomez-Aracena and Fernandez-Cerhuet, 1999). Children have open epiphyseal plate growth zones and better flexibility than adults. This has a big effect on the etiology of injury occurrence and deformations. They are prone to faster recovery rates and a possible correction of deformities with a lower possibility of injury and deformity reoccurrence. Ankle, leg and foot injuries have a 21% prevalence in child and adolescent athletes, which points out to the fact that preventive lower extremities strength trainings should be implemented much more often. Anatomical problems, such as flat feet, are one of the risk factors for injury occurrence. Athletes with expressed foot pronation more often have pain in the plantar part of the foot, just as in the longitudinal foot arc area and are more prone to stress fractures of metatarsal bones (Lutter, 1995). Together with coordination, balance is one of the most important abilities for application of throwing techniques in judo, especially among younger age categories in technique learning phase, especially while the techniques are often performed on a single leg. Practice is pointing out the fact that today's children are more subjected to foot arches deformation out of many different reasons and that can present a difficulty in maintaining the dynamic balance, which shows the problem this paper is addressing. For this reason, coaches from one judo club and researchers from Faculty of Kinesiology University of Zagreb tried to establish the connection between the flat feet grade and the results in basic and specific balance tests in young judoka. The results from this research should lead to the setting up the protocol for the prevention and correction of foot defects.

Methods

44 male and female judoka from one judo club in Zagreb, all of them 9 or 11 years old at the time, participated in this research. They were separated in two groups, distributed by the grade of flat feet; first group consisted of judoka without feet deformations and those with changes on a muscular level; second group consisted of judoka with

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changes in connective tissues and those with changes on a bone level. That kind of distribution was based on the possibility of influencing deformities reduction for different grades of foot deformation. Regarding deformities which cause changes on a muscular level, it is possible to completely change the achieved neuro-muscular pattern, just as completely rectify the deformation. On the other hand, in deformations that cause bigger changes on connective tissues and on the bone level, correction of the said structures can be minimal.

Balance has been evaluated with basic balance tests: Standing Stork Test (SST) (Mackenzie, 2005) and Modified Standing Stork Test (MSST) (Segedi, Glavaš & Sertić, 2018); and a specific judo test for balance evaluation: Dynamic Standing Stork Test (DSST) (Segedi, Glavaš & Sertić, 2018).

Grade of flat feet was determined by a clinical test and by palpation of the medial foot arc for a more precise evaluation. For the clinical test, participants were requested to stand on the floor in parallel stance with their feet in hip width and to distribute their weight equally on both feet. The grade of flat feet was determined by inspecting the condition of the feet and by additional palpation.

Participants conducted balance tests barefoot on judo mat. All participants conducted the tests on the same *tatami* with official (IJF approved) characteristics.

STATISTICA 13.4. programme was used for processing and analysis of results. Evaluation of statistical relevance of differences between groups of participants was determined by the multivariate analysis of variance (MANOVA).

Results

Table 1. shows descriptive parameters of conducted tests: Standing Stork test on the right (SSD) and left foot (SSL), Modified Standing Stork Test on the right (MSSD) and left foot (MSSL) and Dynamic Standing Stork Test on the right (DSSD) and left foot (DSSL).

Table 1. Descriptive parameters of conducted tests

Variable	Number of subjects	Mean	Standard Deviation	Variance	Min	Max
SSL	44	3,02	1,96	3,86	1,04	9,84
SSD	44	3,09	1,34	1,79	1,24	7,31
MSSL	44	30,80	19,19	368,10	2,73	60,00
MSSD	44	31,95	18,24	333,05	2,29	60,00
DSSL	44	20,36	18,33	336,15	1,38	60,00
DSSD	44	21,27	18,43	339,54	1,20	60,00

Table 2. Differences in balance tests between male and female participants

	Test	Value	F	Effect df	Error df	p
Gender	Wilks	0,74	2,12	6	37	0,074

Table 3. Differences in balance tests between younger (9 years old) and older (11 years old) participants

	Test	Value	F	Effect df	Error df	p
Age	Wilks	0,79	1,62	6	37	0,17

Results in balance tests presented in Tables 2. and 3. point out the fact that there is no statistically significant difference in balance tests between participants by gender and age criteria.

Table 4. Differences in balance tests between two groups of participants with different grades of foot deformation

	Value Wilks	F	Effect df	Error df	p
Feet	0,62	3,71	6	37	0,005

Results shown in table 4. point out the differences between participants separated in two groups by the grade of flat feet. Statistically significant difference wasn't determined in the Standing Stork Test (SSTD p = 0,71; SSTL p = 0,25) (Figures 1. and 2.), while it was significant in the Modified Standing Stork Test (MSSD p = 0,004, MSSL p = 0,03) (Figures 3. and 4.) and Dynamic Standing Stork Test (DSSD p = 0,001, a DSSL p = 0,0005) (Figures 5. and 6.). Since balance in judo is manifested mostly in dynamic conditions it can be said that the results in Dynamic Standing Stork Test are the most relevant for specific judo movements. While the participants' results are somewhat similar in certain static balance tests, differences significantly increase in dynamical conditions which clearly points out that feet deformations can significantly affect balance and by that also and judo technique performance in specific and situational conditions.

Figure 1. Differences between groups of participants in Standing Stork Test for the right foot (SSTD)

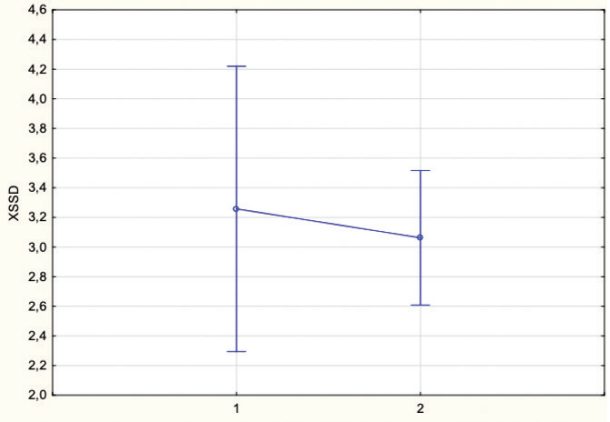


Figure 2. Differences between groups of participants in Standing Stork Test for the left foot (SSTL)

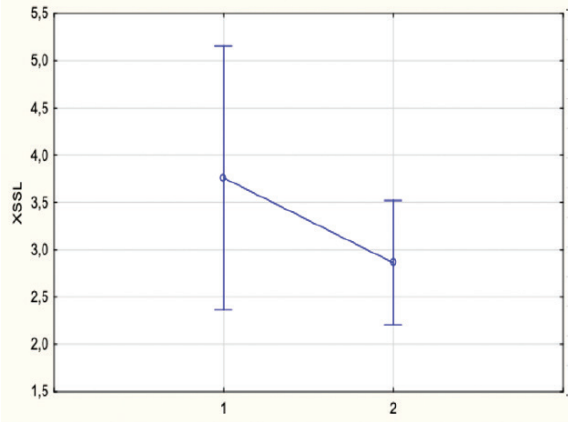


Figure 3. Differences between groups of participants in Modified Standing Stork Test for the right foot (MSSD)

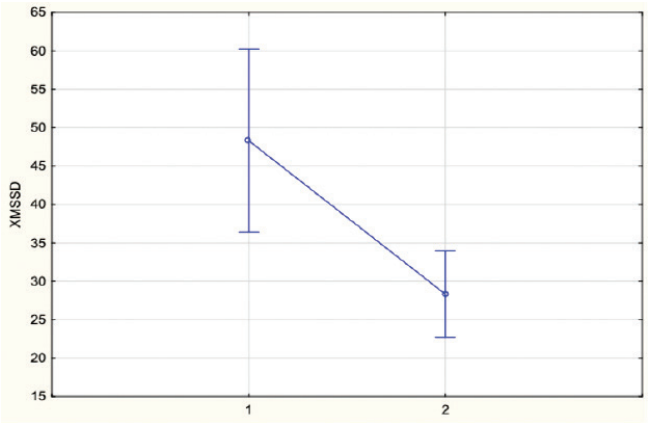


Figure 4. Differences between groups of participants in Modified Standing Stork Test for the left foot (MSSL)

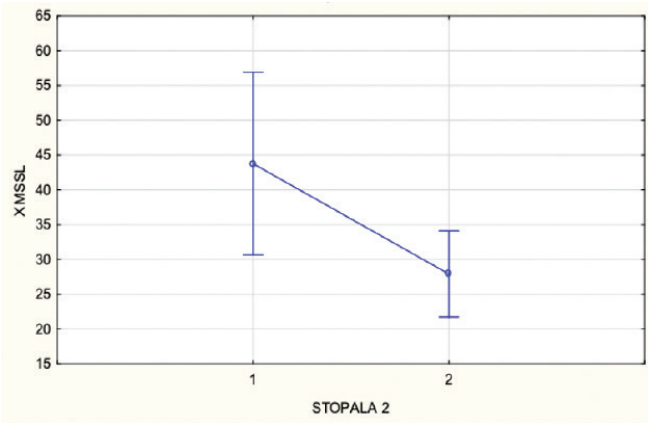


Figure 5. Differences between groups of participants in Dynamic Standing Stork Test for the right foot (DSSD)

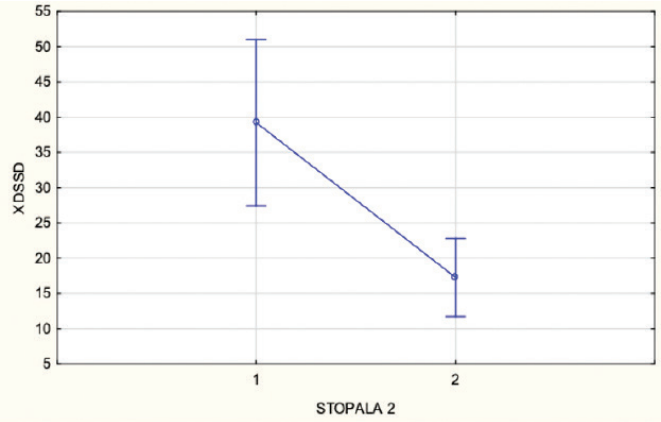
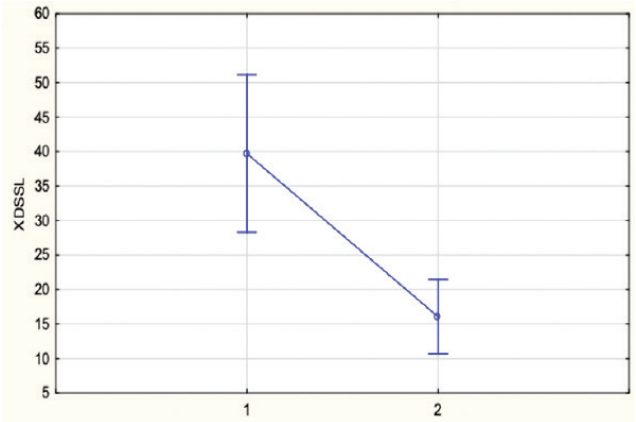


Figure 6. Differences between groups of participants in Dynamic Standing Stork Test for the left foot (DSSL)



Discussion

Coordination and balance as motor abilities have a pronounced role in the application of judo throws, especially those throws that are performed on a single leg, which are among the most commonly used ones in judo bouts (Segedi & Sertić, 2014). Also, one can highlight balance as the one of the most important motor abilities in the acquisition of technique knowledge among younger judoka. Reduced ability to maintain balance affects the efficacy of a throwing technique application, and by that it also makes it impossible for a judoka to perform the technique at his full potential. All throwing techniques that have forward or forward-right *kuzushi* (first phase in the execution of the throwing technique – unbalancing an opponent) and also are performed on a single leg can cause a problem of losing balance sideways in judoka with lowered medial foot arcs.

If we look at flat feet as one of the risk factors for lower extremity injuries, we can single out that a lowered medial foot arc is often tied to a valgus position of the knees, which results in stretched structures of the knee on the medial side and shortened structures on the lateral side. If we elevate that problem on higher segments, in other words hips, we can actually notice the weakness of m. *gluteus medius*, a muscle that prevents a valgus position in the knees by activating at the right time. If we consider all the problems on other segments of lower extremities that can happen because of a lowered medial foot arc, one can conclude that flat feet increase the risk of injury of anterior crucial ligament, medial collateral ligament or meniscus, considering that said deficits are risk factors for the development of injuries on the knee joint (Boden, Sheehan, Torg & Hewett, 2010).

Dabholkar, Shah and Yardi (2012) examined the difference in dynamic balance between participants with flat feet and those with normal feet with a Star Excursion Balance Test. Research was carried out on 30 participants with flat feet, diagnosed by Sit and stand navicular drop test, and 30 participants with normal feet, all aged between 18 and 25 years. The results have shown statistically significant difference between groups with emphasis that the participants with flat feet achieved worst results in dynamic balance in lateral direction.

Dong-chul, Kyoung i Su-kyoung (2014) have examined the impact of short foot exercise on dynamic balance among participants with flat feet. The sample consisted of 18 participants with flat feet that were defined by Navicular Drop Test. They were measuring dynamic balance before and after short foot exercise. After one training they have noticed elevation of all feet arches and improvement of dynamic balance, but those effects were acute.

Alam, Raza, Moiz, Bhati, Anwer i Alghadir (2018) carried out a clinical trial about impact of m. *tibialis posterior* strength training and m. *iliopsoas* stretching training on navicular bone drop, dynamic balance and lower legs muscles activity among participants with flat feet. 28 participants with flat feet were separated in two groups; one group has performed m. *tibialis posterior* strength training and m. *iliopsoas* stretching training, while the other group has performed conventional “towel curl” exercises. Statistically significant results were given for m. *tibialis anterior* and m. *abductor halucis* activity. They have concluded that selective strengthening of m. *tibialis posterior* and stretching of m. iliopsoas, as an update to conventional “towel curl” training, can contribute to significant clinical improvement of navicular bone drop, lower legs muscles activity and dynamic balance among people with flat feet.

This research has revealed one more problem. By observing the participants while they were conducting the balance tests some of the compensation patterns were noticed. Participants with higher degree of foot deformation, in order to maintain balance, did foot inversion and foot eversion and also toes flexion which resulted in loosing balance very quickly.

Practical Application of the Results

One can notice more and more children having flat feet, whether they were athletes or not. Significant impact of foot deformation on balance can be seen from the results, and that should encourage trainers to give their athletes corrective exercises that can improve their posture, biomechanics, technique and reduce the possibility of injuries as well. In further text one can find a short corrective programme that can be done as a part of warming up during every training session. For better transformation results exercises should be performed on a daily basis and started in as earlier age as possible:

1. Ballerina walk for 30 seconds; higher pressure on big toe in purpose of activating peroneal muscles
2. Walking on heels with toes up for 30 seconds; the rest of the body should be straight
3. Walking on lateral edge of the feet with flexed toes for 30 seconds
4. During walking - lifting from heels to toes for 30 seconds
5. Standing position; rolling from heels to toes and backwards - 15 repetitions
6. Standing position; lifting from heels to toes on one leg than repeating the same on the other - 15 repetitions each leg
7. Standing position; flexion of all toes for 6 seconds - 15 repetitions
8. Sitting position; plantar flexion after putting the elastic band around the feet - 15 repetitions
9. Sitting position with flexed feet; hallux abduction - 15 repetitions
10. Sitting position; flexion - extension of the toes with elastic band around them - 15 repetitions
11. Sitting position; small Pilates ball rolling through flexion and extension - 15 repetitions
12. Throwing of small Pilates ball by plantar part of the feet in sitting position; exercise can be done by throwing in pairs or throwing at the wall - 60 seconds

Conclusion

The lifestyle has changed in many ways during the last ten years. Children spend more free time in various forms of screen-time which resulted in physical activity decrease and brought to changes on anatomical, physiological and biomechanical levels. One of the consequences on anatomical level are flat feet deformations with pes planus as one of the most often. Together with coordination, balance is one of the most important abilities for application of throwing techniques in judo, especially among younger age categories in technique learning phase, especially while the techniques are often performed on a single leg. If the supporting point of our body (foot) is deformed, one can expect coordination and balance problems, especially while performing dynamic technical elements such as throwing techniques. Our findings have confirmed statistically significant connection between balance and flat feet, which has great meaning for practical use. The results from this research should lead to the setting up the protocol for the prevention and correction of foot defects. In order to achieve this, judo teachers in clubs should be able to do the diagnostics of foot deformations. That is why it is necessary, in the future, to give the means to the judo teachers to make a preventive diagnostic through the short education seminars which would be carried out by a physician or a kinesitherapist specialised in this type of examination. One of the most important tasks of training is the impact on the shortcomings of young athletes and by performing a short corrective programme, that can be done as a part of warming up during every training session, one could influence the health status especially for young judoka who still have great chances for correcting deformations.

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Comparison of Unsuccessfully Performed Throwing Techniques Between Male and Female Judo Competitors

By Husnija Kajmović

Abstract: *Judo is a credible sport both for men and women, which does not mean that all legalities in those samples are equal or different. The aim of this research is to compare unsuccessfully performed throwing techniques between male and female judo competitors as well as the reasons for their unsuccessful performance. The sample is comprised out of (n=253) unsuccessfully performed throwing techniques of male judo competitors, and a total of (n=81) unsuccessfully performed throwing techniques of female judo competitors. The sample of variables in this research is composed of: successfully and unsuccessfully performed throwing techniques, unsuccessfully performed subgroup of throwing techniques: leg, hand, hip, rear sacrifice and side sacrifice and unsuccessfully performed individual throwing techniques. The results of Chi Square test have indicated a significant difference (p<0.001) between male and female judo competitors in unsuccessfully performed throwing techniques. The greatest number of unsuccessful throwing techniques belong to the group of leg, hand, side sacrifice and hip throwing techniques. Individual throwing techniques which were the most unsuccessful in male judo competitors are the following: ippon seoi nage, uchi mata, tomoe nage, while in female judo competitors those are: ippon seoi nage, o uchi gari, soto makikomi. The reasons of their unsuccessful performance are grip quality, the lack of unbalancing of the opponent (kuzushi), insignificant rotation during the throwing performance and an attempt to attack from a greater distance. The results of this research have an application in the training process within which the coaches and competitors have an opportunity to reduce the mistakes in all age categories and for both genders.*

Key words: *gender, combat sport, men, women, error, performance analysis*

Judo as a sport is a lot more than just a fight. It is performed in dynamic conditions, with a constant exchange of attacking and defensive actions, along with unbalancing and maintaining balance, and a number of attacks and counterattacks. In this way, judo is exponentially progressing from a sport where one just uses the information and energy resources with an aim to destroy the opponent. One can say that judo in its many aspects is a special spiritual enhancement of an individual (Kano, 1994, Kano, 2005). Judo combat is an intense and high dynamic physical and physiological activity, followed by a well-developed aerobic and anaerobic energy systems, where competitors try to successfully apply specific throwing techniques (Pulkkinen, 2001; Franchini et al., 2011; Luque et al., 2016; Callan, 2018) in interaction. Competitors have to create uncertainty (create action-reaction) and have to attack and defend at the same time (Calment, et al., 2015; Franchini, et al., 2008). Judo consists of a great number of different throwing techniques (Daigo, 2005), but only a number of them is efficiently applied during competitions. Usually, the competitors organize a system of attacks in which the number of attacks varies between 4 and 8 attacks (Franchini, et al., 2008). The majority of Top-level judo coaches believed that a judoka should master between 5 - 7 techniques (*nage waza* and *newaza*) to reach high-level: “On the players’ dominant side (normally the right), they should have 8 techniques and on the other side (normally the left) 3 techniques” (Santos, et al., 2015). In order to determine which throwing techniques and techniques on mat are the most efficient during competitions, performances of competitors at different levels of competitions were analysed (Kajmović, et al., 2017; Kajmović, & Rađo, 2016; Miarka, et al., 2014; Kajmović, Rađo, & Kapo, 2007), and the results were applied in the training process. In judo, an analysis of athlete performance plays a special part, because in every sport activity realistic aspects of the same activity must be analysed.

Namely, in judo, that activity is certainly specific in regards to two fundamental characteristics, and these are considered as *physical conditions* within which the activity is performed, and *specific rules* which determine if some movements are allowed, not allowed, encouraged, etc. In this regard, the registration of applied technique elements, general indicators and other similar elements, performed during matches, most certainly offers a great number of useful information about the actions, as well as in regards to individuals performing these techniques. In judo, two competitors attempt to perform activities which will place their opponent in a position to perform an effective destructive throw, grappling and joint lock, or chocking. Therefore, from a biomechanical perspective, it is obvious that this is the case of a complex system conditioned by a division into two individual entities. As long as the components are situated, if not in individual, but in well-defined grip,

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every and even the single body movement, or movement of some body segments will entail a range of individual and global movements which effect other segments, and therefore the opponents themselves, but only in regards to their mechanical system. A great number of research has been conducted in which male and female judo competitors have been compared in the aspect of defensive actions taking place during the match (Boguszewski, 2009; Boguszewski, 2011; Marek, Laskowski, & Smaruj, 2012), demographic profile of combat sports athletes (Sterkowicz-Przybycień,& Franchini, 2013), physiological profiles of elite judo athletes (Franchini, et al., 2011), defragmenting the gripping time (Soriano, et al., 2019), injury assessment of common *nage waza* judo techniques for amateur judoka (Lage, et al., 2016), rules and punishments (Ceylan, & Serdar, 2017; Escobar-Molina, et al., 2014; Franchini, Yuri, & Calmet, 2013; Calmet, Pierantozzi, Sterkowicz, Yuri, & Franchini, 2017), technical tactical actions during the match (Courel-Ibáñez, Escobar-Molina, & Franchini, 2018; Miarka, Sterkowicz-Przybycien, & Fukuda, 2016; Franchini, et al., 2019; Sterkowicz-Przybycień, & Fukuda, 2016; Riccardo, et al., 2018; Bocioaca, 2014; Sterkowicz, Sacripanti, & Sterkowicz-Przybycień, 2013; Franchini, & Ferreira, 2015; Miller,et al., 2015; Pereira, et al., 2019; Miarka, et al., 2014; Julio, et al., 2011; Lima,et al., 2019; Miarka, et al., 2014; Velloso, et al., 2018; Mayo, Dopico-Calvo, & Iglesias-Soler, 2019; Boguszewski, & Boguszewska, 2006; Guedes de Camargo,et al., 2019; Pinto de Souza, et al., 2019; Brito, et sl., 2017), and in a transition from standing position on a matt (Nagai, et al., 2019). The results of these research indicate the difference and similarities between male and female competitors in different aspects of judo sport. Successfulness and unsuccessfulness of throwing techniques is a main training and competition component, and each happen for a reason, i.e. mistakes, as well as, the consequences which reflect the successfulness of the performance of throwing techniques. An error in sport can be defined as a deviation from a specific target technical model (Hossner, Schiebl, & Göhner, 2015), and this deviation in judo is reflected in deviations during the performance of throwing techniques with an aim to successfully perform three phases, and those are unbalancing (*kuzushi*), establishing contact (*tsukuri*) and at the end, as a result of a quality performance of the previous two phases, the throw (*kake*). As a final result of this deviation, the performance of unsuccessful throw takes place, which forces the referees to recognise these attempts as fake attacks and appoint late *shido*. These situations are a clear indicator to the coaches to recognise the reasons which have caused the incorrect and unsuccessful performance of throwing technique, and to find a way to correct these errors. These mistakes can appear during the process of learning the performance of throwing techniques and performance errors which exhibit themselves during competitions (ASEP, 2002:43-45). Learning errors are those that occur because athletes don't know how to perform a skill; that is, they have not yet developed the correct motor pattern in the brain to perform a particular skill. Performance errors are made not because athletes don't know how to execute the skill, but because they have made a mistake in executing what they do know (ASEP, 2002:43-45). Camacho, & Calvo (2017) have systematically reviewed and evaluated the literature related to the effectiveness of the teaching strategy without errors for the teaching of sports skills, in order to know whether making mistakes benefits or impairs learning and / or performance.

During the search process Web of Science, Scopus, SportDiscus with Full Text and PsycInfo databases were consulted along with other sources of research. They identified 10 prospective studies conducted between 2001 and 2016 that met the initial selection criteria. The results indicate that in relation to physiological, psychological and robust fatigue over time, it is the learning groups without errors that in 83.33% of the cases obtain positive results in their performance, compared to 16.67% of learning groups with errors. However, the competitors have a great number of failed attempts when implementing efficient throwing techniques due to certain reasons, i.e. errors. One can say that not one champion has won one competition with only one throw (Calment, et al., 2015). These throws are unsuccessful because they could not achieve specific Ippon or Waza-ari score, in accordance with the criteria defined by the International Judo Federation rules, which at certain moments forced judges to punish contestants for false attacks. Strategies used by the competitor on competition are: to attack to create uncertainty within the opponent, to create and use action-reaction and to attack to win time (Calment, et al., 2015). A number of scientific research have shown a much clearer picture of the error problem during the learning process of certain throwing techniques (Gutiérrez-Santiago, et al., 2009, Gutiérrez-Santiago, et al., 2013, Prieto, et al., 2013, Prieto, et al., 2014; Prieto, et al., 2016). In addition, errors that occur during the performance of the throw can contribute to injuries among competitors (Prieto, et al., 2014), and for this reason, knowing errors that occur during the performance of the throwing technique, both during the competition and training, can lower their number. Among strategies, there are false attacks when a competitor fails. We need to know if this failure could create injury or pathology. Unfortunately, research on performance errors in judo competitions have not been sufficiently conducted, which indicates a good opportunity to pay special attention to this area of judo sport and in regards to all age categories for both genders. The aim of this research is to compare the unsuccessfully performed judo throwing techniques between male and female judo competitors at the 2017 Bosnia and Herzegovina Judo Championships as well as the reasons of their unsuccessful performance.

Participants conducted balance tests barefoot on judo mat. All participants conducted the tests on the same *tatami* with official (IJF approved) characteristics.

STATISTICA 13.4. programme was used for processing and analysis of results. Evaluation of statistical relevance of differences between groups of participants was determined by the multivariate analysis of variance (MANOVA).

Methods

Subjects
The sample is comprised out of a total number (n=253) of *unsuccessfully performed throwing techniques* of male judo competitors and a number (n= 81) of *unsuccessfully performed throwing techniques* of female judo competitors from a National Judo Championships held in 2017.

Variables
The following variables have been analysed:
- Successfully performed throwing techniques of male and female judo competitor,
- The relation between *unsuccessfully performed throwing techniques* of male and female judo competitors,
- Unsuccessfully performed subgroups of throwing techniques: leg (*ashi waza*), hand (*te waza*), hip (*koshi waza*), sacrificed backward (*ma sutemi waza*) and side sacrificed (*yoko sutemi waza*) techniques of male and female judo competitors,
- Unsuccessfully performed individual throwing techniques of male and female judo competitors.

Procedure

The *unsuccessfully performed throwing techniques* were recorded with three Sony cameras (DCR-SR 35), and with each camera one competition space was recorded where the competitors are clearly seen. To analyse the video recording two observers were engaged, who possess years of experience in domestic and international competitions as contestants, judges and academic staff, working in the same conditions and with the same video equipment. Records were kept of all the competitions and judging events. Observers' task was to register unsuccessfully performed throwing techniques. Panasonic NV-HD670 video was used with the following options: pause, slow review of the match and its parts, rewind and forward. In order to determine the validity of performed throwing techniques the following sources were used (Inokuma and Sato, 1986; Kano, 1994; Daigo, 2005).

Ethics

This research fulfils all the standards of research based on Helsinki Declaration, and the consent to perform the research was given by the Teaching Council of the Faculty of Sport and Physical Education, University of Sarajevo, ref no: 01-1147/19.

Reliability testing

In order to determine the accuracy of the measurements, repeated measures (re-test) of intra-observers and inter-observers were used, who analysed up to 40 senior male and female unsuccessfully performed throwing techniques, under the same conditions and with the same equipment. After two weeks the same *unsuccessfully performed throwing techniques* were reanalysed. Percentage error in measuring was calculated by comparing the data from the first measurement (V1) with the data from the second measurement taking into account all the three stages of analysed variables (V2) and using the equation (1) (Hughes, Cooper, & Nevill, 2004).

$$\text{Total \% error} = (V1-V2) / (V_{mean}) \times 100\% \quad (1)$$

For male competitors, intra-observer percentage errors of reliability ranged from 0.00% to 0.20%, and the inter-observers reliability ranged from 0.00% to 0.31%. Intra-observer percentage errors of reliability ranged from 0.00% to 0.17%, and the inter-observers reliability ranged from 0.00% to 0.26%, for female competitors, which is acceptable to 5%, which is the level of limiting error.

Statistical analysis

To determine the difference between male and female competitors, Pearson's Chi-squared test, Yates's Correction and Cramér's V (O'Donoghue, 2010: 186) were used to analyse the level of statistical significance of 0.05% and using SPSS 22.0 (IBM Corporation, USA). In order to determine the significance in the differences between the cells (Field, 2005), standard residuals were calculated (*Std. Residual*). Analysed variables are shown in percentage values.

Results

The results of comparing successfully and *unsuccessfully performed throwing techniques* between male and female competitors (Figure 1), have indicated that there are no statistically relevant differences (Pearson Chi-square = 0.234; df = 1; p = 0.628; Yates' Chi-Square 0.1385; p=.709; Cramer's V = 0.021). Standardized residual in successfully performed throwing techniques in male competitors equals to -0,15 and in female competitors +0,27, while in *unsuccessfully performed throwing techniques* in male competitors, it equals to +0,1 and in female competitors -0,15. The values of the standardized residual belong to a normally distributed sampling distribution with a mean of zero and a standard deviation of ±1.0.

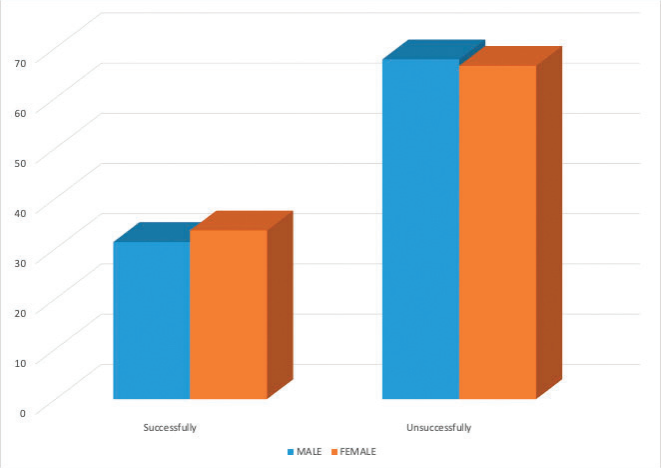

Figure 1. Percentages values of successfully and unsuccessfully performed throwing techniques male and female competitors

Comparing *unsuccessfully performed throwing techniques* (Figure 2) between male and female competitors leads to the results indicating that male competitors have a significantly higher number of unsuccessfully performed throwing techniques, even 75,7%, while in female competitors it equals to 24,3% of unsuccessfully performed throws, demonstrating that male competitors were more active in attempts to perform the throws then the female competitors.

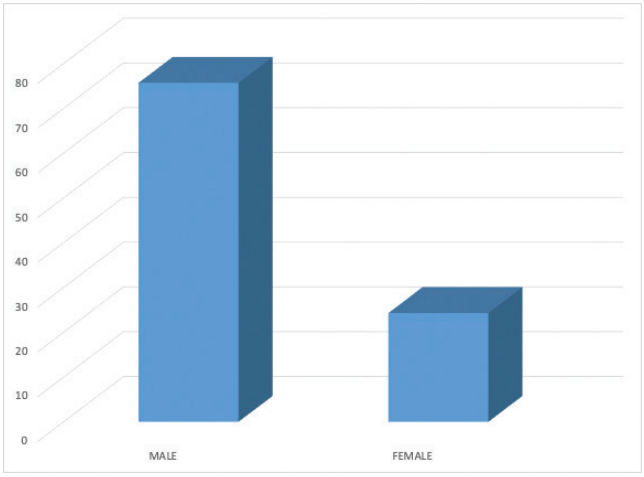

Figure 2. Percentages values of male and female unsuccessfully performed throwing techniques.

Analysing the differences between frequencies of *unsuccessfully performed throwing techniques* of sub-groups judo techniques (Figure 3), statistically significant differences were determined for senior male and female competitors (Pearson Chi-Square 21.957; df= 4; p < .002; Cramer's V = 0.256). Female competitors dominate in the number of unsuccessfully performed hand techniques TE(33,3% - Std. Residual 0,49), hip techniques koshi (12,4% - *Std. Residual 1,34*), and side sacrifice techniques (18,5% - *Std. Residual -2,0*), while male competitors dominate in a number of unsuccessfully performed leg techniques – *ashi* (38,1% - *Std. Residual -0,28*), and rear sacrifice throwing technique *ma sutemi* (17,1% - *Std. Residual -1,13*). Analysing differences in individual cells, the greatest discrepancy from standardised residuals is visible in the group *ma sutemi waza* in female competitors, equalling to -3.0.

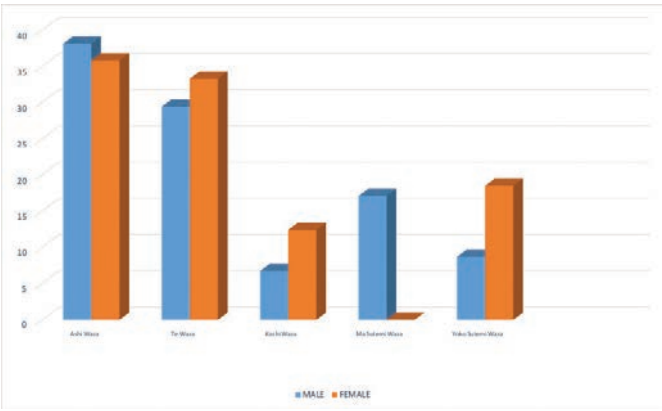

Figure 3. Percentages values of unsuccessfully performed throwing techniques of sub-groups judo techniques.

Comparing unsuccessfully performed individual throwing techniques (Table 1), in male and female competitors show that the greatest number of unsuccessfully performed hand throwing technique is *ippon seoi nage*. Male competitors dominate in unsuccessfully performed throwing technique *uchi mata*, *tomoe nage*, *seoi nage* and *o uchi gari*, while the greatest number of *unsuccessfully performed throwing techniques* in female competitors are: *o uchi gari*, *soto makikomi*, *o soto gari*, *uchi mata* and *harai goshi*.

Table 1. Percentages values of individual unsuccessfully performed throwing techniques

MALE		FEMALE	
Techniques	%	Techniques	%
ippon seoi nage	19,8	*ippon seoi nage*	28,4
uchi mata	18,2	*o uchi gari*	13,6
tomoe nage	11,9	*soto makikomi*	13,6
seoi nage	8,7	*o soto gari*	11,1
o uchi gari	8,7	*uchi mata*	11,1
o soto gari	5,5	*harai goshi*	9,9
sumi gaeshi	5,1	*seoi nage*	3,7
yoko tomoe	3,9	*sumi gaeshi*	3,7
harai goshi	2,8	*sode tsurikomi goshi*	2,5
tani otoshi	2,4	*tani otoshi*	1,2
deashi barai	2,0	*kata guruma*	1,2

Discussion

Match as a concept includes two participants, but it is not just the case of summing up the elements performed by the competitors. It includes „hidden" data attesting to the relations between the two competitors. In this way, judo generally accumulates a great number of information, upon which the achievement of specific activity is based, and therefore the analysis of athletes' performance during the competition represents the best quality data gathering procedure. The results of this analysis helped to fully realize the defined goal of this research, whose aim was the comparison of *unsuccessfully performed throwing techniques* between male and female judo competitors and the reasons for the unsuccessful throw.

Judo is a credible sport both for men and women. This provides with the opportunity to compare two fundamental samples, which are based on gender. This does not mean that all legalities in those samples are equal, but that it is a case of differential activities. Even though one match is not a match between a man and woman, one cannot ignore the fact that spatial, physical and professional features of judo sport as such are unique and unequivocal, as well as the fact that a group of standard actions, even though a big group, is as well recognised in both samples. For that reason, the approach by which one wishes to analyse possible comparisons is justified, and in regards to understanding the logic of judo sport as such.

The results of this research are similar to the results of the analysis of the process of Judo match in different weight categories at the World Championship for Seniors 2011, that was held in Paris (Stanković, et al., 2015). The results indicated that more then 2/3 of all actions in lightweight and middleweight category were unsuccessful throwing attempts. In the heavyweight categories this percentage is smaller (54,7%) and it was suggested that judokas need to perform a great number of attempts to attack so as to achieve efficient throw (65,38% of all actions was characterised as unsuccessful throwing attempts). It is important to note that the most efficient throwing techniques performed by male senior competitors in the one third of efficient throws were *uchi mata* (11,0%), *tani otoshi* (9,0%), *de ashi barai* (6,0%), *seoi nage* (5,8%) and *ippon seoi nage* (5,2%), while for female seniors the most efficient throwing techniques were: *tani otoshi* (19,5%), *ippon seoi nage* (14,6%), *o soto gari* (14,6%), *harai goshi* (9,7%) and *de ashi barai* (9,7%). By reviewing these results it is evident that male and female senior competitors use different throwing techniques, whose efficient performance is significant at Bosnia and Herzegovina Judo Championships. The errors that occur in the throwing techniques differ depending on the throwing technique used. In general, the most common reasons for failure during the attempt to perform a throw for male and female senior competitors are: conditional preparation and fatigue effect the quality of throwing technique performance, and therefore it is necessary to correct the throwing technique during the period of exhaustion, and in regards to the conditions which the competitors are to face during the match.

Then, the competitors lose the established grip while performing the throw, the insufficiently unbalanced opponent in the first stage of the throw (*kuzushi*), during the *ippon seoi nage*, *uchi mata*, seoi nage, *harai goshi* techniques, the hand (*hikite*) holding the opponent's sleeve does not pull forward, but is next to the *tori*'s body, the *Tori*'s insufficient rotation during the execution of the throw, the attempt to carry out the attack without preparation, the attack begins at a great distance, the *uke*'s weight is not supported by the leg that is to be attacked by a certain judo technique, so *uke* has the ability to evade attacks and switch to a counter attack.

During the rear sacrifice technique (*ma sutemi waza*) *tomoe nage*, which is the third unsuccessful technique in male competitors, the most common errors are that the *tori* is not pulling the *uke* towards him, his arms are by his body, his foot used to step forward to *uke* is set away from his feet, and the *tori*'s hips are away from his feet. It is noticeable that after the unsuccessful use of *tomoe nage*, *tori* attempts to apply the *ude hishigi juji gatame* arm lock, which was also unsuccessfully performed. Unlike male senior competitors, female senior competitors did not even try to use the throwing technique *tomoe nage* during the match, but are very dominant in unsuccessful side sacrifice techniques (*yoko sutemi waza*). Several authors have investigated errors in various throwing techniques. A question as to why *seoi nage* technique is the most unsuccessfully performed throwing technique both in male and female competitors is raised? Or what are the reasons that the both groups of competitors have the biggest number of these throwing attempts? It is certain that the coaches are responsible for this, because they insist in using this technique during the training, and for this reason the competitors themselves try to gain the advantage or even victory by using this technique. However, it is evident that its application has specific technical and physical flaws. Camerino et al. (2014) have identified and analysed temporal patterns (T-patterns) in behaviour, to detect technical errors and behavioural sequences in the *ko soto gari* judo throw, and, based on this, to propose changes to the way in which judo is taught. The results, derived from descriptive statistics and a sequential analysis of T-patterns conducted by means of Theme 5, revealed that the students committed a series of typical errors when learning to perform the throw. Furthermore, these errors often appeared in sequence, mainly involving a lack of balance, the position of the feet and hips/trunk, an incorrect reap and the final arm movement.

Cych, Błach, Koleśnik, & Levitskiy (2016) have researched the occurrence of error in junior and senior judo bouts in two different groups of competitors (seniors and juniors). A total of 85 bouts (58 junior bouts and 27 senior bouts) were analysed. Observations were made within 2006-2008. The findings suggest that senior competitors made the same amount of errors as juniors but that the occurrences of errors were different. Moreover, points given by referees in the form of different penalties are of great importance in judo bouts. The observation carried out shows also that the type of action related to the highest number of points is throwing. It gives 80% of the points from all actions at junior tournaments and 61% in senior tournaments (p=0.010). The second activity related to 10% of points obtained in all junior actions are points awarded to opponent for noncompliance with the bout rules. In comparison 29% of all points were for penalties to the opponent in senior bouts. In this respect the test again showed a significant difference. Gutiérrez-Santiago, et al.(2009) conducted research whose purpose was to provide a tool, based on the knowledge of technical errors, which helps to improve the teaching and learning process of the *uki goshi* technique. The results show that the absence of a correct initial unbalancing movement (45,5%), the lack of proper right-arm pull (56,8%), not blocking the receiver's body (*uke*) against the attacker's hip -*tori*- (54,5%) and throwing the *uke* through the *tori*'s side are the most usual errors (72,7%). They have concluded that not blocking the body with the *tori*'s hip provokes the *uke*'s throw through the *tori*'s side during the final phase of the technique (95,8%), and positioning the right arm on the dorsal region of the *uke*'s back during the *tsukuri* entails the absence of a subsequent pull of the *uke*'s body (73,3%). Gutiérrez-Santiago, et al., (2013) studied the most common technical errors, and their behavioural sequences, in the judo throw *morote seoi nage*. The results showed that a sub-optimal knee bend produces a throw around the side rather than over and towards the front of the shoulder, an inadequate hip and trunk position, caused by prior incorrect placement of the left foot, leads to a failure of weight bearing, which itself is the cause of the side throw. Prieto,

et al. (2013) concluded the most frequent technical errors, and their associated behavioural sequences, in the judo throw *o soto gari*, proposing improvements to the way in which judo is taught and learnt.

The most common errors were related to the initial failure to put the adversary off balance, to an incorrect position of the supporting foot and of the pectoral area, to an incorrect reaping action, to insufficient traction and incorrect direction of the arms in the final part of the throw, and to insufficient trunk flexion in the final stage. Prieto, et al., (2014) studied errors in the teaching-learning process of judo techniques: *o soto guruma*, and the aim of this article was to suggest some changes in the teaching-learning process methodology of the judo *o soto guruma* technique, establishing the action sequences and the most frequent technical errors committed when performing them. They identified following errors: the presence of typical inaccuracies during the technique performance; a number of errors affecting body balance, the position of the supporting foot, the blocking action and the final action of the arms. Prieto, et al. (2016) conducted a study whose aim was to detect the most frequent errors and their associated behavioural sequences in relation to the judo technique *o uchi gari*, the ultimate objective being to propose improvements to the way in which judo is taught. The most common errors detected were related to an initial failure to put the adversary off balance, an inadequate position of the right arm, an incorrect positioning of the face and trunk, the height of the centre of gravity during the *tsukuri* and *kake* phases of the throw, insufficient traction effect of both arms in the final phase of the throw, and an incorrect reaping action. The reasons for unsuccessful throws can be found in: Beginners' mistakes during the learning process of the throwing technique, which the trainers did not correct at the early stage of judo technique learning, and which is reflected at the senior competition. Then, in the inability to switch from school techniques to situational competition techniques. Finally, the creation of a low torque during the body rotation when performing the throw, which points to the insufficient fitness preparation of the contestants for this competition. It is obvious that, based on this research, and research by other authors who dealt with the problem of errors in the execution of the throwing technique, it is necessary to focus more seriously on correcting the errors using new motor tasks and technologies during training. Due to everything stated above, it is clear that a different approach in learning, repeating, perfecting and automation of judo techniques is necessary, with a special accent being placed on younger age categories. Each competitor should develop an ability to recognize mistakes and to evolve its performance at the competition (Schmidt & Wrisberg, 2004). Elite judo coaches recommend the use of five traditional methods of learning judo techniques, and those are: *uchi komi*, *yaku soku geiko*, *kakari geiko*, *nage komi* and *randori*, and several of them recommend *renraku waza*, *renzoku waza*, *tandoku renshu* and *shiai* (Santos, et al., 2015) as well.

Conclusions

The results of this research have the possibilities to be directly applied in research and training practice. When we are talking about research perspective, a detailed analysis of mistakes during the throwing technique performance is necessary. In regards to the training practice, the coaches of Judo Federation of Bosnia and Herzegovina have the possibility to apply the results of this research in practice, and in that way introduce an innovative aspect in their training processes by correcting the mistakes performed during the throwing techniques at competitions. This will result in increasing the quality of technical preparations of judo competitors of both genders and different age categories to a higher level.

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Research note

The Contribution of Judo to the Development of Key Cognitive Skills Needed in Contemporary Society

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Abstract: *Judo was created as a tool for people to develop their minds and bodies in order to achieve what they believe to be success, contributing to society and adapting to their time. Kano empirically noted that several cognitive skills that are fundamental to succeeding in life could be acquired through the practice of judo. In neuroscience, the set of these cognitive skills is called executive functions. The purpose of this research note is to correlate current neuroscientific studies with Jigoro Kano's empirical findings about the benefits of judo practice for the development of mental skills essential for success in contemporary society. Approaches to the development of executive functions have been the subject of scientific studies in various areas, including their relationship with physical activity. Studies report that the development of executive functions through physical activity is dependent on the type of physical activity performed. The most effective physical activity for the development of executive functions are those that involves complex movements with cognitive demands. Researchers found that martial arts that involves both mind and body and requires a high level of cortical recruitment may be considered a mediator of executive functions, since this training may result in an increased cerebral blood flow to the areas of the brain responsible for executive function. Judo is a method of perfecting the human being, including improving mental skills. Studies have shown that martial arts such as judo, that emphasizes self-control, discipline and character development, are means for develop executive functions.*

Key words: *executive functions; mental training; cognitive skills; judo; neuroscience; martial arts; physical activity*

Jigoro Kano, the founder of judo, said that the prosperity of nations depends on the mental training that people receive, and that mental training is among the most interesting and beneficial aspects of judo. Judo was created as a tool for people to develop their minds and bodies in order to achieve what they believe to be success, contributing to society and adapting to their time (Kano & Murata, 2012, 55-99). In his days, Kano empirically noted that several cognitive skills that are fundamental to succeeding in life could be acquired through the practice of judo, such as caution, reasoning, judgement, the ability to take decisions quickly, the ability to remain calm and resolute, observation, memory, experimentation, imagination, language, and the ability to being open-minded.

In neuroscience, the set of these cognitive skills is called executive functions. Funahashi (2001, 147) defines executive functions as "a product of the coordinated operation of various processes to accomplish a particular goal in a flexible manner". These skills include: response inhibition, working memory, emotional control, sustained attention, task initiation, planning / prioritization, organization, time management, goal-directed persistence, flexibility and metacognition (Dawson & Guare, 2009, p. 15).

For Qehaja-Osmani (2013), "life success depends increasingly on the mastery of executive functions" (p. 247). In the same line of thought, Hendry, Jones & Charman (2016, 3) describe executive functions as "the cognitive toolkit of success". Diamond (2013, 137), going further, specified the aspects of life in which executive functions are key: mental health, physical health, quality of life, school readiness, success at school, success at work, marital harmony and public safety.

Although scientists have devised various models for categorizing and labeling executive functions, there is a consensus that these skills consist primarily of "(1) plan and direct activities, including getting started and seeing them through, and (2) regulate behavior—to inhibit impulses, make good choices, change tactics when what you're doing now isn't working, and manage emotions and behaviors to achieve long-term goals" (Dawson & Guare, 2009, 4).

Located in the prefrontal cortex (Ball, et al., 1), executive functions develop from birth to early adulthood (Best & Miller, 2010, 1641), they are trainable and can be improved at any age, probably through several different approaches (Diamond, 2013, 156). Approaches to the development of executive functions have been the subject of scientific studies in various areas, including their relationship with physical activity. According to Sibley & Etnier (2003, 244), the relationship between cognition and physical activities can be explained through physiological mechanisms and learning/developmental mechanisms. As for physiological mechanisms, physical activities increased cerebral blood flow, facilitating the arrival of more oxygen and nutrients to the brain. There are also changes in brain neurotrans-

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mitters, structural changes in the central nervous system, and modified arousal levels that may increase cognitive performance. As for the learning/developmental mechanisms, physical activity and movement promote learning experiences that aid proper cognitive development.

However, studies report that the development of executive functions through physical activity is dependent on the type of physical activity performed. According to Diamond (2012, 337), the most effective physical activity for the development of executive functions are those that involves "both exercises and character development (e.g., traditional martial arts) or activities that involve both exercise and mindfulness (e.g., yoga)", that is, those activities that require complex movements with cognitive demands (Crova et al., 2013, 2).

In a groundbreaking study, the researchers found that martial arts training, as it involves both mind and body, and requires a high level of cortical recruitment due to the inherent complex patterns of movements, may be considered a mediator of executive functions (Douris, et al., 2015, 281), since this training may result "in an increased cerebral blood flow to the areas of the brain responsible for executive function".

In this sense, the aforementioned scientific studies conclude that martial arts that emphasizes self-control, discipline and character development, as judo, has the ability to improve executive functions, considered the set of key cognitive skills for success of the human being in contemporary society (Diamond & Lee, 2011, 960). As previously mentioned, Kano argued that judo was able to improve these same skills, which he also considered fundamental to the individual's success.

Judo is a method of perfecting the human being, including improving mental skills. In the words of Jigoro Kano, the objective of judo «is the improvement of the human being, who must contribute to society and adapt to his time» (Kano & Murata, 2012, 79), thus, with regard to mental training provided by judo, recent advances and discoveries in neuroscience validate what Kano has found empirically in the past, that is, that we can reach a higher level than we are today, empowering us to the demands of a world whose pace of change accelerates every day and which more than ever requires agents of change with mental and physical strength to make a difference in the world.

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Blood Lactate Response in Two Different Methodological Proposals of Judo Training

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Abstract: *New pedagogical proposals are important to promote debates regarding the judo training process. Thus, Olivio Junior and Drigo (2015) proposed a new methodology called Judo Complex Pedagogy. Such proposal is an alternative to the traditional training model (TT), usually composed of cyclical training of techniques and simulation of fights, since it advocates the organization of the training in Functional Units (FU): approach, contact, opportunity creation, unbalance, application, projection, transitioning and ground combat and using them with the objective of developing the athlete's tactics through the situational method (ST). As a methodological proposal, ST intensity has not been compared with TT. Hence, the objective of this study was to compare the intensity of TT and that of ST. 24 judo practitioners were evaluated during a training session. 12 of them underwent TT, and 12 underwent ST. The intensity of training was verified through the analysis of blood lactate response [La-], measured 1 minute after the ending of Uchikomi (UCK), judo techniques training, 1 minute after the ending of fight training (RAN), and 1 minute after the ending of the training session. [La-] at the end of UCK was significantly higher in TT = 3.8 ± 1.7 in comparison to FT =1.9 ± 0.4 mmol/L, while in RAN (TT = 4.0 ± 2.7 and TF = 3.7 ± 1.5 mmol/L) and in the total session (4.0 ± 2.2 and TF = 3.3 ± 1.1 mmol/L) there was not a significant difference. On the other hand, although there was not a significant difference in [La-] in the training as a whole, ST athletes did 10 minutes less in UCK and 16 minutes less in RAN, which may be an indicative of training optimization. That is also possible that the reduction in the number of Randoris in TT, as well as the analysis of all the athletes undergoing both training sessions, for paired analysis, may give further information. Different physiological parameters and the subjective perception of athletes should also be studied.*

Contemporary sport creates growing demands for high performance, characterized by psycho-biological requirements that push the human organism to its limits. Hence, the methodology and control of this process is of paramount importance in order to avoid overtraining and injuries, and at the same time the stimuli should be sufficient to attain the proposed objectives (Soligard et al., 2016). Such complexity is enhanced by a saturated competitions calendar and the pressure for immediate positive results that might jeopardize the training process considered ideal by the coach and long term development (Lloyd et al., 2015).

In judo specifically, despite an increasing number of discussions on the matter, other discussions should emerge, mainly in relation to methodological applications of training. In Brazil, investigations and pedagogical proposals are still scarce, despite judo being a widespread sports modality and also the one with the most Olympic medals awarded, 22. Therefore a new methodology was proposed, namely Judo Complex Pedagogy (Olívio Junior & Drigo, 2015), based on two concepts, currently adopted for collective modalities: the situational method (Greco, 2013) and tactical periodization (Garganta, 1997). This proposal is an alternative to the traditional training model (TT), because it recommends that the training be organized in Functional Units (FU) which are the parts that compose the whole of judo fight: approach, contact, opportunity creation, unbalance, application, projection, transitioning and ground combat, advocating Situational Training (ST), while a TT session is mainly composed by technical training through cyclical repetitions of moves - Uchikomis (UKC) and fight training - *randori* (RAN).

The relevance of proposing new technical and tactical methodologies for judo relies on the importance of these two components as performance factors, knowing that the best athletes have distinguished technical-tactical conditions

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(Miarka et al., 2016). The aim of technique is to perform an specific move as effectively as possible and also saving the most power, and when decontextualized, it could hamper its transference to the sports games , or the combat in judô (Franchini, Sterkowicz, Meira Jr, & Go Tani, 2008). The aim of tactical training is to understand the structure of the sports modality, oriented in accordance with each one's specificity and objective, in a contextualized and dynamic way, allowing athletes to perfect decision making during a competition (Bocioaca, 2014). Therefore, the TT, with an emphasis on cyclical repetitions, in a stable environment, without contextualizing the parts that make up the fight can hinder the process of understanding the dynamics necessary for competitive success, while the ST allows all parts of the fight to be explored in open environment and worked in an organized way, facilitating that the deficient points or those programmed for certain training periods are more emphasized, constituting training closer to reality.

For example: in a TT the simulation of a fight will have a predetermined time and the objective of the judokas will be to achieve scores, projections, and immobilizations, without prioritizing certain aspects of the fight. In the ST, with an assumptive emphasis on the transition FU, the judokas will be instructed to score mainly in the moments when the fight is moving between the standing part and the ground part, in order to improve this specific aspect.

Meantime, as a methodological proposal, the intensity of the ST has not yet been compared with the TT. Some parameters have been used to determine the effort in the judo training sessions such as heart rate (HR) (Morales et al., 2015), the Rating of Perceived Exertion (RPE) (Agostinho et al., 2017) and the Work Endurance Recovery (WER), which was developed for specific load control for sessions of RAN (Morales et al., 2016). However, in judo, due to its high glycolytic demand (Degoutte, Jouanel, & Filaire, 2003; Franchini, Del Vecchio, Matsushigue, & Artioli, 2011; Torres-luque, Hernández-garcía, Escobar-molina, Garatachea, & Nikolaidis, 2016), lactate has been an important internal and the most used load marker for determination and control of intensity in judo training and competitions (Bonitch-góngora, Bonitch-Domínguez, Padial, & Feriche, 2012; Branco et al., 2013; Obminski, Lerczak, Witek, & Pintera, 2010; Serrano, Salvador, Gonzalez-bono, Sachís, & Suay, 2001).

Studies demonstrate that lactate threshold [La-] in judo may vary from 5 $mmol.l^{-1}$ to 13 $mmol.l^{-1}$ in competitions of several levels (Franchini, Artioli, & Brito, 2013; Nunes, Andrade, Paiva, & Klemt, 1998; Serrano et al., 2001) and from 5 $mmol.l^{-1}$ to 18 $mmol.l^{-1}$ in training of judo with practitioners of several nationalities, competitive categories and levels (Bonitch-Domínguez, Bonitch-Góngora, Padial, & Feriche, 2010; Bonitch-góngora et al., 2012; Detanico, Dal Pupo, Franchini, & Dos Santos, 2015; Drigo, Amorim, Martins, & Molina, 1996; Touguinha et al., 2011).

Therefore the objective of the present study was to compare the intensity of TT with ST's for U-18 and U-21 Brazilian judo practitioners.

Methods

24 judo practitioners, from the U-18 and U-21, state, national and international classes were evaluated during a training session. They trained for 3 hours per day, 5 times per week. The present research was approved of by the University Research Ethics Committee (CAAE: 53686516.7.0000.5398), in accordance to Brazilian current legislation. After the presentation of the study and the coach's agreement, the athletes under his responsibility were invited to participate and made aware of the procedures. They agreed to participate voluntarily. Before data collection, participants signed an Informed Consent Form (ICF) agreeing to participate in the research. Minor athletes had to be authorized by their parents.

The athletes were divided, intentionally, in two groups of 12 (each group consisting of 6 men and 6 women), according to their level of competitiveness and weight category. Each group consisted of 2 world class athletes, 3 national class athletes, and 7 state class athletes. 4 of the women in the groups weighed between 48 and 63 kg and 2 weighed more than 70 kg. Regarding men, 3 judoka weighed between 60 and 73 kg and 3 weighed between 81 kg and 100 kg. A group undertook TT and the other ST. Training sessions were thus developed:

a. TT: Warm up: 15 min. of stretching exercises and running, and 5 min. Ukemis and rolling breakfalls; 15 min. static UCK (effort-pause relationship 1:1 ratio); RAN: 10 x 4 min / 1 min recovery in between fights; and 5 min. of active stretching.
b. ST: Warm up: 15 min. of acrobatic/gymnastics exercises; Situational UCK, based on the following FU: opportunity creation; application and projection (effort-pause relationship 1:4 ratio, 20 min total); RAN with tactical aims, guided by the FU trained in UCK (12 x 2 min / 2 min of recovery in between fights) and 5 min. of active stretching.

The intensity of training was verified through the analysis of the blood lactate response [La-] measured 1 min. after the end of UCK, 1 min. end of the sessions of RAN and 1 min. to the ending of the training. Twenty-five microliters (25 µL) were collected from the earlobe, in heparinized microcapillary tubes. The collected samples were placed in polyethylene micro tubes, Eppendorf type, with 50 µl of anticoagulant solution (sodium fluoride, 1%) and, later, analyzed with the lactate analyzer YSL 2300 (YSL, Ohio, USA).

Statistical Analysis

To test for the normality of data the Shapiro-Wilk test was used. Once the normality of data was confirmed, Student's test-t for independent samples was used. The adopted level of significance was of 5%.

Results

The comparison between two types of training methodologies are shown in Table 1:

Table 1. Intensity comparison between TT and ST sessions

Parameters	TT [La-]	TS [La-]
UCK	3.8 ± 1.7 mmol.l^{-1}*	1.9 ± 0.4 mmol.l^{-1}
RAN	4.0 ± 2.7 mmol.l^{-1}	3.7 ± 1.5 mmol.l^{-1}
END OF TRAINING	4.0 ± 2.2 mmol.l^{-1}	3.3 ± 1.1 mmol.l^{-1}

* Statistical significance P < 0,05

Statistical difference was found between training sessions only in the part of UCK technique where TT was more intense than TS. There was no difference in combat training sessions and in the analyzed total training session.

Discussion

The different application of the UCK may explain the difference of intensity in this part of the training. In the TT the intensity of the UCK was carried out in accordance with what is usually employed in judo technique trainings (Machida et al., 2009) and in the TS the intensity was purposely lesser, so that practitioners could train the proposed FU. The idea to carry out the technique part of the training with lesser fatigue seems in accordance with proposals which indicate that fatigue can harm the development and assimilation of technical components (Greco & Viana, 1997) because the fatigue process is characterized by a loss of the functional capacities emphasized by the transitory reduction of physical capacities, such as force, power and speed (Soligard et al., 2016).

However, in the RAN training the groups had similar intensities despite the difference of volume for each methodology. We observed the same phenomenon when comparing the intensity of the whole training session, for the athletes of the ST group did 10 min less of UCK and 16 min less of RAN. Such results may point to an optimization of the training session, since the technique training part was carried out with lesser intensity, though without compromising the intensity of the RAN training and the whole training session, even with a lesser total volume of 26 min.

Although, we must point out that in both sessions [La-] was below that found in other studies. Viveiros, Costa, Moreira, Nakamura, and Aoki (2011) had found [La-] between 5.4 and 7.8 mmol.l^{-1} in 4 distinct sessions of judo training. Drigo et al. (1996) had verified similar lactate responses in simulated combats ne waza (6.7 ± 2.8mmol/l) and tachi waza (6.5 ± 2.8mmol/l), both protocols of three combats of two minutes, with 90 seconds interval. Other studies had demonstrated that [La-] after session of RAN was even bigger varying from 8 ± 2.6 to 12.3 ± 0.8 mmol.l-1 for state class athletes (Degoutte, Jouanel, & Filaire, 2004; Franchini et al., 2011), of 9.0 ± 2 18.1 ± 4.4 mmol.l- for national and international class athletes (Bonitch-Domínguez et al., 2010; Bonitch-góngora et al., 2012; Franchini, Takito, Kiss, & Sterkowicz, 2005).

A possible explanation for the difference of [La-] in the training sessions, compared with other studies, relies mainly in the variations that may occur in the RAN training in which the differences in technical level, physical aptitude, strategy and motivation can intervene with the intensity of this type of training. Training with athletes from the same team can lead to intensity reduction in this training since knowing the opponent's style may facilitate the offensive and defensive actions of a combat. In practice, the coaches should consider varying the opponents in the RAN training, and also train with practitioners of other teams, so as to promote alternation of the intensity of this type of specific training. Moreover, some studies suggest that the peak of [La-] is higher after the first combat, in relation to the next ones (second, third and fourth), which indicates a lesser glycolytic contribution as the practitioners perform consecutive combats (Bonitch-Domínguez et al., 2010; Bonitch-góngora et al., 2012). Perhaps if [La-] was measured at the end of the first combat, the results could have been different.

Concerning the athletes' opinion regarding these two training methods (TT and ST), a previous study (Olívio Junior, Tavares Junior, Olívio, Dos-Santos, & Drigo, 2018) investigated U18 and U21 judokas, divided into 2 groups, and who experienced 1 week of TT and 1 week of ST. They were asked about the following indicators: motivation, pleasure, fatigue, understanding of the goals, physical preparation, technical-tactical preparation, *randori* variability, creativity, problem solving and general preparation. The results showed that the athletes preferred the ST model regarding motivation, pleasure and understanding of the objectives, which seems to be related to the monotony of the TT session and greater possibility of variations in the ST. The judokas also considered ST best for technical-tactical preparation, variability of randori, creativity, problem solving and general preparation, deeming it to prepare them in a more coherent way and in one which is closer to fight reality. In contrast, TT was identified as the one that generated the most fatigue and also as the best to prepare physically, which seems to be related to the subjective perception of effort and linked to the impression that the more stressful the training is, the more physically prepared the athlete feels. The [La-] of the sessions of these two different methodologies have similar intensities, notwithstanding.

As a limitation of this study, we highlight that it would be important for all athletes to carry out both training methodologies in a randomized manner, for a paired analysis. That could bring more information about the differences between the aforementioned methodologies. We suggest future research that uses other forms of intensity control between different methodologies such as RPE (Agostinho et al., 2017) and WER (Morales et al., 2016), and in addition to equalizing the volume of RAN and the total training session, which may result in new information and debates.

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Suwari Seoi Safety
From Children *Dojo* to High Level Competition

Attilio Sacripanti[1], Tania De Blasis[1], Michel Calmet[2], Emanuela Pierantozzi[3]

Abstract: *There is no knowledge about tori (the performer) safety, connected to one specific technique in judo, suwari seoi: a two knees kneeling variation of the seoi-nage family, also known as drop seoi-nage. Objective of the study was to perform a thorough biomechanical analysis to understand the specific mechanics of suwari seoi throwing in order to link impact results with safety related to sudden trauma to tori's knees. Participants analyzed range from children to high level athletes, testing all performances on IJF certified tatami.*
This paper provides an original and unique research about the mechanical properties of the impact of tori's knees during the suwari seoi throwing and the safety analysis, regarding the sudden trauma to his knees.
The final results, despite the small number of participants, suggest that if the technique is performed with no mistakes, on IJF certified tatami, the impact received will have a negligible effect with respect to sudden trauma, on the target ligament of the knee, the posterior cruciate ligament (PCL), for both children and adult athletes. The theoretical analysis carried out, indicates that, most of the damage that occurs in competition or as long-term degenerative trauma to the other knee ligaments is likely to occur during complementary movements performed by athletes to refine competition results. In fact, during the performance of a suwari seoi executed correctly, the impact of the knees on the tatami can at most lead to a bruise, while the danger of potential damage to the tendinous-ligamentous structures seems more connected with the complementary torsional movements that often complete the technical follow up.

Key words: *judo biomechanics, tori safety, suwari seoi, classical mechanics, falling chimney paradox, free fall, tatami compressibility, heat transfer, elasto-caloric effect, natural convective cooling, thermal analysis, crash test methodology*

Judo throws are very complex movements and until now biomechanical studies in judo have been applied to understand how a throw should be performed, in terms of forces applied, center of mass motion, etc. With a multidisciplinary approach, the authors focus, for the first time, on the safety of an athlete, with the aim of showing whether it is safe for judoka, from children to elite athletes, to use a specific judo throw, or whether this use is potentially dangerous for their safety.

Only two researches, prior to this, focused on the safety of *uke* (the receiver) only, who is thrown on the mat (tatami), by suwari seoi with potential danger.

This work focuses on *tori*'s (the performer) safety, focusing on the kneeling type of throwing techniques, applied with two knees on the mat. The two knee kneeling positions analysed are 'seiza' position (kneeling with both feet flexed in a Japanese style for sitting down) and 'deep kneeling' with both pointed feet on the tatami. This class of throws is used often in every level of competition. The authors focused on *tori*'s safety during the execution of seoi nage variations called, for convenience, 'suwari seoi,' performed with two knees on the mat, with feet either pointed or flexed.

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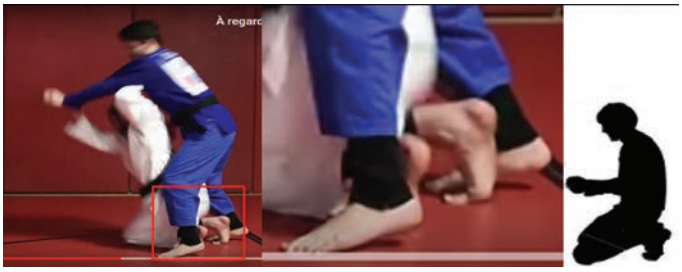

Figure 1: White judoka is throwing with pointed feet (deep kneeling position) (https://www.jitseasy.com/drop-morote-seoi-nage-adonis-diaz/)

Figure 2: Blue judoka is throwing with flexed feet (seiza position) (https://www.ijf.org)

Methods and analysis

26 subjects, including children and International level athletes, male and female, were analyzed, performing three trials each. Execution of the throw was performed alone (*tandoku renshu*), gripping *uke* (the receiver) without throwing and then performing a complete throw on *uke*. For each trial the velocity of the knees' impact with the *tatami* was measured, with a slow-motion HD video (960 frame per seconds). The contact areas between knees/legs on the *tatami* were measured, by 437 video images, measuring the 'cooling shadow' left by the athlete's legs on the tatami. A very sensitive Japanese AVIO thermal camera was used to measure the surface values. Then applying the crash test methodology, we obtain the safety evaluation, referred both at the "*Standard Judo Child*" (SJC) and "*Standard Judo Athlete*"(SJA).

The safety approach, deriving from engineering methods, is developed in the judo world and in this paper, like the one presented in 'Safety for Judo Children: Methodology and Results' (Sacripanti & De Blasis, 2017). The problem is to establish if the impact of the two knees, more or less simultaneously, is dangerous or not, for producing sudden trauma in the knees.

Usually, in a safety analysis, as standard procedure, the worst condition is analyzed as input for the final evaluation. in our situation this is the highest impact velocity of knees on the *tatami*. The highest intensity pressure can be found experimentally and / or theoretically and applied as input stress to the knee (the structure under examination in our situation) to verify the capability of the stress to overcome some structural limit of the bone and ligaments (the analyzed sample). If the stress overcomes this limit, a more careful analysis could be performed to verify the potential damage; if it doesn't, then the stress can be tolerated.

Normally safety is connected to the following constituent parameters: consequence class for the structure (knee), characteristic loads (impact pressure), load factors and combination factors, material properties (bone and ligaments), material factor. The load and material factors are chosen in such a way that a safety level belonging to the 'consequence class' can be obtained. To generalize the results, the concept of 'standard reference athlete' is introduced, like the standard dummies in crash tests (Starret & Liddle, 2005), or like the reference man in nutrition, radioprotection and preventive medicine (Snyder et al., 1975), with the goal to validate, optimize and monitor the effects, in our case of the impact stress on the knees.

Study Design

The reference population for this study consisted of judo players graded as 5st *kyu* (yellow belt) or above.

Independent variables were as follows: age, sex, athletes' knee height (from center of patella to the *tatami*), impact surface (evaluated by the thermal images on the *tatami*), time of the fall, *tatami* structure.

Dependent variables: falling mean velocity of the knee, impact force and related pressures on the tibia head (the target point).

The research was approved by the Ethics Committee at Genoa University. Details of the study were explained

to each participant and informed consent was obtained prior to their participation in the study. For children, parents gave written consent and participants were informed.

The focus of the research was the safety of the performer, in terms of sudden knee damage. For sudden trauma

we must consider that the impact energy is a function of the height of the jumping or the falling. The applied

load on the knees and legs during free landing varies according to height, ground softness, joint flexion, landing

positions and direction, athlete mass, etc. It is unquestioned that the magnitude of the load increases as height of jump increases, whereas the time of impact decreases. In contrast no significant differences were measured between periods of falling from the various heights analyzed, because adult and child athletes are used to not jumping high, but sliding between *uke*'s legs while taking their feet off the *tatami*.

The impact time (impact duration) was quite short and measuring the frame of the super slow-motion captures made, we evaluated an average time of 0.04s. Therefore, this average impact time of 0.04s was chosen and applied in the analysis, both for landing (jump losing contact with the *tatami*) and falling (falling down with feet not detaching from the *tatami*). The mean landing/falling times were evaluated for each performer in six different trials, to lessen the personal variation as much as practically possible. With a thermal camera it is possible to capture the thermal image of knee on *tatami* (Starret & Liddle, 2005) and to evaluate the impact surface. Then, by calculating the impact pressure on the knees, the knee safety information can be evaluated.

Sample

The reference population for this study consisted of 26 subjects, males and females. The subjects were separated into two groups: one group of child judoka (5male and 3 female) and one of adult judo athletes of a national team (12 male and 6 female). Children were aged between 10 and 15 years and were graded between yellow belt (5st kyu) and blue. Adult judoka, aged 17 to 23 years, were all black belts from 1st to 3rd *dan*. The two means were performed to define the standard references for both judo children and adult athletes, as described in the previous paper (Sacripanti & De Blasis, 2017).

Biomechanics of Falling and Landing Styles Until the Time of Impact. The mechanics of the knees 'impact is, physically speaking, very hard, from the calculation point of view. This proves the complexity of biomechanical analysis of judo throwing techniques.

For biomechanics, the *suwari* family is based on the mechanics of the lever with the maximum arm, but there is a more subtle difference in the styles studied: A) pointed feet and B) flexed feet (Figure 3).

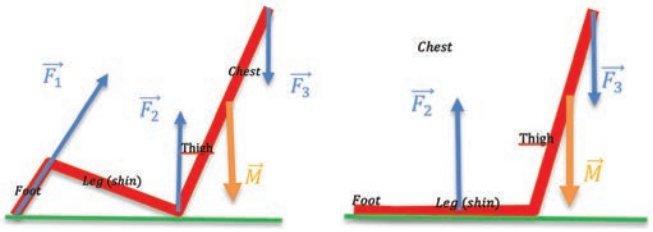

Figure 3: Force diagram

A) Pointed feet (kneeling) B) Flexed feet (seiza)

In red, we can consider *tori* as a non-deformable structure. In Blue: $\vec{F_1}$ the strength from *tori*' s toes.

$\vec{F_2}$: the reaction from the ground with the knee in contact with the ground head of the tibia (pointed) or the tibia tuberosity (front head) in contact (flexed). $\vec{F_3}$: Strength from *tori* to pull *uke* and throw him/her down

In orange : *tori*'s mass. In green: *tatami*

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. 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 we must consider the restitution of the jump energy accumulated for the initial jump of the throwing movement (Linthorn, 2001).

A) The situation of the pointed feet is interesting; the net torque on the leg is τ=k Lmg cos φ {1}

With L= length of leg, k= <1 (variable location of CM), m =body mass, g =gravity acceleration.

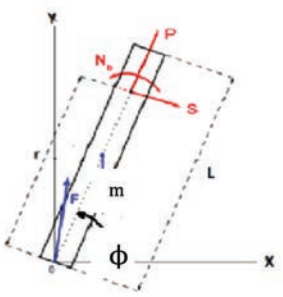

Figure 4: Model representation of leg not detaching the mat (fall)

The equation of the dynamic motion of the leg is:

$$\tau = I\alpha = I\frac{d\omega}{dt} = I\frac{d^2\varphi}{dt^2} = kLmg\cos\varphi \quad \{2\}$$

The inertial momentum is $I = \beta mL^2$ {3} from equations 2 and 3 it is possible to evaluate the angular acceleration α.

That is : $\alpha = \frac{kg}{\beta L}\cos\varphi$ {4}

if we define the constant $\omega_c^2 = \frac{kg}{\beta L}$ {5}

it is possible, by integration, to obtain the angular velocity ω :

$$\omega^2(t) = 2\omega_c^2(\sin\varphi_0 - \sin\varphi) + \omega_0^2 \Rightarrow \left(\frac{d\varphi(t)}{dt}\right)^2 = 2\omega_c^2(\sin\varphi_0 - \sin\varphi) + \omega_0^2 \quad \{6\}$$

The differential equation gives us the variation in time of the angle by the solution of elliptical integral.

It is also very important to analyse the position of the total CM of body, because normally if the mass is put before the collision center of the leg it can accelerate the vertical velocity of 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 throw, body weight, during the controlled falling in deep kneeling with pointed feet, is moved near the foot position.

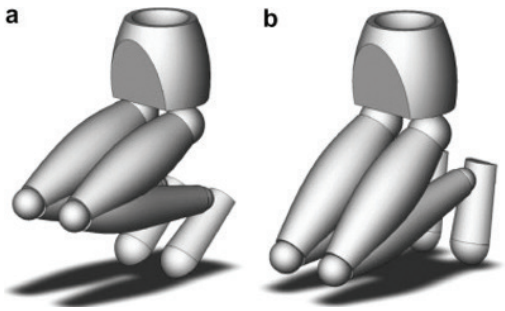

Figure 5 Way to fall with pointed feet

Under these conditions, if we call M the body mass and m the calf mass (% of M), the tangential component aT of the knee acceleration in horizontal position is (Calderon & Gil, 2011; Vareschi & Kamiya 2003):

$$a_T = \frac{3}{2} gL \left[\frac{Ml + mL}{Ml^2 + mL^2} \right] \{9\}$$

we can analyse the two limit situations: Ml=mL and M>>m and easily we obtain:

$$a_T \equiv a_n \simeq 3g \{10\}$$
$$a_T \equiv a_n \simeq \frac{3L}{2l} g \{11\}$$

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 knees 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 them in reference (Erman 2007; Calderon & Gil 2011). We give only the final result, useful for our safety analysis, in terms of the ratio of the free fall time divided by the knee falling time. If the ratio is less than 1 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, considering this situation as a model of a falling chimney, to obtain rough data about internal stresses of the knee, following and adapting the results of Vareschi and Kamiya (2003) in our specific situation. For the calf of the leg that progressively bends in some situations, it is potentially under the combined actions of a longitudinal force P and a bending moment N and the stress at the knee, considering the leg bone composed by one homogenous piece, is in non-dimensional form:

$$\frac{\pi \rho^2}{mg} \sigma_k = \frac{1}{2}\left(1 - \frac{r}{L}\right)\left[\left(5 + 3\frac{r}{L}\right)\cos\varphi - 3\left(1 + \frac{r}{L}\right)\right] + \frac{3}{2}\frac{L}{2\rho}\frac{r}{L}\left(1 + \frac{r}{L}\right)^2 \sin\varphi \{14\}$$

This equation depends on L/2ρ, with L= length of 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 on the bending moment playing a more important role in the safety of the athletes' knees.

From the other side, the sheer stress can be another leading cause of rupture. About the impact, it is easily seen that, for any specific angle, the magnitude of the force has an absolute positive maximum and usually originates near the ankle, meaning that large forces, can affect the ankle joint that serves as a pivot in the throwing action, before the impact.

B) In the situation of landing, athletes jump and land on the *tatami* with flexed feet, landing in seiza position. The mechanics of this throwing style are the simple mechanics of human body free fall. In terms of safety we must consider that the impact energy depends on the height of the jump. In equations we can write, remembering the conservation of mechanical energy:

$$\frac{1}{2} mv^2 = mgh \{15\}$$

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 increases as height of jump grows incrementally, 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 to not jumping high but they slip between *uke*'s legs with a jump. The velocity of each subject during free-fall, in terms of safety, was evaluated, starting from the knee height, using the following well known elementary equations:

$$\frac{1}{2} mv^2 = mgh \Rightarrow v_f = \sqrt{2gh} \{16\}$$

whereas the average theoretical time to fall was calculated by the following calculation:

$$t = \sqrt{\frac{2h}{g}} \{17\}$$

The knowledge of the impact time (0.04s) allows the impact load to be identified using the following equation:

$$\int_0^t F dt = \int_0^{v_f} m dv \{18\}$$

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 (Blais 2004; Blais, Trilles & Lacoture, 2007; Ishii & Ae, 2014; Ishii, Ae, Kobayashi & Suzuki, 2012; Ishii, Ae, Koshida & Fujii, 2016; Ishii & Ae, 2015; Ishii, Suzuki, Kobayashi & Ae, 2013; Ikai & Matsumoto, 1958), whereas from Spain comes the highest number of theses and papers that advise against the use of this technique for children (Montero Carretero & Lopez, 2014; Torres, 2016). The goal of this paper is to evaluate if there is danger of sudden trauma in both styles.

Biomechanics and Safety of Complementary Movement Styles After the Time of Impact

When athletes perform suwari seoi in competition, because it is very difficult for *tori* to control the defensive body direction of *uke* (Sacripanti, 2014) the necessity to perfect the final part of the throw, using some complex movements, usually called tactical tools (Sacripanti, 2018) arises. Starting from the two body positions (a) seiza and (b) kneeling (Figure 6), that represent the basic arrival position of *tori*'s body after the drop, 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 rotation or flexion, assisted by some specific arm movements.

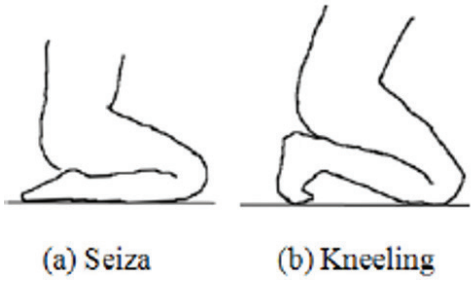

Figure 6: Arriving position

Figure 7: Execution of a complementary movement in competition, see equation {19}

In the fully flexed position, the extensor muscle pulls at less than 7o relative to the tibia.

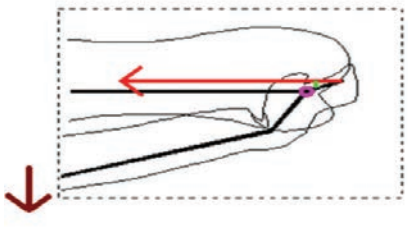

Figure 8: Quadriceps action pushing on the mat

The situation of pointed feet gives the extensor muscle a mechanical handicap relative to the ground of between 1/150 and 1/260 (it is hard to measure accurately); the muscle has to produce a great deal of force in order to produce a quite modest thrust on the ground (Figure 8) (Hirokawa & Fukunaga, 2013). The same action would be energetically more expensive if the athlete started from a seiza position. For these reasons more often, a different basic variation is applied in real competition; an intermediate form between seiza and deep kneeling. Normally *tori* takes support not on both legs, but differentiated support, more on one leg than the other. This different weight distribution varies the stability of *tori*, which becomes more mobile and can apply complementary tools more easily. The price of this greater freedom of movement is the potential danger due to the choice of only one support base for the dropping action, rather than two, in which the pressure, due to the impact of the fall on the knees, can decrease.

Japanese research was developed to study knee force production in seiza and deep kneeling, both descending and rising (Fukunaga & Morimoto, 2015; Nagura, Dyrby, Alexander & Andriacchi, 2002). 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 muscle 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 (Nagura, Dyrby, Alexander & Andriacchi, 2002).

The follow up to refine the throwing action of one of the suwari seoi family of techniques and the complementary movements (Figure 7), can be modeled as a linear combination of different contributing lifting force, plus elastic force, plus torsional force, with variables in time contributions:

$$F_{TT} = (m_1 + m_2)\, a \frac{t_l}{t_{TT}} - k(L \sin\varphi) \frac{t_f}{t_{TT}} + \tau_{\max} \frac{d^3}{5L} \frac{t_r}{t_{TT}} \qquad \{19\},$$

where: m1 m2 = 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, tTT= time of tactical tool application, ti= time: lift, forward, rotation.*

This theoretical equation enables us to evaluate the order of magnitude of the effort in the knee, in order to verify if the ligament structures of *tori*'s knees are possibly put at risk during the execution of these movements. We put the right physiological values in, for a theoretical movement performed in 0,26s divided into three sub-movements of the same time duration, all applied to two athletes of the category up to 66kg, 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 correct study of this part of the technique. Remembering the previous equation {19} and that the physiological parameters are related to the most used thigh extensor muscles (quadriceps femoris for wo-

men and hamstring group for men) (Fukunaga & Morimoto, 2015). The theoretical evaluation, for a 65 kg athlete versus a 62 kg athlete, shows us that for female and male the relative results are: 1750 N and 1560 N, with rotational contribution about 400 N. Remembering that normal resistance to traction is for ACL 2000 N, PCL 1500 N and lateral structures around 500 N (Race & Amis, 1994; Mommersteeg, Blankevoort, Huiskes, Kooloos & Kauer, 1996) we easily understand how delicate the perfect execution of this is. The last notation is that, during competitive application, most of the rotatory effort applied, in a safe way, is performed by the trunk-hip complex, lightening the task of the knees.

Dynamic Heat Conduction Between the Human Body and the Surface Layer of the Tatami

The evaluation of impact surface measurements is based on the dynamic heat conduction between the human body and the surface layer of the tatami, followed by the natural convective cooling. Few studies using infrared thermography have been devoted to sports performance diagnostics (Quesada, 2017; Sacripanti, De Blasis, Rossetti, Andreatta, Camilleri & De Crèe, 2015; De Blasis, Rossetti, Andreatta, Camilleri, De Cree & Sacripanti, 2012; Urbani, Sist, Alem & Capelletti, 2013) and to sports pathology diagnostics. No sports safety and prevention studies have ever been developed for judo techniques focusing on *tori*. In our case, to obtain the contact surface of *tori*'s legs on the tatami, we focus on capturing the thermal image of the surface body contact left by *tori* after the fall while throwing with *suwari seoi* and on his geometric measure, in both cases: pointed feet and jumping with flexed feet. This is possible because *tori*'s body, falling, touches the *tatami* and leaves one thermal track, produced by dynamic thermal conduction. This is not visible and the thermal track disappears very fast due to the cooling by convention of the surface layer, when the body leaves the tatami.

In formula the heating of the *tatami* surface, due to conduction between human body contact and *tatami* surface, is driven by the classical equation: $Q_{cond} = -k\nabla T$ {20}

The cooling of the *tatami* surface is driven by the natural convection in closed environment $Q_{conv} = \rho c_p VT$ {21} Remembering also that the general equation for convection is the well-known: $Q_{conv} = h(T - T_0)$ {22} It is possible to obtain the differential equation that shows the variation in time of temperature during cooling.

$$\frac{dT}{dt} = \left(\frac{h}{\rho c_p \Delta x}\right)(T_0 - T)$$

{23}The solution of this differential equation is:

$$T = T_0 + (T_1 - T_0)e^{-\left(\frac{h}{\rho c_p \Delta x}\right)t} \quad \{24\}$$

The evaluation of the inverse of the exponent gives us the order of magnitude of the time of cooling phenomenon, that is, introducing the material parameters, about 45s. That is very slow (Levesque, 2014). The idea, already utilized (Sacripanti & De Blasis, 2017), is to capture by a fast and sensible thermal camera this evanishing image of the contact surface, to measure it and evaluate the stress received by the body, that is the maximum impact force divided by the measure of evanishing thermal image of surface contact.

Procedures

Each participant performed two specific trials (flexed feet and pointed feet) with three subcases, (one to perform *suwari seoi* alone, a second gripping *uke* without throwing and a third throwing *uke*), with a total of six different throws performed (Table 1). The children repeated all trials four times for statistical reasons, to decrease the variance between one's personal performances. Adult execution was the same but only two repetitions were performed due to reasons of training program and competition preparation.

Table 1. Test execution programme

Trial			Number of executions	
			Children	Adults
A) pointed Feet	1	suwari seoi alone	4	2
	2	S.S. without throwing *uke*	4	2
	3	S.S. throwing *uke*	4	2
B) flexed Feet	4	suwari seoi alone	4	2
	5	S.S. without throwing *uke*	4	2
	6	S.S. throwing *uke*	4	2
		tot	24	12

This means that each child *tori* performed 24 actions with the same *uke* and adult *tori* performed only 12 trials each, with the same *uke*. Children performed the tests over three days, adult athletes over two days. In order to ensure greater safety and avoid potentially dangerous mistakes during executions due to fatigue. The diversification in the throwing way was made to study the influence of *uke*, on the speed of falling of *tori*'s knees in the dynamic of the couple. The first trial is falling with both pointed feet, always touching the *tatami*. The contact area is smaller than the second trial. It is only the tips of pointed feet and small tibial area. The second trial is the other way to apply *suwari seoi* in competition, jumping with the flexed feet out, not touching the *tatami* at all. In that case the contact area is larger, namely the long tibial surface projection

and back of the feet. We take the time of fall's trajectory for each throw, to evaluate the mean speed of fall. Then the protocol is very simple on a prepared *tatami*, on which both children and athletes performed the two trials of throws, one with pointed feet and another with flexed feet. The lay out of the research this time is organized with two prepared *tatami* and a cooling system to cool the *tatami* and speed-up the research time.

Figure 9: Cooling system and *tatami* with copper tape useful for thermal images

Two digital chronometers were utilized to evaluate the flight time or the trajectory time of the subjects, to have a better mean time evaluation. Simultaneously a slow-motion capture of the falling knees was tacked, 80 films, by an Xperia ZX3 phone with 19 MP Motion Eye™ camera. 1/ 2.3 Exmor RS™ for mobile memory-stacked sensor. Pixel Pitch 1.22µm, 25mm wide Sony G Lens F2.0. Predictive Hybrid Autofocus (0.03s), BIONZ™ for mobile image-processing engine. Predictive Capture (motion / smile). Autofocus burst x8 Digital Zoom. With 960 fps super slow-motion video (FHD/HD) arranged in the following system: 30 fps for 10s 960 fps for 5s 30 fps for the last 10s, to study carefully the biomechanics of the impact phenomenon. Then, by a Japanese Thermal Camera AVIO 600 from Nippon Avionics, equipped with the software InfReC Analyzer 9500, sampled the surface of contact for each trial. In Figures 10, 11, 12 and 13 there are examples of thermal images of the contact surface relative to the two styles analyzed. The differences among surfaces are clear.

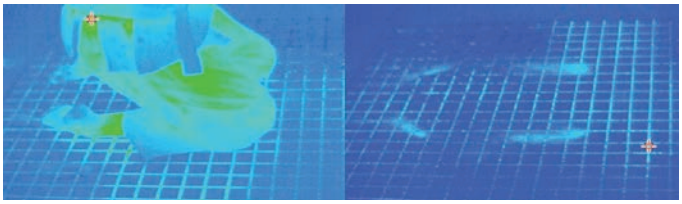

Figure 10: Children flexed feet and surface thermal image

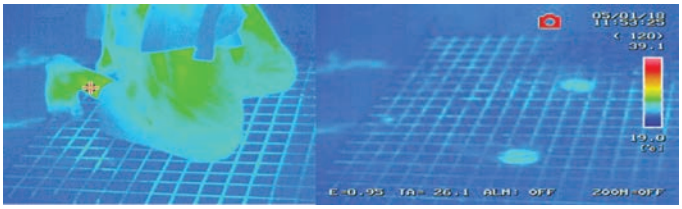

Figure 11: Children pointed feet and surface thermal image

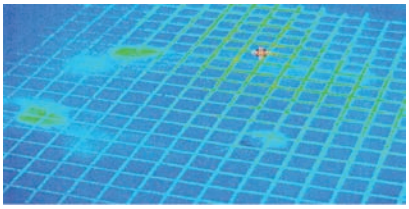

Figure 12: Adult pointed feet

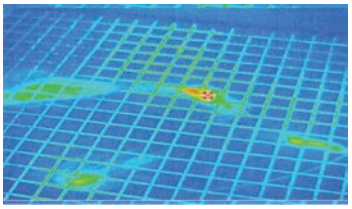

Figure 13: Adult flexed feet with preponderance from one leg

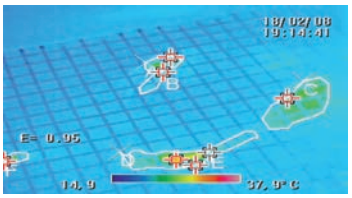

Figure 14: Adult measurement of surface area of suwari with right side preponderance

Normally it is very difficult to connect impact biomechanics results to the physiological and medical effects that follow. The only acceptable way is to connect these results with the crash test methodology, accepted worldwide, in which impact biomechanics results are connected in various ways to the medical evolution of the collision. As already applied in our previous paper, the mean result can be applied to judo children or athletes.

Statistical Analysis

The focal point in any design study is the adequate precision for the estimates of the measures, in the safety analysis like the present report. A reasonable approach is to take a random sample and make an inference from the sample to the population. How is this inference made? We use an estimator form. Think of an estimator as a function of the sample values used to estimate m. A logical estimator form is the sample mean $\bar{x} = \Sigma_i \frac{x_i}{n}$ {25} (Siebert & Siebert, 2018).

The most important problem is the variability in the value among trials of each person. To overcome this, we repeat the throws four times and evaluate the mean value of the speed of falling.

Safety analysis is based on a central value applied to a '*standard athlete*' that is a theoretical individual, whom has perfectly 'normal' characteristics, such as average body size, mass, age, sex, and race etc. In this paper we start to collect data with the proven methodology in use, obviously more data is collected, a best estimation will be made to define the '*standard athlete*.'

Results

The in-depth work carried out on the techniques was: analysis of 437 thermal films, (223 of the children and 214 of the national athletes) each of which averaged about 60 frames, allowing evaluation of the average of the contact surfaces between the four tests performed for the child-

ren and the two performed for adults in the case of both executions (with pointed feet and flexed 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*.

Average time of fall or flight, two measures for each style, made it possible to calculate the experimental fall velocity of *tori*'s knees, verified also by slow motion frame calculations. This speed was compared to the theoretical one, measured by the equations of the biomechanical models. The biomechanical models made it possible to also calculate the impact force in the worst conditions (safety analysis), which resulted in the highest pressure 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 differences. This comparison, in terms of safety, is based on the SBA (Surface Body Area) calculation.

Normally for children the Costeff formula (Costeff, 1966) is utilized and is more accurate than the well known formula of Du Bois and Du Bois (Du Bois & Du Bois, 1916) that overestimates the body surface for children. However, we use the Du Bois and Du Bois formula for children only, in the case of comparison with adults.

Speed Experimental Results

Some interesting safety evaluations are singled out from the experimental protocol utilized. At first, children show a constant decrement of the falling velocity in both the pointed feet and flexed feet approaches, starting from the exercise alone and ending with the projection exercise. This behavior is very important from a safety point of view. It is easily explained both by the poor technical ability and by the dynamic equilibrium between *tori* and *uke*, in other words, the presence of *uke*'s body slows the knee falling speed of *tori* who is relented by the action of moving the body mass of *uke*. In this way the final pressure will have less intensity and will be less dangerous for the children's knees. Since the data obtained from the experimental protocol is extensive, it was decided, for reasons of length, to present a single example of a table, one of a boy and one of a girl, and the global trend data of the speeds. In the following tables and diagrams there are two examples of this phenomenon shown, decreasing in speed, averaged from five trials. Equivalent results were found for 95% of the other children, with the last 5% almost equal at knee falling speed.

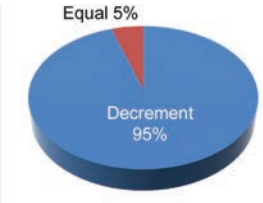

Diagram 1: Distribution average knees speed trials, all children

Tori alone		Gripping *uke* no throwing		Throwing *uke*	
Pointed feet	Flexed feet	Pointed feet	Flexed feet	Pointed feet	Flexed feet
1,88	1,46	1,38	1,56	1,23	1,34
2,13	1,62	1,56	1,95	1,42	1,17
2,04	1,95	1,04	1,51	1,27	1,23
2,23	1,88	1,42	1,62	1,51	1,17
1,77	2.01	1,61	1,39	1,29	1,29

Table 3: Average knees' falling speed example of a same boy (m/s)

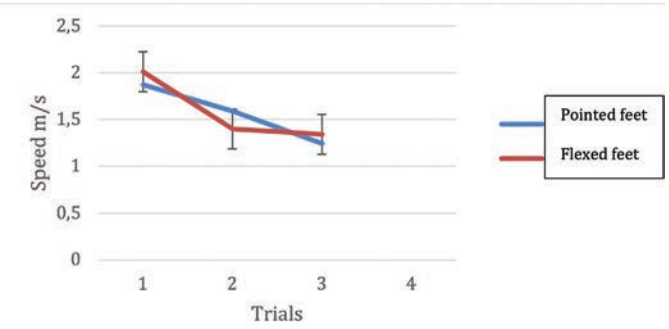

Diagram 2: Example of boy average speed decreasing (male)

Tori alone		Gripping *uke* no throwing		Throwing *uke*	
Pointed feet	Flexed feet	Pointed feet	Flexed feet	Pointed feet	Flexed feet
1,28	1,58	1,44	1,4	1,48	1,16
1,75	1,96	1,32	1,44	1,25	1,4
1,48	1,36	1,48	1,36	1,36	0,94
1,63	1,88	1,48	1,48	1,13	1,4
1,64	1,58	1,4	1,39	1,32	1,29

Table 4: Average knee falling speed, example of a same girl (m/s)

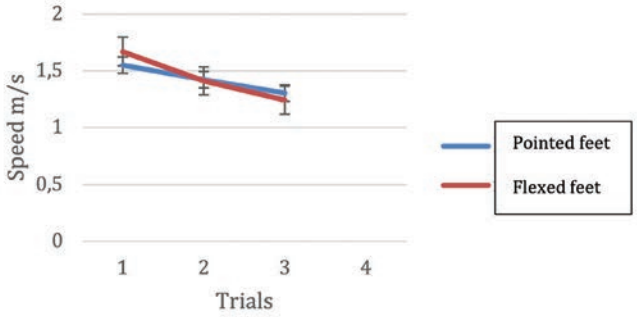

Diagram 3: Example of child average speed decreasing (female)

A more variable trend is found in the adults of the Italian national team, that possess a greater technical ability and more accentuated automatisms. In the next two diagrams we give, in an indicative way, the percentage trends

found between the athletes of the national team, divided as males and females. Among male judoka about 63% showed the expected decrease, while 7%, more or less, showed a constant speed and a 30% increase in speed of correspondence with the acquired competitive technique. Among female judoka 61% showed a decrease, 30% showed an increase and 9% more or less showed a constant speed.

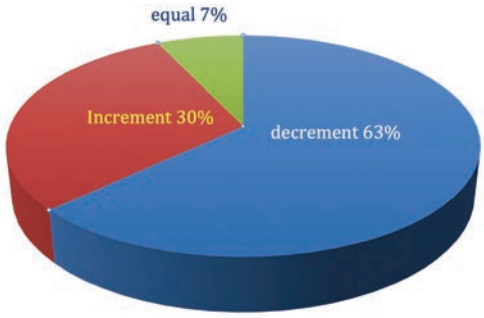

Diagram 4: Distribution average knees speed trials, adult national team (male)

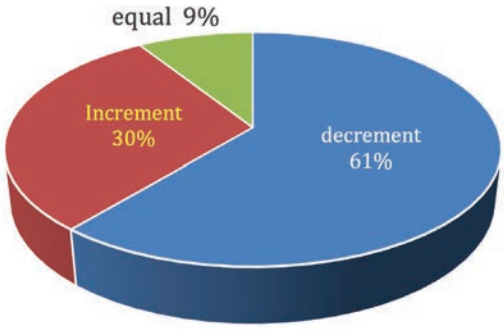

Diagram 5: Distribution average knees speed trials, adult national team (female)

Connections between speed and skill of the athlete highlighted that the fastest ever was a former world champion.

Tori alone		Gripping *uke* no throwing		Throwing *uke*	
Pointed feet	Flexed feet	Pointed feet	Flexed feet	Pointed feet	Flexed feet
1,9	2,5	2,31	1,3	2,31	2,04
1,13	1,9	2,12	2,31	2,37	2,31

Table 5: Fastest adult male athlete trials (m/s)

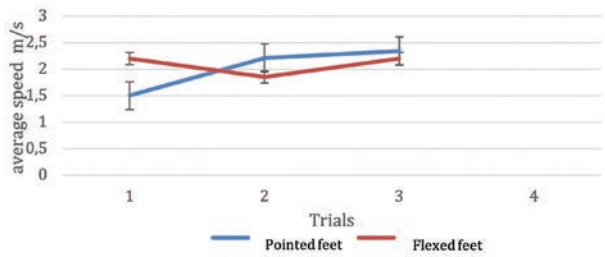

Diagram 6: Average trend fastest adult male athlete, increase in speed (m/s)

Tori alone		Gripping *uke* no throwing		Throwing *uke*	
Pointed feet	Flexed feet	Pointed feet	Flexed feet	Pointed feet	Flexed feet
1,64	1,88	2,13	2	1,95	2,24
1,62	1,88	1,84	2,23	1,95	2,35

Table. 6: Fastest female adult athlete trials (m/s)

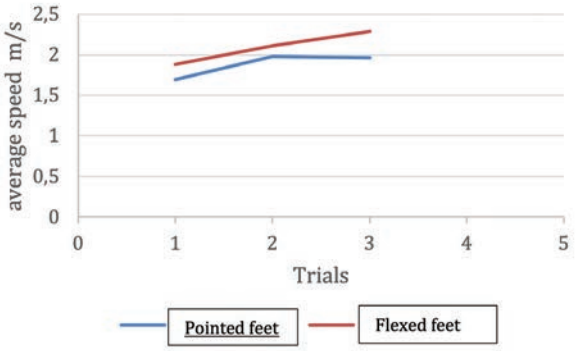

Diagram 7: Average trend fastest female adult athlete, increase in speed (m/s)

The safety aspect of the throw for children and even for athletes, is guaranteed by the experimental data that for both boys and athletes. The next step will be to measure the average standard judoka child (Sacripanti & De Blasis, 2017) the stresses that are produced at the knees in the two styles at impact (Rich, Dean & Power, 2005; Koshida, Deguchi, Miyashita, Iwai, & Urabe, 2010; Han, Ge, & Liu, 2014) .

Finally, we evaluate the AIS (Abbreviated Injury Scale) (Sacripanti & De Blasis, 2017; US Department of transportation, 2012; Euro ENCAP, 2017) for the determined compression, to see if there is danger in the application of the *suwari seoi* throwing family.

AIS = -3,78 + 19,56C C=Ψ/E=F/AE

The Compression factor **C** is evaluated by the stress received divided, by the young modulus of *tatami* E: E= 0,44 Gpa (Ionescu, 2016 ; Mane, Chandra, Sharma, Ali, Chavan , Manjunath & Patel, 2017 Lerch, & Sullivan, 2006). In terms of safety, considering the maximum available values of forces in the two styles, pointed feet and flexed feet, that are respectively 3 BW (Erman, 2007) and 7BW (Montero Carretero, Lopez, 2014), we can evaluate the results in light of AIS.

	CHILDREN		ADULTS	
	MALES	FEMALES	MALES	FEMALES
MEAN Surface POINTED FEET	0,014 m²	0,012 m²	0,0167 m²	0,0132 m²
MEAN Surfaceflexed feet	0,022 m²	0,017 m²	0,047 m²	0,029 m²
BSA MEAN DUBOIS	1,5787 m²	1,614 m²	1,9456 m²	1,5242 m²
category Es. A	1,36977 m²	n.p		
category Es. B	1,53498 m²	n.p.		
cadets	1,87469 m²	1,59843 m²		
juniors	1,53829 m²	1,62961 m²	1,811481 m²	1,47425 m²
seniors			2,07980 m²	1,57434 m²
MEAN WEIGHT NAKED	54,45 Kg	55,5 Kg	78,8 Kg	52,35 Kg
category Es. A	45 Kg	n.p.		
category Es. B	54 Kg	n.p.		
cadets	63,5 Kg	52,5 Kg		
juniors	55,3 Kg	58,6 Kg	69,52 Kg	49,6 Kg
seniors			88,08 Kg	55 Kg
MEAN WEIGHT WITH JUDOGI	55,7 Kg	56,5 Kg	81,3 Kg	54,45 Kg
category Es. A	46 Kg	n.p.		
category Es. B	56,1 Kg	n.p.		
cadets	64,6 Kg	53,4 Kg		
juniors	56,4 Kg	58,6 Kg	71,8 Kg	52 Kg
seniors			90.8 Kg	56,9 Kg
MEAN YEARS all subjects	2001	2001	1995	1997

Table 7: Children and adult mean data (surfaces, weights with and without judogi, BSA, years)
n.p.: not present

children	**Male f.p.s (m²)**	**Male f.s.s (m²)**	**Max Force Fp 3 BW (N)**	**Max Force Fs 7 BW (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
Standard Child	**0,014**	**0,022**	**1618,65**	**3776,85**	**55**	**0,11**	**0,17**	**0,25**	**0,38**
Athletes Adults	**Male f.p.s (m²)**	**Male f.s.s (m²)**	**Max Force Fp 3 BW (N)**	**Max Force Fs 7 BW (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
Standard Athlete	**0,0167**	**0,047**	**2392,6**	**5582,8**	**81,3**	**0,14**	**0,12**	**0,31**	**0,26**

Table 8: Male children and male adult athletes final standard reference results (in red)
fps =pointed feet surface; fss =flexed feet surface ; Fp= pointed feet; Fs =flexed feet

children	Female f.p.s (m^2)	Female f.s.s (m^2)	Max Force Fp 3 BW (N)	Max Force Fs 7 BW (N)	Mass Kg	Stress Fp MPa	Stress Fs MPa	Compression A-dimensional 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
Standard Child	**0,012**	**0,017**	**1633,365**	**3811,185**	**55,5**	**0,135**	**0,22**	**0,30**	**0,49**
children	**Female f.p.s (m^2)**	**Female f.s.s (m^2)**	**Max Force Fp 3 BW (N)**	**Max Force Fs 7 BW (N)**	**Mass Kg**	**Stress Fp MPa**	**Stress Fs MPa**	**Compression A-dimensional 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
Standard Athlete	**0,0132**	**0,029**	**1602,46**	**3739,081**	**54,45**	**0,12**	**0,13**	**0,27**	**0,29**

Table 9: Female children and female adult athletes Final Standard Reference Results (in red) fps =pointed feet surface; fss =flexed feet surface; Fp= pointed feet; Fs =flexed feet.

The AIS (0) values both for children and athletes are always negative and this means extremely light trauma. So there are no «silent» or obvious traumas but only minor bruises. From that we can evaluate that both applications of *suwari seoi* styles (pointed feet and flexed feet), if correctly applied, are safe for all judoka, from children in local dojos to high level athletes in competition, in terms of sudden trauma to the target body part: the posterior cruciate ligament (Siliski, 1994 ; Prill, Coriolano, Michel, & Alfuth, 2014). Doubts about the danger linked to the collateral ligaments (Prill, Coriolano, Michel, & Alfuth, 2014 ; Handler, Moser, Toca-Herrera & Burtscher, 2017) focus at this point on the complementary movements that are carried out by *tori* after he has touched the ground with his knees. These movements, that are essentially hyperextensions or torsions carried out by *tori* with knees locked to the mat, are performed essentially to perfect the result of the technique in competition (Sacripanti, 2018).

Discussion

The experimental part of this research, applied to the safety of *suwari seoi* family of techniques against the immediate trauma, was performed at Italian Olympic Centre Matteo Pellicone in Rome, with 8 children ranging from Cadet (u17) to Junior (u21), 5 male and 3 female and 18 adult athletes, ranging from junior to senior, 12 male and 6 female.

There were two styles of *suwari* throws evaluated: one with pointed feet, in which *tori* is in a deep kneeling position and another in which *tori* is in *seiza* position (Fukunaga & Morimoto, 2015). During the procedures (2.6) the experiment and the time spent were described, recommending 3 days for children and 2 days for adult athletes, for safety reasons for the participants.

The first interesting result was that for children, the speed of knees dropping decreases from alone in the first trial to throwing *uke* in the third trial. This means, in terms of safety, that the presence of a body to throw slows down the speed of fall, making the knees' impact on the *tatami* less risky for the posterior cruciate ligament. For the adults, both male and female show one interesting behavior: 60% of subjects slowed down, 30% accelerated and 10% showed no increase or decrease in speed. This almost standard behavior could be connected to the personal skill of athletes performing this technique. The specific calculation of the compression of the mat during the trials, both for children and adult athletes, on IJF licensed *tatami* in PU, range from 0,88mm to 2,28mm (Sacripanti, De Blasis, 2017; Purvi, Shepherd & Hukins, 2008; Gaskell & Laughlin, 2018), depending on the mass and velocity involved. It is well known in biomechanics in the orthopedic world that the knee structure can absorb part of the stress moving forward to backward, of about 5-10 mm (A.A.V.V., 2010) . The total stress received by the *tatami* is evaluated by elasto-caloric effect (Sychev, 1973) and is connected to the elastic properties of the knee (Race & Amis 1994; Mommersteeg, Blankevoort , Huiskes, Kooloos & Kauer, 1996).

Conclusions

We consider the worst stress on the knees or knees and tibia ranging from 0,11 MPa 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 (A.A.V.V., 2010) gives a very small compression, which provides as a result a negligible stress on the posterior cruciate ligament, which is able to resist at a force of 1500 N (Race & Amis, 1994). The final result, despite this small number of samples, suggests that if the technique is performed with no mistakes, on IJF certified tatami, the impact received will be of negligible effect with respect to sudden trauma, to the target ligament of the knee, that is 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 (Prill, Coriolano , Michel & Alfuth, 2014) shows that for seoi, our target structure of the PCL is connected to 0.05%, whereas ACL and patella are to 0.15%, MCL and LCL to 0.10%. Because, from literature, other knee target structures are much more involved with seoi than the PCL, it is possible to state that the theoretical analysis carried out correctly indicates that most of the damage that occurs to the different ligaments of the knee, they are most likely produced, during the complementary movements carried out to refine the result in competition, by unsafe twisting knee actions.

Although surely related, both the low number of samples and the safety assumptions made on the impact forces, the experimental results on standard children show that a slightly larger stress is associated with the style of flexed feet rather than 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 more 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 started with this new methodology, applied for the first time on *tori*'s 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 to define the standard athletes and consequently obtain more precise evaluations about the safety of the technique.

In light of the above, this work must be considered substantially, as a first solid basis for being able to obtain more precise data, on *Tori*'s safety during *suwari seoi* execution (Cariou, 2019).

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Validity of competitive judo performance Collective insights from the Japanese judo coaching community

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Abstract: *The sport of judo is one of combat sports originated in Japan and became an Olympic Games event for the first time in 1964 (Tokyo). Judo was founded by Dr. Jigoro Kano (1860-1938) and there have been rapid technological developments of modern judo with developments of science and art of coaching. However, evidence-based characteristics of competitive judo performance are not well documented. The aim of the study was to establish content validity of competitive judo performance by experts of the Japanese judo coaching community. The structure model of competitive judo performance was identified by literature review and constructed with 5 national coaches. The content validity of the structure model was confirmed by 21 judo experts with 98.0 ± 3.4% agreement after a two-round Delphi study. Three main characteristics in competitive judo performance were extracted: 1. fundamental movements e.g. etiquette (reiho), posture (shisei), moving forward, backward, or to sides (shintai); 2. interpersonal basic techniques - throwing techniques (nage-waza) and grappling techniques (katame-waza); and 3. interpersonal applied skills developed/shaped through the free sparring (randori) or competitions. It was also found that the development stages shifted from focusing on the fundamental movements, interpersonal basic techniques, and then interpersonal applied skills. The insights gained from this study provided a basis for improved understanding of competitive judo performance and it might be useful for judo coaches and other combat sports communities.*

Key words: *performance analysis, structure model, content validity, Delphi study*

The sport of judo is one of combat sports originated in Japan and became an Olympic Games event since 1964 (Tokyo). In total, Japan has won 84 medals in judo at the Olympic Games, with the highest number of gold medals for Japan to date. The founder of judo is Dr. Jigoro Kano (1860-1938), who had established a logic in technical skills in judo by learning from jujitsu and other martial arts (Kano, 1930). There are more than 100 technical skills in judo, and Matsumoto (1975) has created a coaching framework to develop the technical skills. Since then, there have been rapid technological developments of modern judo at the Olympic level. The Japan Sport Association (formerly Japan Amateur Sports Association which was founded by Dr. Kano as the inaugural chairman) initiated a range of sports science projects to better understand the performance characteristics of various sports including judo from 1959 to 1999 (Asami et al., 1999). In the 1950's and 19060's, one of pioneer researchers in judo was Dr. Ikai and he studied various aspects including attitudinal reflex (Ikai, 1958a), biomechanical analysis (Ikai & Matsumoto, 1958), heart rate (Ikai & Matsumoto, 1969), blood pressure (Ikai, 1958b), and breathing (Ikai & Yamakawa, 1957).

More recently, biopsychosocial factors of judo have been studied (Franchini et al., 2011; Franchini et al.; 2013; Torres-Luque et al., 2016; Ziv & Lidor, 2013). Competitive judo demands high-intensity intermittent activities, in which optimal physical attributes are necessary to achieve technical-tactical development and success in judo (Franchini et al., 2011). In international competitions, judo athletes (judokas) typically perform 5-7 matches per day with competition recovery intervals of 15 min (Franchini et al., 2009). One of the physiological characteristics of judo is that it is intermittent in nature with 20-30 s of high intensity efforts with a 10 s rest interval (Franchini et al., 2013). Further, judo specific test protocols have been developed to mimic intermittent activities and specific movement patterns (Sterkowicz-Przybycień & Fukuda, 2014; Sterkowicz-Przybycień et al., 2019). Moreover, it is known that most of the combat time is spent in grip disputes which require high isometric strength and endurance, especially from the forearms (Franchini et al., 2013). Epidemiological studies during Olympic Games in 2008 and 2012 confirmed that sprains, strains, and contusions of the knee, shoulder, and fingers are the most frequent injury in judo with being thrown as the most common injury mechanism (Pocecco et al., 2013). The recent study on Under 23 judo athletes at European Judo Championships in 2015 also confirmed the most common type of injury was contusion (Čierna et al., 2019). However, many researchers focus on one or few aspects of performance in judo and the whole structure of competitive performance and how the key characteristics were systematically developed in judo were less studied.

Through a systematic process incorporating scientific principles and methods, strucutre models of competitive perfor-

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mance is documented in several sports (Castellano et al., 2012; Hellard et al., 2019; James et al., 2017). For example, a 20-year cohort study of elite swimmers has revealed that progressive increases in training load, macrocylces lasting 14-15 weeks, were associated with competitive performance (Hellard et al., 2019). In elite mixed martial arts, the grappling activity and technique accuracy were particularly important contributing factors for competitive performance (James et al., 2017). Although several researchers (e.g. Franchini et al., 2011; Franchini et al.; 2013; Sterkowicz-Przybycień & Fukuda, 2014) examined some aspects of judo, there is still a lack of understanding the whole characteristics of competitive judo performance in a valid and consistent manner.

Evidence-based characteristics of competitive judo performance are needed so that coaches with various coaching levels and practitioners can use these characteristics as a shared language. Therefore, the aim of the study was to establish content validity of competitive judo performance by experts of the Japanese judo coaching community.

Methods

Scope and purpose

The study was approved by the Ethics Committees of the Japan Institute of Sports Sciences and all participants provided written informed consent. To improve understanding of modern trends in competitive Olympic judo events, a hypothetical structural model was needed to explain competitive judo performance. The content validity of the hypothetical structural model was examined based on the literature review and collecting and documenting expert knowledge. The hypothetical structural model was developed by determining its scope and purpose, synthesizing existing literature, and establishing content validity of the structural model alongside expert insights (Figure 1).

The members of the research team (n = 5) discussed the objective of constructing the structural model as to identify the practical matters to be considered by end users and provide the key concepts to be the basis of future studies. Practical questions addressed included: What are the defined competitive performance characteristics? What are the contributing factors to competitive performance? How do you train these factors to enhance performance? Target populations were judo practitioners, coaches, researchers, and sporting organisations across ages, gender, competition levels, and additional end users from other sports organisations such as combat sports and martial arts were also included.

Literature review

To clarify the historical development of research in judo, the research team conducted a literature review based on published works in Japanese and English books and journals. The Kodokan Judo Institute was founded by Dr. Jigoro Kano in 1882. Within the Institute, there is the Kodokan Library which is considered to hold the most extensive collection and 4,823 Japanese books in the Kodokan Library were searched (as of March 31, 2018). The search keywords included “Technique” and “Science” with “Judo” from 1882 when Kodokan was founded to March 2018 and classified the articles based on the historical development of judo. Further, a comprehensive literature search of English articles was performed using the search engine SPORTDiscus, a database in the field of sports science, combining keywords of «Judo AND Technique», «Judo AND Science» in the search period of 1882 (when Kodokan was founded) to March 2018 which was the same period as the search of Japanese articles for comparison.

Aggregation of expert knowledge

The revised Appraisal of Guidelines for Research & Evaluation Instrument (AGREE-II) evaluation method (AGREE Next Steps Consortium, 2017), which has been used for developing clinical practice guidelines (Evans et al., 2018), and the Delphi method, which is a structured group communication process that aims at the collection of knowledge and judgements of experts (Hsu & Sandford, 2007), were used for qualitative analysis of competitive judo performance.

The knowledge aggregation was developed as follows:

1 Construction of a hypothetical structure model

Based on the literature review, the hypothetical structure model of competitive judo performance was constructed by the research team members.

2 Interviews with experts (National coaches)

A semi-structured interview of national coaches (n = 5) of the All Japan Judo Federation (AJSF) were conducted in a group to gain insights from the experts on developing the hypothetical structure model. The 2-hour roundtable meeting was organized by the research team and open ended practical questions such as the defined competitive performance and the contributing factors were discussed. The six domains of «scope and purpose», «stakeholder involvement», «rigor of development», «clarity of presentation» and «applicability» were also evaluated individually. The anonymous responses by the experts were obtained on a 7-point Likert scale (from 1 ‘Strongly disagree’ to 7 ‘Strongly agree’) (AGREE Next Steps Consortium, 2017). Tests for agreement were examined based on the AGREE II evaluation method and a minimum level of 70% agreement was set for consensus (AGREE Next Steps Consortium, 2017).

3 Reconstruction of the hypothetical structure model

After the semi-structured interview, the hypothetical structure model was revised by the research team members.

4 Delphi questionnaire: Round 1

In the first round of the Delphi study, the practitioners and researchers of AJSF High Performance Committee Scientific Research Department were recruited as the participants (mainly the professors from the various universities). They were selected as the expert panels as the field of expertise might affect the results of the study (Hsu & Sandford, 2007). A total of 43 individuals from the AJSF High Performance Committee Scientific Research Department were contacted via email outlining research aims and procedures and 21 of them agreed to participate (the response rate of 48.8%).

An anonymous online questionnaire (the Google Forms) was sent to the 21 participants and requested to be returned within 4 weeks. They responded (i) to rate the importance of each contributing factors of the reconstructed model on a 5-point Likert scale from 1 'not at all important' to 5 'very important' and (ii) to rate the clarity from 1 'not at all' to 5 'very easy to understand' (Pilgrim et al., 2018). The participants were allowed to suggest new contributing factors proposed for addition to the reconstructed model.

5 Delphi questionnaire: Round 2

In the second round of the Delphi study, the participants received the results from the previous round and a list of proposed revisions. At least 67% consensus on the test of consensus (Pilgrim et al., 2018) was set and it was re-examined until consensus was reached among the participants.

6 Finalisation of the competitive performance structure model

The final version of the structure model was confirmed by the research members based on the results of the Delphi study.

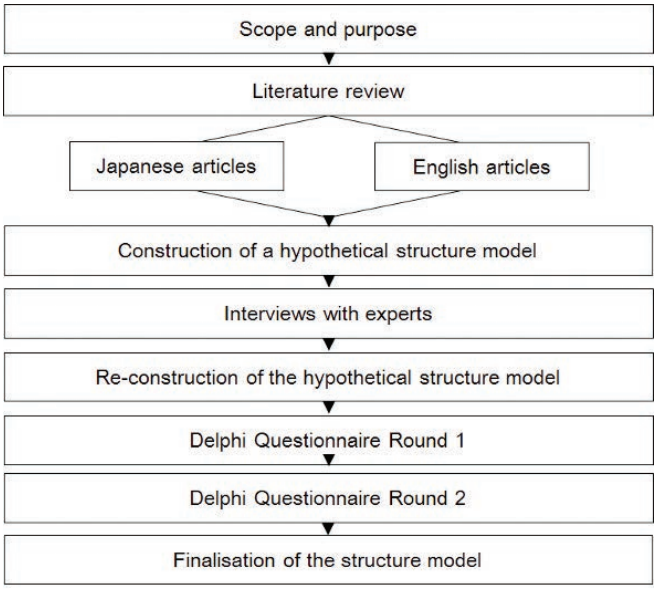

Figure 1 The process for establishing content validity of competitive judo performance

Data analysis

The study period of literature review was divided into five distinct periods based on the historical development of domestic and international trends in judo: the foundation of the Kodokan in 1882 (period 1), the formation of the European Judo Union in 1948 (period 2), the foundation of Japanese Academy of Budo in 1968 (period 3), the publication of *Judo Science Research* (in Japanese) in 1993 (period 4), and the foundation of *Archives of Budo* in 2005 (period 5). The results of literature review were presented as the number of articles published in each period and the average number of articles published per year. In the AGREE II and Delphi methods, all the responses were collected by the coordinating researcher (TI) and analysed by a principal researcher (TK). The group averages of the responders were calculated and the respondent agreement was expressed as percentage.

Table 1. The number of published articles in Japanese and English on judo during the study periods (1882-2018)

	Judo & Technique in JPN	Judo & Science in JPN	Judo & Technique in ENG	Judo & Science in ENG
Period 1 (1882-1947): Foundation of Kodokan and domestic development of judo in Japan	46 (0.7/year)	90 (1.4/year)	0 (0.0/year)	0 (0.0/year)
Period 2 (1948-1967): Form of European Judo Union and international development of judo	24 (1.3/year)	103 (5.4/year)	0 (0.0/year)	0 (0.0/year)
Period 3 (1968-1992): Found of Japanese Academy of Budo and afterwards	89 (3.7/year	326 (13.7/year)	4 (0.2/year)	7 (0.3/year)
Period 4 (1993-2004): Publication of Judo Science Research (in Japanese) and afterwards	152 (13.8/year)	268 (24.4/year)	21 (1.9/year)	38 (3.5/year)
Period 5 (2005-2018): Publication of Archives of Budo and afterwards	130 (10.0/year)	414 (31.8/year)	137 (10.5/year)	286 (22.0/year)

Results

A total of 1,542 articles were published in Japanese from 1882 to March 2019. Table 1 presents the number of publications over five study periods. Technical aspects of judo in Japan were published in greater numbers during period 4, following the establishment and publication of *Judo Science Research* in 1993. Overall, studies on the scientific aspects of judo have been steadily increasing in English and to some extent in Japanese, over the five different periods. There were no published articles related to judo technique and science between period 1 and period 2. While a total of 936 articles were published in English from 1968 to March 2018 with 162 articles on technique and 331 articles on science, the greatest growth in the number of publications per year increased approximately 5.5 to 6.6 times from period 4 to period 5, despite fewer comparative years between period 5 and period 4 (e.g. 21 years and 13 years).

Based on the literature review, the main success factors extracted for competitive judo performance were related to fundamental movements, interpersonal basic techniques, and interpersonal applied skills by inductive reasoning. The main factors were then subdivided by the biopsychosocial elements to construct a hypothetical structure model. As a result of the interview process with the national coaches, all parties agreed (100%) on the hypothetical structure model in judo. As for the consensus process of constructing the structure model, an average agreement of 73.3 ± 7.0% was obtained for the six domains of «scope and purpose», «stakeholder involvement», «rigor of development», «clarity of presentation» and «applicability».

From the first round of the Delphi study, 21 experts answered with the response rate of 48.8%. The «importance» of each contributing factor scored 5 on the Likert scale in the median and the «clarity» of each contributing factor scored 4 in the median, respectively. As a result of the second round of the Delphi study (n = 14, a response rate of 66.7%) average respondent agreement achieved 98.0 ± 3.4%, thus confirming the content validity of the structure model. Therefore, the hypothetical structure model was now accepted and adopted as the competitive performance characteristics in judo.

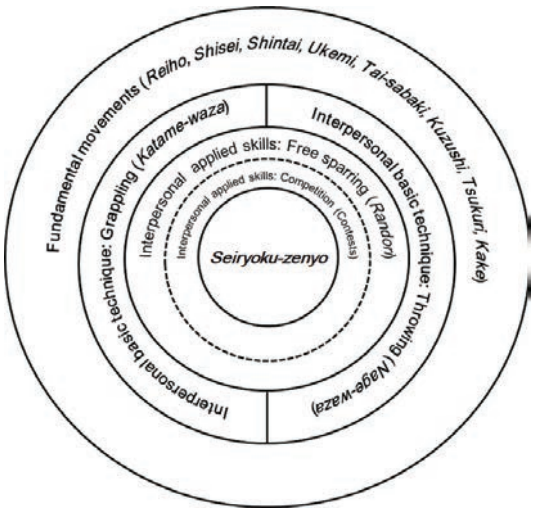

Figure 2. A constructed structure model of competitive judo performance.

The following competitive performance characteristics in judo were validated and adopted after the semi-structured interview with national coaches and the Delphi study of experts (Figure 2):

(1) Judo techniques in competition (contests) have a holistic structure to achieve the goal of throwing and grappling.

(2) The main characteristics of competitive judo performance are fundamental movements, interpersonal basic techniques, and interpersonal applied skills that compose the overall performance structure in judo.

(3) Fundamental movements, as the basis of the overall performance structure, are the basic movements necessary for competitive judo including elements such as etiquette (*reiho*), posture (*shisei*), moving forward, backward, or to sides (*shintai*), fall breaking (*ukemi*), body control (*tai-sabaki*), balance breaking (*kuzushi*), set up to execute (*tsukuri*), and execution (*kake*).

(4) Interpersonal basic techniques, as the middle part of the overall performance structure, are internationally recognized basic techniques with the universal acceptance by the IJF and are classified as throwing techniques (*nage-waza*) and grappling techniques (*katame-waza*).

(5) Interpersonal applied skills, as the top part of the overall performance structure, are the development of basic techniques into applied skills with personal features. The skills are developed (shaped) through the free sparring (*randori*) or competitions (contests) on an individual basis at various phases and situations by offense and defense, individuality and originality, and practice modalities etc. Interestingly, interpersonal applied skills have mature styles in each country (e.g. Korean Judo (Kim et al., 2015) and Georgian Judo (Zubitashvili & Mayashvili, 2012) and they greatly affect the performance structure. The elements of interpersonal applied skills include specific physical fitness and the psychological aspects such as mental toughness. It was considered that biopsychosocial elements cannot be separated due to the complex combination of these factors contribute to overall performance (Filaire et al., 2001). The elements of competitive techniques include strategies and tactics, and they are also greatly affected by the revision of the IJF refereeing rules.

(6) The overall performance structure of competitive judo is closely related to the developmental stages of judo. On the premise of general skills and general physical fitness mostly acquired in early childhood and childhood, there is a transition of technical development from the initial stages of learning and acquiring fundamental movements and interpersonal basic techniques to the later stage of acquiring more interpersonal applied skills.

(7) *Seiryoku-zenyo* is one of the core principles in judo and means the most efficient use of physical and mental energies to achieve an intended purpose (Kano, 1986).

It is always the foundation of the development in judo regardless of competition levels and developmental stages (The ambition and pursuit to become world champions are also included in this element).

Discussion

After Dr. Kano's foundation of judo with the establishment of the Kodokan, coaching practices in judo have clearly modernised and evolved over the years. Scientific research in judo has been well developed through understanding biopsychosocial factors of judo (Franchini et al., 2011; Franchini et al.; 2013; Torres-Luque et al., 2016; Ziv & Lidor, 2013). There was a need for an evidence-based structure model of competitive judo performance to understand the whole characteristics of competitive judo performance in a valid and consistent manner.

In this study, it was found that the structure model of competitive judo performance could be qualitatively structured and validated using the social science research techniques such as the AGREE-II and Delphi methods. We theoretically identified the structure model of competitive judo performance from inductive reasoning by literature review and deductive reasoning by expert knowledge. At the macro level, three characteristics (fundamental movements, interpersonal basic techniques, and interpersonal applied skills) were extracted as the main characteristics of competitive judo performance. In a review study, gold medalists at Olympics or World Champions displayed high levels of psychological factors (e.g. confidence, mental toughness) and other factors such as genetics may influence them (Rees et al., 2016). In Japan, several researchers initiated to investigate genetics (Itaka et al., 2016) and relative age effect (Hirokawa et al. 2019) in elite judo athletes. Further studies are needed from the micro level to identify specific characteristics and developmental trajectories of judo athletes.

It was also found that the development stages shifted from focusing on the fundamental movements, interpersonal basic techniques, and then interpersonal applied skills. From the practical point of view, we will need to clarify the pros and cons of applying the structure model in practice in wider coaching communities in judo and other combat sports as some coaches have different views. From the scientific point of view, the construct validity of the structure model is still unclear. In addition, it has known that the emphasis in the structure model (the deterministic performance model) is very much on the outcome rather than the causative mechanisms and underpinning the outcome (Lees, 2002). Further studies are needed to clarify with the detailed phase analysis of main techniques by dividing them into preparation, action, and follow-through etc. (Lees, 2002).

The identification of key successful factors and elements which directly or indirectly affect competitive performance is always a major concern for coaches and athletes. Although there were several attempts to understand time motion and physiological responses to judo (Franchini et al., 2013), more experimental studies are needed to quantify training effects of all different combinations of key elements of competitive judo performance. Modern sports scientists working in the high performance sport environment should take advantage of the wide range of experimental designs available in other sports to identify unique performance characteristics in judo. It is also important to focus on areas such as evidence-based practices, applied experimental and observational research, and statistical models to refine our understanding of characteristics of competitive judo performance. The insights gained from this study provided a basis for improved competitive judo performance. The judo practitioners might find it useful for considering training programs in a scientific matter.

Conclusion

The content validity of the structure model in competitive judo performance (Olympic events) by the experts of the Japanese coaching community was confirmed theoretically. In particular, it has become possible to unveil the structural model of competitive judo performance via qualitative analysis such as the Delphi method, in which the knowledge of experts is summarised, in addition to the literature review.

It is important to use a shared and common language in a judo coaching community when coaches and sports scientists assess competitive performance and identify training profiles of judo athletes. It is considered that the constructed structure model of competitive judo performance may be used as the common language for judo coaches and other combat sports communities.

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Judo Technique - Application of Judo in Different Situations Through a Prism of Emotion Regulator

By Slaviša Bradić

Abstract: *The analysis of the judo technique in the structural part is an integral part of any research in order to better understand the functioning of the technique according to all laws and principles. The mental components made up of the regulator mechanism that affect the performance of the technique can give interesting information.*

Differences in the application of some judo techniques in training, competition or self-defense are one of the basic indicators of the manifestation of self-control mechanisms. The development of self-control through practicing judo technique is closely linked to emotional states during exercise and the manifestation of these states through emotion regulators. Understanding and analyzing these mechanisms are crucial to understanding the development of mental side in judo.

Key words: *judo technique, self-control, emotion regulators, combat sport*

The classification of the judo technique as we know it today is the product of evolutionary changes during the development of judo in the world. Definitely that since the inception of Kodokan judo, technique has changed depending on the goals of the exercise (Kano, June, 1936). The primary use of judo is self-defense, originated in old-school *ju jutsu* (Kano, 1934). The primary purpose was to guard against attacks with the aim of defeating opponents while inflicting pain or destruction. Secondary purpose is a form of physical education that contains a sports course, where technique is learned and exercised in order to achieve good health status or as a competition, in order to achieve sports achievement points (Kano, 2005). The third directions purpose is related to the development of the psychological characteristics of man and moral development (Kano, 1932). Comparing the structural part of the implementation of the technique in all the above levels, we find a great correlation, because the technique in its implementation is subject to methodical and biomechanical principles.

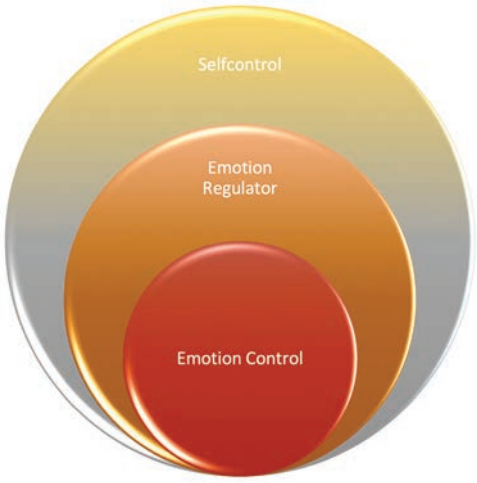
Discussion

By comparing the learned form of the basic technique of judo in different applications, we can see that the adaptation of the acquired knowledge is achieved very successfully with small adjustments.

However, if we compare psychological factors when performing one technique in situations of training, competition, or self-defense, we can conclude that mental states are completely different. A person undergoing continuous judo training very easily adapts to different interpretations (Ishikawa & Draeger, 1962).

The reason for this is that practicing judo from the very beginning is imbued with rules, both through methodical procedures and a whole host of other elements. Adherence to the hierarchy and rules of exercise through *randori* and *shiai*, techniques and principles of judo have been put under different psychological states that develop certain psychological mechanisms and regulators that are later very useful for applying the judo technique itself in different situations (Takšić, Bradić, Đonlić, Smojver & Ažić, 2015).

Scheme 1. Showing the relationship between emotions.



All techniques in judo is of a combat character, which means that the purpose is to destroy opponents with the aim of achieving the effectiveness of the technique (*geiko, uchikomi, randori*), to achieve victory by obtaining points (*shiai*), or inflicting pain or destruction in order to overcome the opponent from attack (*goshin-jutsu*). In the training of judo through *randori* and shiai, through principles, the technique is performed on the opponent at full force

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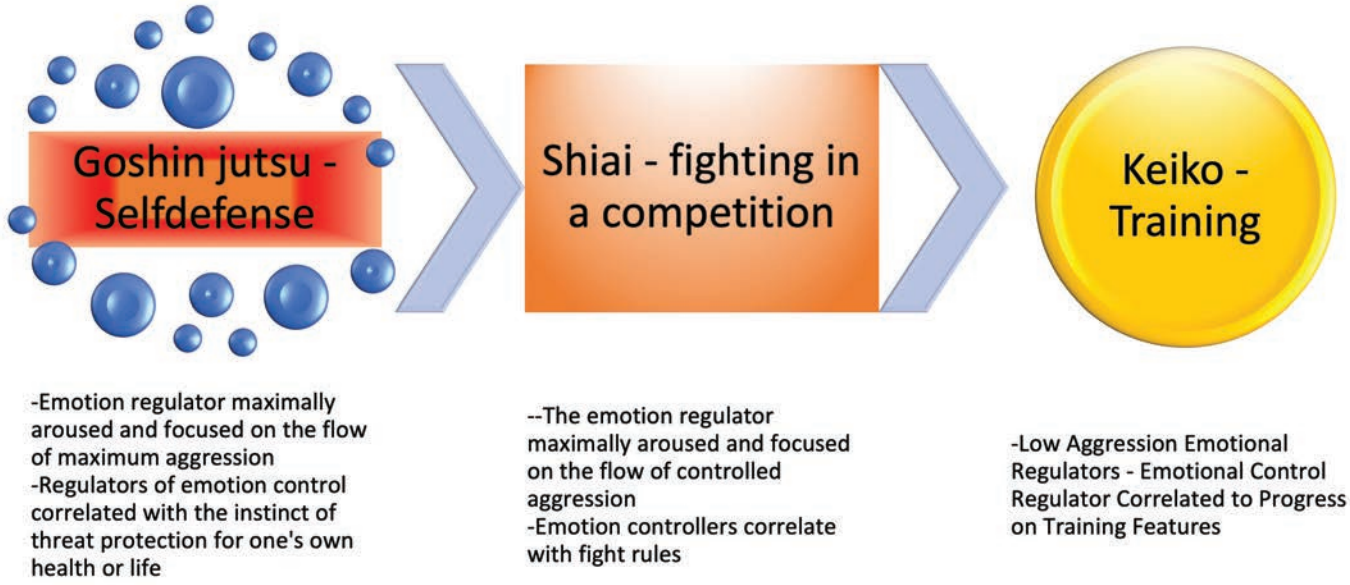
Scheme 2. Showing regulators of emotions and aggression in different situations of judo activity

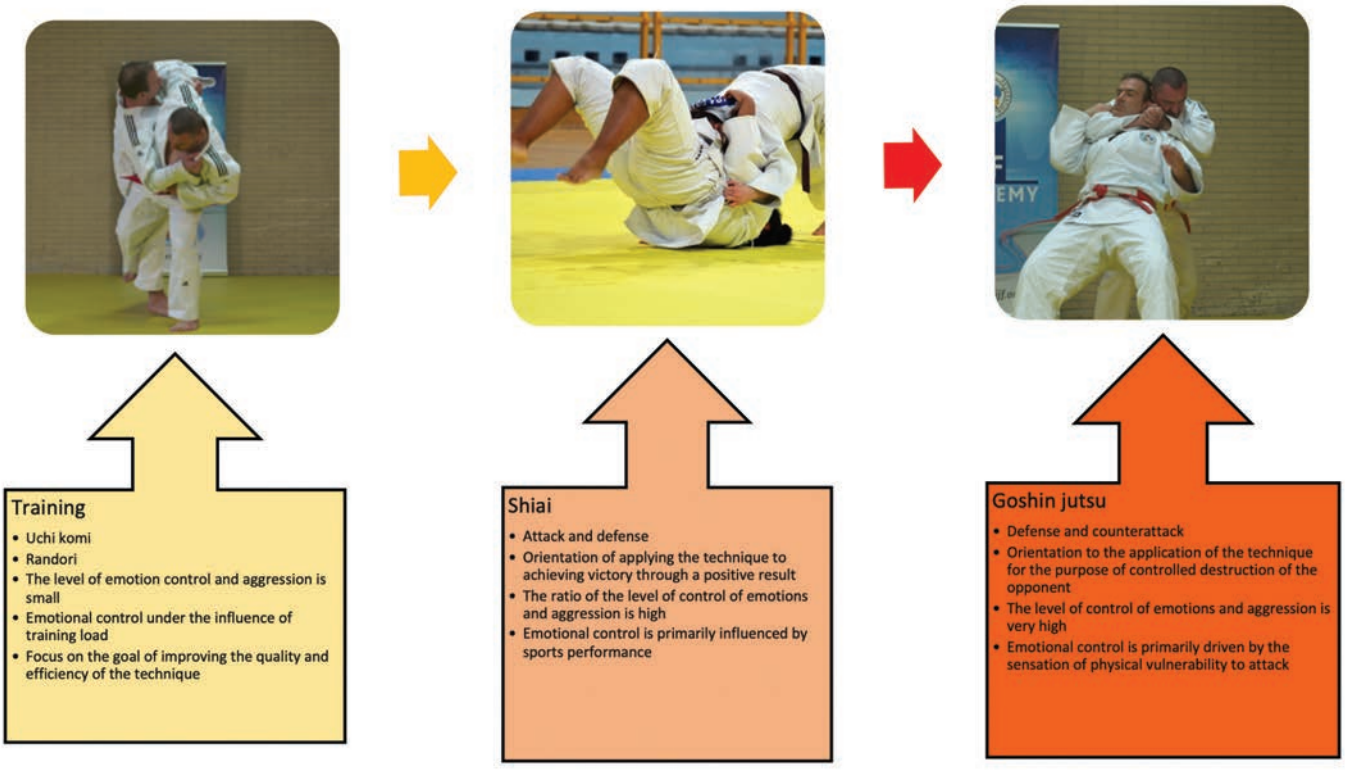


in order to achieve victory. Performing a technique that aims at destroying an opponent is impossible without a dose of aggression, which in a sports combat is aimed at achieving a win or a point, and in self-defense towards the actual destruction of the opponent.

Competition takes place according to the rules and only the observance of the rules is defined by the control and the regulator of emotions. An individual's emotional state in situations where he or she is on the verge of obeying or disobeying rules is directly related to the development of self-control (Takšić, Mohorić, & Duran, 2010). The equivalent of sports in the emotional value of development is not the same. In various sports, including judo, there is an essential difference in the threshold value of emotional state in the situation of observing the rules of sport in order to win. Structural judo is a combat sport that uses techniques in its technical field that aim to defeat an opponent in combat.

The effectiveness of judo technique and principles is beyond question, since such elements have been substantially implemented in almost all systems of military and police structures in the world. What makes the police field more special than others where some of the technical elements and principles are applied are the goals of ap-

Scheme 3. Comparison of different forms of application of judo technique



plying the techniques. In police work, the primary goal is to protect oneself or others who are threatened with an attack but with the utmost respect of the rules to avoid the destruction of opponents (Stanislas, 2013). There are many situations where an attack is carried out by a person who does not require the equivalent of physical destruction, only to overcome resistance and gain control of the attacker. This is precisely the advantage of police officers who practice judo because they have developed a great degree of self-control mechanism through emotion regulators developed through training. In training they are in a situation where they applied the technique with maximum power to the opponent who also uses maximum power, but at the moment of reaching the final stage of the technique, through the developed mechanism of self-control and emotion regulator, the onset of interruption and exercise continues in the normal mental state. The mental state in the conditions when a great degree of aggression is achieved during the execution of the technique and the rapid, almost simultaneous, restoration to normal state, has an extremely positive effect in the development of control of emotions and, consequently, of self-control. Therefore, judo is a technique that a police officer applies to an attacker with a high level of control of emotions and self-control (Đonlić, 2015).

Judoka who achieves a great degree of self-control through the training process and the self-control regulator is crucial for determining the beginning and end of the technique. The technique performed by a trained person, judoka, emotion controller and self-control can be interrupted at any time. A technique performed by an untrained person or a person who does not develop an emotion control and self-control controller through exercise can definitely be dangerous of true positions for the job of a police officer. Examples from police experience in some countries show that choking, leverage, or kicking due to an underdeveloped regulator of emotion and self-control, and the level of technique learned, ended tragically for the person to whom the force was applied (Rowe & Wedlake, 2009).

Conclusion

In addition to learning techniques and principles that are easily adaptable to different situations, judo training is ideal for developing mental components such as regulators of emotion control and self-control. Training judo, therefore, according to the very idea of his creator Jigoro Kano, means that benefits are transferred to daily life and are beneficial to the wider community (Kano & Lindsay, 1889). Research to understand the mechanisms triggered by the mental components in judo, may be a platform to demonstrate the positive psychological effects on humans. This characteristic position judo high on the list of sports because of its value for the community.

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Application of Kodokan Classified Judo Techniques in *Shiai*

By Florin Daniel Lascau[1], Kariya Chikara[2], Mike Callan[3]

Abstract: *Judo techniques are classified by the Kodokan into throws, grappling techniques and strikes. For use in randori (free practice) and shiai (matches), 68 nage-waza (throws) and 32 katame-waza (grappling techniques) have been identified in the official Kodokan list since 2017. The remaining 129 techniques found in the recognised Kodokan kata and in atemi-waza are outside the scope of this review. The correct identification, terminology and classification of techniques is important as the 100 nage-waza and katame-waza techniques are listed in the IJF Sports and Organisation Rules, they are used as the teaching syllabus in the IJF Academy, they are used to define the scoring techniques in the IJF Database and by the IJF Media Department to describe our sport.*

There are many forms and variations of techniques which can be found in books and literature written by expert judoka over the last century, key texts have been reviewed to identify alternate terminologies. Technical similarities and differences have been clarified. The text was then reviewed by the Kodokan for technical accuracy.

The clarification of the forms and variations are grouped into the eight categories of te-waza, koshi-waza, ashi-waza, ma-sutemi-waza, yoko-sutemi-waza, osaekomi-waza, shime-waza and kansetsu-waza. A review of Kodokan terminology addresses naming conventions and identifies techniques that are forbidden in modern day shiai. The differences between tachi-waza and nage-waza and between ne-waza and katame-waza are explained. The use of the Kodokan classification in all aspects of IJF affairs respects the origins of the way of judo developed by Jigoro Kano as an education.

Key words: *judo, Kodokan, techniques, terminology, classification*

The Kodokan Judo Institute classifies judo techniques as *nage-waza* (throws), *katame-waza* (grappling techniques), and *atemi-waza* (strikes). Throwing and grappling techniques are also called "*randori* techniques" and may be used in kata (formal practice), *randori* (free practice) and *shiai* (during matches). Striking techniques involve striking of the body's vital points with hands, elbows, feet and knees, because of their inherent danger these are prohibited during *randori* and are practiced only as *kata* (forms; formal exercises) (Kawamura & Daigo, 2000).

The latest list of 100 names for Kodokan techniques for *nage-waza* (including 68 official throwing techniques) and *katame-waza* (including 32 official grappling techniques) was published on 1st of April 2017, on the Kodokan web site (Kodokan, 2017). The list of 24 *atemi-waza* techniques (including 17 *ude-ate* techniques and 7 *ashi-ate* is techniques) can be found in the Kodokan Japanese-English Dictionary (Kawamura & Daigo, 2000). The list of 129 *kata* techniques used in IJF events (five *kata*) and Kodokan Institute (nine *kata*) includes *Nage-no-Kata* (15), *Katame-no-Kata* (15), *Kime-no-Kata* (20), *Ju-no-Kata* (15), *Kodokan-Goshin-jutsu* (21), *Itsutsu-no-Kata* (5), *Koshiki-no-Kata* (21), *Seiryoku-Zenyo-Kokumin-Taiiku* (17) and *Kodomo-no-Kata* (no official number yet), is presented in the official Kodokan web site (Kodokan, 2020a). Whilst other *kata* have been developed the ones listed are the nine *kata* that are officially recognised by the Kodokan.

Whilst this paper considers the application of the list of techniques which were classified in 2017, the list is an evolution of previous classifications by the Kodokan. The Kodokan established the *Gokyo-no-Waza* (five doctrines) in 1895 consisting of 42 techniques. In 1920 it was updated as a list of 40 techniques with 25 more techniques added in 1982 and two more in 1997. In the new year message of 2015, Kodokan President Haruki Uemura expressed a desire that the *Gokyo-no-Waza* be researched and verified, which led to the 2017 revision (Uemura, 2015).

The International Judo Federation Sport and Organisation Rules (IJF SOR) (IJF, 2019) is the document that defines the rules of judo. It includes sections such as; contest duration, competition systems, world ranking list system, seeding and draw procedure, weigh-in regulations, coaches code of conduct, venue requirements, *kata* regulations, judogi rules, the IJF refereeing rules, medical handbook, disciplinary code and the names of the 100 techniques 'Approved by the Kodokan' (page 195).

The IJF World Tour is a series of international judo events spread across the globe throughout the year. Individual contests are won by the application of techniques in order to achieve scores which decide the outcome of the contest. The winning of contests results in progression through the draw and in the awarding of points on the IJF World

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Ranking List. This list underpins the seeding in future IJF events and the qualification procedure for the Olympic Games. It is outside the scope of this paper to explain the importance or relevance of the Olympic Games.

Since 2016, following an arrangement between the Kodokan and the IJF the scores achieved during each of the matches are reviewed by the Kodokan technical panel either live or on video (Kariya, 2020). Each technique is named, classified and recorded in the IJF Database. Each scoring technique is classified as one of the 100 Kodokan recognised techniques. On the rare occasions where the panel are unable to classify appropriately, they will use the two categories 'indeterminate technique in *nage-waza*' or 'indeterminate technique in *katame-waza*'. Therefore, all variations of a technique, including those which may also be known by an alternate terminology, will be categorised into one of those 102 labels.

The IJF Database information is available through the Judobase website and provides the official record of the events, including the scores and the techniques. The IJF database informs the points allocation on the IJF World Ranking List.

The purpose of this paper is to show that as the Kodokan technical panel apply the terminology to categorise a very wide range of techniques and variations used on the IJF World Tour into 102 labels, the correct application of terminology and the understanding of its interpretation is important. The techniques form the basis of the curriculum in most judo classes around the world and the basis for the education of judo teachers and coaches by national federations and the IJF Academy. As already explained the techniques are the basis of successful performance in shiai. Not only is the application of the 100 Kodokan judo techniques the basis for judo in teaching, development, performance, education and presentation, but also for the application of the IJF Sport and Organisation Rules (IJF, 2019), the pathway of IJF Academy, the collection of scores in the IJF Database and the correct dissemination of information through the IJF Media department.

Nage-waza (throwing techniques)

Nage-waza (throwing techniques) is the general name for techniques in which the opponent is thrown and is divided in *tachi-waza* (standing techniques) and *sutemi-waza* (sacrifice techniques) (Daigo, 2005; Kudo, 1967).

Tachi-waza has three groups: *te-waza* (16 hand techniques), *koshi waza* (10 hip techniques) and *ashi-waza* (21 foot and leg techniques). *Sutemi-waza* has two groups: *ma-sutemi-waza* (5 supine or rear sacrifice techniques) and *yoko-sutemi-waza* (16 side sacrifice techniques) (Kodokan, 2017).

Tachi-waza (standing techniques)

Tachi-waza are standing techniques and include throws executed from a standing position and has three groups: *te-waza*, *koshi-waza* and *ashi-waza*.

Te-waza (hand techniques)

Te-waza, hand techniques, is the classification for 16 throwing techniques in which the use of the hands plays a central role (Kawamura & Daigo, 2000).

Table 1: Kodokan classified *te-waza*

ID number	Japanese name	Romaji name	IJF identifier
101	背負投	*Seoi-nage*	SON
102	一本背負投	*Ippon-seoi-nage*	ISN
103	背負落	*Seoi-otoshi*	SOO
104	体落	*Tai-otoshi*	TOS
105	肩車	*Kata-guruma*	KGU
106	掬投	*Sukui-nage*	SUK
107	帯落	*Obi-otoshi*	OOS
108	浮落	*Uki-otoshi*	UOT
109	隅落	*Sumi-otoshi*	SOT
110	山嵐	*Yama-arashi*	YAS
111	帯取返	*Obi-tori-gaeshi*	OTG
112	双手刈	*Morote-gari*	MGA
113	朽木倒	*Kuchiki-taoshi*	KTA
114	踵返	*Kibisu-gaeshi*	KIG
115	内股すかし	*Uchi-mata-sukashi*	UMS
116	小内返	*Ko-uchi-gaeshi*	KOU

Forms and variations of *te-waza* (hand techniques)

Seoi-nage and *ippon-seoi-nage*

The Kodokan Institute classifies both *seoi-nage* and *ippon-seoi-nage* (Kawamura & Daigo, 2000). The IJF Database makes the difference between variations using two hands *kumikata* for *seoi-nage* and using one hand *kumikata* for *ippon-seoi-nage*. All similar *seoi-nage* techniques explained in the literature under different names are classified into either *seoi-nage* or *ippon-seoi-nage*.

Examples of variations presented in the literature include; *morote-seoi-nage, eri-seoi-nage, seoi-goshi, nihon-seoi-nage, eri-seoi-nage* mentioned by Nakanishi and others (Adams & Carter, 1986b; Blais et al., 2007; Bradic et al., 2017; Ishii et al., 2017; Maruyama et al., 2017; Nakanishi & Finch, 1992; Sweeney et al., 1969), *kata-sode-seoi-nage*, a cross between *ippon-seoinage* and *morote-seoi-nage* (Hoare, 1994; Nakanishi & Finch, 1992), eri-seoi (Matsumoto et al., 1963), and *eri-seoi-nage* (Hoare, 1994; A Sacripanti, 1989). Other versions mentioned are: *hiza-seoi* (Hoare, 1994; A Sacripanti, 1989), *kata-eri-seoi* (Hoare, 1994; Kodokan, 2020b), *kata-seoi* used in the *nage-waza* classification of Kawaishi (Kawaishi, 1954; Attilio Sacripanti, 1989), and *kata-sode-seoi-nage* (Hoare, 1994; Nakanishi & Finch, 1992).

Seoi-otoshi

One old name of this technique is *kata-hiza-tsuki-seoi* (Nakanishi & Finch, 1992). *Eri-seoi-otoshi* is a variation (Adams & Ferrie, 1990; Hoare, 1994). *Soto-muso* is a the ancient version of *seoi-otoshi* (Nakanishi & Finch, 1992), and *suso-seoi* and *suwari-seoi* are present in the literature (A Sacripanti, 1989; Sacripanti, 2020). All variations are recorded in the SOR as *seoi-otoshi* (IJF, 2019)

Seoi-nage* vs. *seoi-otoshi

There are two different principles of throwing using the shoulder, which constitute the difference between *seoi-nage*, where *uke* is lifted and thrown, and *seoi-otoshi*, where *uke* is dropped directly down, without lifting. The confusion comes from the current English translation "*drop seoi-nage*" (Miller et al., 2015), a mix of English and Japanese, which translated would mean "*seoi-nage-otoshi*" – a conflict in using two principles of throwing in one throw. The IJF Academy explains during the practical courses the differences between those two techniques.

Soto-muso is the ancient version, a small but useful little addition to an *ippon-seoi-nage* armoury, has its origins in the *sumo* technique that is still used today (Benjamin, 2010), and the variation can be performed as a standing version but also as a drop version. *Ganseki-otoshi* is a hand throw which looks very close like a *seoi-nage* or *seoi-otoshi* (Hoare, 1994; Mifune, 1960; Mifune, 1954; Mifune et al., 1955).

Tai-otoshi

Tai-otoshi is an example of a *choshi-waza*. These are techniques where *tori* relies on opportunity, rhythm and timing. Respected judoka Trevor Leggett described it as similar to a handclap, seizing the right opportunity and applying the technique swiftly (Hoare, 1994).

Uki-otoshi

This group of variations also includes *hiki-otoshi*, part of *Koshiki-no-Kata* (Hoare, 1994; IJF, 2015; Kotani, 1970) and *dai-sharin*, a variant of *uki-otoshi* demonstrated by Koizumi in "My study of judo" (Koizumi, 1960) and used in his *nage-waza* classification as *kuruma-waza* (rotation techniques) (A Sacripanti, 1989).

Sumi-otoshi

Similar to *sumi-otoshi* is also *furi-nage* (Hoare, 1994; Kotani, 1974; Kudo, 1967).

Sukui-nage

The hand technique *sukui-nage* has three variations, and one of them is *te-guruma* (Hoare, 1994; A Sacripanti, 1989), the others are described as *obi-otoshi* and *waki-otoshi*.

Obi-tori-gaeshi

The colloquial name "Khabareli" for this technique is linked to the Georgian Olympic Champion from 1980, Shota Khabareli (Miller, 2012; Soames & Inman, 1990). The IJF Media department makes efforts to clarify this aspect during World Judo Tour (Pickering, 2019). According to Hoare (1994), *hikikomi-gaeshi* is sometimes called *obi-tori-gaeshi*, (Hoare, 1994; Kashiwazaki & Donovan, 1985; Kotani, 1974; Mifune, 1954; Yokoyama & Oshima, 1915). The technique should not be confused with *obi-tori* from *Ju-no-Kata* (Leggett, 1964).

Kuchiki-taoshi

As *kata-ashi-dori* sometimes this throw is done by catching the leg and running the opponent backwards (Hoare, 1994; Kawaishi, 1954). *Kata-ashi-dori* and *rio-ashi-dori* are used in the *nage-waza* classification of Kawaishi (Kawaishi, 1954; A Sacripanti, 1989). According to the current 2019 IJF Refereeing Rules, the application of this technique and its variations is forbidden (IJF, 2019).

Koshi-waza (hip techniques)

Koshi-waza, (hip techniques), is the classification for 10 throwing techniques in which the use of the waist and hips play a central role.

Table 2: Kodokan classified *koshi-waza*

ID number	Japanese name	Romaji name	IJF identifier
201	浮腰	*Uki-goshi*	UGO
202	大腰	*O-goshi*	OGO
203	腰車	*Koshi-guruma*	KOG
204	釣込腰	*Tsurikomi-goshi*	TKG
205	袖釣込腰	*Sode-tsurikomi-goshi*	STG
206	払腰	*Harai-goshi*	HRG
207	釣腰	*Tsuri-goshi*	TGO
208	跳腰	*Hane-goshi*	HNG
209	移腰	*Utsuri-goshi*	UTS
210	後腰	*Ushiro-goshi*	USH

Forms and variations of *koshi-waza* (hip techniques)

Tsuri-goshi

The *tsurite* is the fishing or lifting hand of *tori*, the pulling hand is known as the *hikite* (Lascau & Callan, 2012). Usually the *tsurite* hand grips the *judogi*, but not always. For *tsuri-goshi* taking into consideration the *tsurite* hand, there are two forms: *o-tsuri-goshi* and *ko-tsuri-goshi*, used in the *nage-waza* classification of Kawaishi (Kawaishi,

1954; Sacripanti, 1989) and in the *nage-waza* classification of Gleeson as a lifting technique (Gleeson, 1969; Sacripanti, 1989).

Harai-goshi* vs *uchi-mata/ashi-guruma/o-guruma

The Kodokan and the IJF SOR classify *harai-goshi* as a *koshi-waza* (Daigo, 2005; IJF, 2019), where the hip plays central role, as distinct from *uchi-mata*, *ashi-guruma* and *o-guruma* which are classified as *ashi-waza*, where the central role is played by the legs. There are many other excellent explanations of *harai-goshi* in the literature (Imamura et al., 2007; Pucsok et al., 2001; Ross & Goodger, 1969; Rouge, 1991).

Ashi-waza (foot and leg techniques)

Ashi-waza, (foot and leg techniques), is the classification for 21 throwing techniques in which the use of the feet and/or legs plays the central role.

Table 3: Kodokan classified *ashi-waza*

ID number	Japanese name	Romaji name	IJF identifier
301	出足払	*De-ashi-harai*	DAB
302	膝車	*Hiza-guruma*	HIZ
303	支釣込足	*Sasae-tsurikomi-ashi*	STA
304	大外刈	*O-soto-gari*	OSG
305	大内刈	*O-uchi-gari*	OUG
306	小外刈	*Ko-soto-gari*	KSG
307	小内刈	*Ko-uchi-gari*	KUG
308	送足払	*Okuri-ashi-harai*	OAB
309	内股	*Uchi-mata*	UMA
310	小外掛	*Ko-soto-gake*	KSK
311	足車	*Ashi-guruma*	AGU
312	払釣込足	*Harai-tsurikomi-ashi*	HTA
313	大車	*O-guruma*	OGU
314	大外車	*O-soto-guruma*	OGR
315	大外落	*O-soto-otoshi*	OSO
316	燕返	*Tsubame-gaeshi*	TSU
317	大外返	*O-soto-gaeshi*	OGA
318	大内返	*O-uchi-gaeshi*	OUG
319	跳腰返	*Hane-goshi-gaeshi*	HGG
320	払腰返	*Harai-goshi-gaeshi*	HGE
321	内股返	*Uchi-mata-gaeshi*	UMG

Forms and variations of *ashi-waza* (foot and leg techniques)

Harai* vs. *barai

The Kodokan and the IJF Database use the terms of *de-ashi-harai* and *okuri-ashi-harai* (Otaki & Draeger, 1983). The literature presents the techniques named also as *de-ashi-barai* and *okuri-ashi-barai* (Hoare, 1994; Sato, 1990). The Japanese kanji is the same 払, the difference arises when the word is transposed into romaji for the western reader.

Hiza-guruma* vs *sasae-tsurikomi-ashi/harai-tsurikomi-ashi

The differences between these techniques can be best explained by comparative teaching, such as during the practical courses of the IJF Academy. The principle of throwing in *hiza-guruma* is to perform the technique without lifting *uke* (Swain et al., 1994), opposed to *sasae-tsurikomi-ashi* and *harai-tsurikomi-ashi*, where "*tsurikomi*" is translated as "lift-pull" (Sato, 1990).

Ko-uchi-gari

Ko-uchi-barai is a variation of *ko-uchi-gari* (Sacripanti, 1989), used in the *nage-waza* classification of Geesink (Geesink, 1967; Sacripanti, 1989). As a former Olympic Champion and 10th Dan, we can see from the Geesink classification that many technical variations have been named by experts previously. However, *ko-uchi-barai* will not be found in the official IJF records since the 2016 collaboration with the Kodokan. Such a technique would be classified as *ko-uchi-gari*.

O-soto-gari

Tenjin Shinyo Ryu, a *jujutsu* style founded in the later years of the Edo period, around 1830 by Mataemon Isoh had a technique called '*kaeri-nage*' which we know today as *o-soto-gari* (Hoare, 1994; Hoare et al., 1968; Yamashita & Soames, 1991). Another former name for this technique is "*gyakyu-gama*" (reverse sickle) which comes much closer to its modern term (Hoare, 1994; Yamashita & Soames, 1991). *Ke-kaeshi* is another variation of *o-soto-gari* (Hoare, 1994). *O-soto-gake* is mentioned by different authors (Adams & Carter, 1986b; Sacripanti, 1989; Yamashita, 1993) and is used in the *nage-waza* classification of Koizumi as *tsumazukase-waza* (moving technique) (Koizumi, 1960; Sacripanti, 1989). All forms and variations are presented through the IJF Media department as *o-soto-gari*.

O-soto-otoshi* vs *o-soto-gari* vs *o-soto-guruma* vs *o-soto-gaeshi* vs *o-soto-makikomi

The common factor here is "*o-soto*" translated as "large outer". The first four techniques mentioned here are classified as *ashi-waza*, last one as *yoko-sutemi-waza*. The principles of throwing are different: dropping in *o-soto-otoshi*, reaping in *o-soto-gari*, performing a wheel in *o-soto-guruma*, countering in *o-soto-gaeshi*, and sacrifice through wrapping around in *o-soto-makikomi*. Knowing the differences between the techniques, can increase the application of the IJF Refereeing Rules in competition.

Ko-soto-gari

A variation is *nidan-ko-soto-gari*, a throw in which *tori* reaps both the opponent's (Kawamura & Daigo, 2000; Sato & Okano, 1973; Swain et al., 1994).

Ko-soto-gari* vs *ko-soto-gake

There are two different principles of throwing: in *ko-soto-gari*, *tori* reaps the leg of *uke*, as opposed to *ko-soto-gake* where *tori* hooks the leg of *uke*, lifts and then throws *uke* (Kawamura & Daigo, 2000). Interestingly, the 1955 text 'Illustrated Kodokan Judo' explains that formerly *ko-soto-gake* was regarded as a variation of *ko-soto-gari*, but nowadays it is classified as an independent technique (Kodokan, 1955).

Uchi-mata

Uchi-mata is an emblematic judo throw with different variations, such as *tobikomi-uchimata*, *ken-ken-uchi-mata* (Inokuma & Satō, 1979; Matsumoto et al., 1963; Sugai, 1991) and *o-uchi-mata*, used in the *nage-waza* classification of Geesink (Geesink, 1966; Sacripanti, 1989). Researchers such as Sacripanti (2016), Maruyama (2017), Kwon (2005) and Yoon (2005) have conducted biomechanical analyses of *uchi-mata* (Kwon et al., 2005; Maruyama et al., 2017; Sacripanti, 2016; Sugai, 1991; Yoon, 2005).

Uchi-mata-makikomi* vs *Uchi-mata

Uchi-mata has variations as a direct attack, in combinations and counters. *Uchi-mata* is classified as *ashi-waza*, where the central role is played by the leg, *uchi-mata-makikomi* is classified as *yoko-sutemi-waza*, where the sacrifice is performed as a wrap-around.

Uchi-mata-sukashi* vs *uchi-mata-gaeshi

In *uchi-mata-sukashi* the counter technique classified *te-waza* is done by the arms and in *uchi-mata-gaeshi*, classified in *ashi-waza*, the counter of *uchimata* is performed by the leg. The SOR and the IJF Database have an important role in the accuracy of statistics, therefore the understanding of techniques and its groups is essential.

Sutemi-waza (sacrifice techniques)

Sutemi-waza are sacrifice techniques and is the general term for sacrifice throws in which the thrower "sacrifices" himself by falling to the rear or side as part of the process of the throw, it has two groups: *ma-sutemi-waza* (rear or supine sacrifice techniques) and *yoko-sutemi-waza* (side sacrifice techniques) according to the direction of the fall.

***Ma-sutemi-waza* (supine or rear sacrifice techniques)**

Ma-sutemi-waza, (supine or rear sacrifice techniques), is the classification for 5 throwing techniques in which *tori* (the thrower) "sacrifices" himself by falling onto his back in the process of throwing the opponent.

Table 4: Kodokan classified *ma-sutemi-waza*

ID number	Japanese name	Romaji name	IJF identifier
401	巴投	*Tomoe-nage*	TNG
402	隅返	*Sumi-gaeshi*	SUG
403	引込返	*Hikikomi-gaeshi*	HKG
404	俵返	*Tawara-gaeshi*	TWG
405	裏投	*Ura-nage*	UNA

Forms and variations of *ma-sutemi-waza* (supine or rear sacrifice techniques)

Tomoe-nage

Yoko-tome-nage is a variation of *tomoe-nage*, where after swinging the foot into the opponent's stomach, the throw is done to the side. (Adams & Ferrie, 1990; Kashiwazaki, 1989). *Yoko-tomoe* is used in the *nage-waza* classification of Kawaishi (Kawaishi, 1954; Sacripanti, 1989). *Ke-age* is translated as kick lift, and is a variation of *tomoe-nage* (Hoare, 1994).

Hikikomi-gaeshi

This throw is sometimes pronounced *hikkomi-gaeshi* (Hoare, 1994) and sometimes called *obi-tori-gaeshi* (Hoare, 1994; Kotani, 1974; Mifune, 1954).

Yoko-sutemi-waza (side sacrifice techniques)

Yoko-sutemi-waza, side sacrifice techniques, is the classification for 16 throwing techniques in which *tori* (the thrower) "sacrifices" himself by falling to the right or left in the process of throwing the opponent.

Table 5: Kodokan classified *yoko-sutemi-waza*

ID number	Japanese name	Romaji name	IJF identifier
501	横落	*Yoko-otoshi*	YOT
502	谷落	*Tani-otoshi*	TNO
503	跳巻込	*Hane-makikomi*	HNM
504	外巻込	*Soto-makikomi*	SMK
505	内巻込	*Uchi-makikomi*	UMK
506	浮技	*Uki-waza*	UWA
507	横分	*Yoko-wakare*	YWA
508	横車	*Yoko-guruma*	YGU
509	横掛	*Yoko-gake*	YGA
510	抱分	*Daki-wakare*	DWK
511	大外巻込	*O-soto-makikomi*	OSM
512	内股巻込	*Uchi-mata-makikomi*	UMM
513	払巻込	*Harai-makikomi*	HRM
514	小内巻込	*Ko-uchi-makikomi*	KUM
515	蟹挟	*Kani-basami*	KBA
516	河津掛	*Kawazu-gake*	KWA

Forms and variations of *yoko-sutemi-waza* (side sacrifice techniques)

Tani-otoshi vs. *yoko-otoshi* vs. *uki-waza*

Tani-otoshi, *yoko-otoshi* and *uki-waza* are classified as *yoko-sutemi-waza*. According to Professor Matsumoto, the difference is in the directions of the breaking balance: *tani-otoshi* to *uke*'s back corner, *yoko-otoshi* to *uke*'s side, and *uki-waza* to *uke*'s front corner. That is, they are one and the same in theory and practice, only with different directions (Matsumoto et al., 1963). The correct application of the directions is part of the IJF Academy courses.

Makikomi techniques

Techniques that use the *makikomi* (wrap-around) principle, are called *makikomi-waza* (wrapping techniques), which is general classification for side sacrifice throwing techniques in which parts of the *tori* thrower's body are completely entwined or wrapped by the opponent as part of the throw (Kawamura & Daigo, 2000). There are different applications of "*makikomi*" principle: direct and indirect.

Direct *makikomi* techniques

The direct application of "*makikomi*" principle, where *tori* can perform just attacking directly with *yoko-sutemi-waza* is in: *soto-makikomi, uchi-makikomi*, and *ko-uchi-makikomi*.

Direct and indirect *makikomi* techniques

The direct and indirect applications of "*makikomi* principle", where *tori* can choose between attacking directly with *yoko-sutemi-waza* technique or attacking with another technique, and after unsuccessful attack, *tori* continues with *yoko-sutemi-waza* are in: *harai-makikomi, hane-makikomi, uchi-mata-makikomi*, and *o-soto-makikomi*.

According to the explanation of Daigo Sensei, the two techniques are connected to each other. For example *hane-goshi* + *soto-makikomi* = *hane-makikomi*, where both are sequence techniques (direct application) (Daigo, 2005). Analysis based on observations by the first author at the IJF World Tour events is that sometimes *tori* applies *hane-goshi*, and after *uke* blocks the technique, *tori* continues with *hane-makikomi* as an indirect application.

Kani-basami

Hoare (1994) links *hasami-gaeshi* as an alternate name for *kani-basami* (Hoare, 1994). *Kani-basami* is also known as *kugi-nuki* (Hoare, 1994). Good knowledge about this technique is essential for correct applying of IJF Refereeing Rules as it has been banned in competition since 1980 when it was used in the final of the All-Japan Championship between Sumio Endo and Yasuhiro Yamashita resulting in a break to Yamashita's fibula (Yamashita, 1993).

Katame-waza (grappling techniques)

Katame-waza (grappling techniques) is general name for techniques designed to hold-down, strangle and apply joint locks used in grappling. It is divided in *osaekomi-waza* (10 pinning techniques), *shime-waza* (12 strangling techniques) and *kansetsu-waza* (10 joint techniques).

Osaekomi-waza (pinning techniques)

Osaekomi-waza, pinning techniques, is the classification for 10 mat techniques used to pin a supine opponent to the mat, generally from the side of diagonally, to inhibit his freedom of movement and prevent him from rising.

Table 6: Kodokan classified *osaekomi-waza*

ID number	Japanese name	Romaji name	IJF identifier
601	袈裟固	*Kesa-gatame*	KEG
602	崩袈裟固	*Kuzure-kesa-gatame*	KKE
603	後袈裟固	*Ushiro-kesa-gatame*	UKG
604	肩固	*Kata-gatame*	KAG
605	上四方固	*Kami-shiho-gatame*	KSG
606	崩上四方固	*Kuzure-kami-shi-ho-gatame*	KKS
607	横四方固	*Yoko-shiho-gatame*	YSG
608	縦四方固	*Tate-shiho-gatame*	TSG
609	浮固	*Uki-gatame*	UGT
610	裏固	*Ura-gatame*	URG

Forms and variations of *osaekomi-waza* (pinning techniques)

Kesa-gatame, kuzure-kesa-gatame and *ushiro-kesa-gatame*

According to the Kodokan classification *kesa-gatame, kuzure-kesa-gatame* and *ushiro-kesa-gatame* are the three techniques using the "*kesa*" principle.

Hon-kesa-gatame is used in *Katame-no-Kata*. *Gyaku-kesa-gatame* and *makura-kesa-gatame* as a variation of *kuzure-kesa-gatame* are mentioned in the English syllabus from 1985 (Geesink, 1966; Sacripanti, 1989). The IJF Media department present in their reports the correctly applied "*kesa*" technique.

Kami-shiho-gatame and *kuzure-kami-shiho-gatame*

The literature mentions one variation as *hon-kami-shiho-gatame* (Adams & Carter, 1986b). Another variation named as *sankaku-gatame*, translated as triangle immobilising hold (Geesink, 1966), performed with the legs in a triangle form, is classified by the Kodokan as *kuzure-kami-shiho-gatame*.

Yoko-shiho-gatame

Different variations are: *hon-yoko-shiho gatame* (Adams & Carter, 1986b), *mune-gatame* (Adams & Carter, 1986b; Geesink, 1966), *kuzure-yoko-shiho-gatame* (Adams & Carter, 1986a) and *kuzure-yoko-shiho-gatame* (Geesink, 1966). According to the Kodokan, all forms of *yoko-shiho-gatame* are classified as *yoko-shiho-gatame*.

Tate-shiho-gatame

Variations of this technique are: *hon-tate-shiho-gatame* (Adams & Carter, 1986b), *sankaku-tate-shiho-gatame* (Geesink, 1966), *kuzure-tate-shiho-gatame* (Adams & Carter, 1986b), and *kuzure-tate-shiho* as part of the English syllabus in 1985 (Attilio Sacripanti, 1989). According to the Kodokan, all forms of *tate-shiho-gatame* are classified in *tate-shiho-gatame*.

Shime-waza (strangling techniques)

Shime-waza, strangling techniques, is the classification for 12 techniques in which the opponent is strangled by applying pressure to parts of his neck.

Table 7: Kodokan classified *shime-waza*

ID number	Japanese name	Romaji name	IJF identifier
701	並十字絞	*Nami-juji-jime*	NJJ
702	逆十字絞	*Gyaku-juji-jime*	GJJ
703	片十字絞	*Kata-juji-jime*	KJJ
704	裸絞	*Hadaka-jime*	HAD
705	送襟絞	*Okuri-eri-jime*	OEJ
706	片羽絞	*Kataha-jime*	KHJ
707	片手絞	*Katate-jime*	KTJ
708	両手絞	*Ryote-jime*	RYJ
709	袖車絞	*Sode-guruma-jime*	SGJ
710	突込絞	*Tsukkomi-jime*	TKJ
711	三角絞	*Sankaku-jime*	SAJ
712	胴絞	*Do-jime*	DOJ

Forms and variations of *shime-waza* (pinning techniques)

Hadaka-jime

According to Geesink *hadaka-jime* is named *ushiro-jime*, and is one of the strangles most applied in contest judo (Geesink, 1966).

Okuri-eri-jime

One variation of *okuri-eri-jime* is presented as *koshe-jime* (Adams & Carter, 1986a) or *koshi-jime* (Adams & Carter, 1986b; Hoare, 1994). According to the Kodokan dictionary, koshi-jime is classified as *okuri-eri-jime* (Kawamura & Daigo, 2000). The IJF Database uses the same list of techniques as the SOR (IJF, 2019), in order to evaluate the correct applied strangling technique.

Kansetsu-waza (joint techniques)

Kansetsu waza, joint techniques, is the classification for 10 techniques that act on an opponent's joint. The only joint techniques that are allowed in *shiai* (judo matches) are those that act against the opponents' elbow joint. The IJF Refereeing Rules cover when and how the techniques of this group can be applied.

Table 8: Kodokan classified *kansetsu-waza*

ID number	Japanese name	Romaji name	IJF identifier
801	腕緘	*Ude-garami*	UGR
802	腕挫十字固	*Ude-hishigi-juji-gatame*	JGT
803	腕挫腕固	*Ude-hishigi-ude-gatame*	UGA
804	腕挫膝固	*Ude-hishigi-hiza-gatame*	HIG
805	腕挫腋固	*Ude-hishigi-waki-gatame*	WAK
806	腕挫腹固	*Ude-hishigi-hara-gatame*	HGA
807	腕挫脚固	*Ude-hishigi-ashi-gatame*	AGA
808	腕挫手固	*Ude-hishigi-te-gatame*	TGT
809	腕挫三角固	*Ude-hishigi-sankaku-gatame*	SGT
810	足緘	*Ashi-garami*	AGR

Forms and variations of *kansetsu-waza* (joint techniques)

Ude-hishigi-juji-gatame

In the application of this technique, often referred to by the shorter name *juji-gatame*, there are different ways of execution such as rolling *juji-gatame*, spinning *juji-gatame* (Adams, 1989; Adams & Carter, 1986a), as combination with *uki-gatame* (Adams, 1989), and *tobi-juji-gatame* (Fighting-Films, 2017). According to the current IJF rules, presented in the SOR (IJF, 2019), applying *kansetsu-waza* in *tachi-waza* is forbidden, therefore jumping *juji-gatame* is forbidden.

Ude-garami* and *ashi-garami

Ude-garami is an armlock allowed in *ne-waza randori* and *ne-waza shiai*, as opposed to *ashi-garami*, which is leg entanglement (Kawamura & Daigo, 2000), or leg winding (Leggett, 1963), which is forbidden in *randori* and *shiai*.

Sankaku-jime* and *ude-hishigi-sankaku-gatame* and *kuzure-kami-shiho-gatame

The literature mentions *sankaku-waza* by grouping techniques belonging to *osae-komi-waza*, *shime-waza* and *kansetsu-waza*, using the principle of griping in a triangle with the legs (Geesink, 1966). According to the Kodokan *sankaku-jime* (triangular strangle) is a strangle classified in *shime-waza*, *ude-hishigi-sankaku-gatame* (triangular armlock) is an arm lock classified in *kansetsu-waza*, and the pinning technique using the triangle leg grip (*sankaku*) is classified in *osaekomi-waza* as *kuzure-kami-shiho-gatame* (Kawamura & Daigo, 2000), and the IJF Media department present the techniques in this way.

Atemi waza (striking techniques)

Atemi-waza (striking techniques) is the general name for techniques using thrusts, strikes and kicks, particularly to physiologically weak areas of the body (vital points), using fists, fingertips, the edges of the hand, elbows, knees, or various parts of the feet (Kodokan, 1955). Because of their inherent danger, *atemi-waza* are prohibited during *shiai* (judo matches) and *randori* (sparring sessions). *Atemi-waza* is divided in *ude-ate* (17 hand and elbow striking techniques) and *ashi-ate* (7 foot and knee striking techniques).

Ude-ate is the classification for 17 techniques in which hand and elbow striking pay the central role. The hand and elbow techniques are divided in four groups: *yubisaki-ate* (3 techniques), *kobushi-ate* (11 techniques), *tegata-ate* (2 techniques), *and hiji-ate* (1 technique)

Ashi-ate is the classification for 7 techniques in which the foot and knee striking play the central role. The foot and knee striking techniques are divided in three groups: *hizagashira-ate* (1 technique), *sekito-ate* (3 techniques), and *kakato-ate* (3 techniques). *Atemi-waza* techniques, forbidden in *shiai* and *randori*, are not the subject of this review.

Review of Kodokan terminology

Nage-waza* vs. *tachi-waza

Throwing judo techniques are classified as *nage-waza* (throwing techniques). Kodokan judo includes 68 official throwing techniques: 16 *te-waza* (hand), 10 *koshi-waza* (hip), 21 *ashi-waza* (foot and leg), 5 *ma-sutemi-waza* (rear or supine sacrifice), and 16 *yoko-sutemi-waza* (side sacrifice). Therefore, speaking about techniques classification, the term *nage-waza* is used (Daigo, 2005).

Tachi-waza (standing techniques) refers to one subdivision of *nage-waza* in the judo techniques classification, but also to the place where judo exercises/action happen: *tachi-waza randori* (free practice in standing), *tachi-shisei* (standing posture) and *tachi-shobu* (standing match). Therefore, when referring to the place of the action, the term *tachi-waza* is used.

Katame-waza vs. *ne-waza*

Grappling techniques are classified as *katame-waza*. Kodokan judo includes 32 official grappling techniques: 10 *osaekomi-waza* (hold-downs), 12 *shime-waza* (strangles) and 10 *kansetsu-waza* (joint and other locks) used in grappling. Therefore, when speaking about techniques classification, the term *katame-waza* is used.

Ne-waza refers to mat and ground techniques, executed from non-standing positions such as while lying with your opponent on the mat, but also to the place where judo exercises/action happen: *ne-waza randori* (free mat work: free practise involving primarily mat work), *ne-shisei* (mat posture) and *ne-shobu* (grappling; mat work). Therefore, when referring to the place of the action, the term *ne-waza* is used.

Kata and *randori*

The Kodokan list of names covers 100 techniques, which with some exceptions, can be used in *randori* (free practice; free sparing). In addition to this list, there are techniques not inside this classification, used in *kata* (formal exercises; pattern practice), techniques which are part of IJF *kata* competitions (*Nage-no-Kata, Katame-no-Kata, Kime-no-Kata, Ju-no-Kata* and *Kodokan-Goshin-jutsu*) and of Kodokan Institute (the five kata presented, and in addition *Itsutsu-no-Kata, Koshiki-no-Kata, Seiryoku-Zenyo-Kokumin-Taiiku* and *Kodomo-no-Kata*) (Messner & Crowley, 2020). Similar to the *atemi-waza*, the IJF and Kodokan kata are not the subject of this review.

Names of judo techniques

The largest part of classified Kodokan techniques are descriptive, mentioning parts of the body involved in action, principles of throwing, combination of body parts and principles, but some are also symbolic names.

Symbolic names

The following techniques have symbolic names: *yama-arashi* (“mountain-storm”), *tsubame-gaeshi* (“swallow counter”), *tawara-gaeshi* (“bag of rice throw”), and *tani-otoshi* (“valley drop”).

Counter techniques

The Kodokan classification include techniques used as counter techniques such as: *ko-uchi-gaeshi*, *tsubame-gaeshi*, *o-soto-gaeshi*, *o-uchi-gaeshi*, *hane-goshi-gaeshi*, *harai-goshi-gaeshi*, *uchi-mata-gaeshi*, and *uchi-mata-sukashi*.

Attacking and counter techniques

There are techniques which can be used both as a direct application but also as counter techniques: *utsuri-goshi, ushiro-goshi, ura-nage, tani-otoshi*, and *yoko-guruma*.

IJF Refereeing Rules

Judo as a dynamic and competitive Olympic sport is exposed to innovative solutions, variations and adaptation of techniques. Athletes and coaches are innovatively exploring new forms and methods to reach winning scores. The IJF Refereeing Rules are constantly changing and adapting for the safety of athletes and the conservation of Kodokan judo. The updates are in the Sport and Organisation Rules (IJF, 2019), and are used by the IJF Database for statistics, by the IJF Media department for presenting our sport, and the IJF Academy for teaching properly the next generation of instructors and coaches.

Forbidden techniques

As education and Olympic sport safety is a major priority in judo, therefore, a part of the Kodokan classified techniques are forbidden in *randori* and *shiai*: *kani-basami* (KBA/P26), *kawazu-gake* (KWA/P26), *do-jime* (DOJ/P08) and *ashi-garami* (AGR/P04). As a dynamic sport, judo through the IJF has to adapt the competition rules continuously, to ensure the safety of judoka. Therefore, there are techniques that cannot be applied in certain situations, such as the application of *kansetsu-waza* techniques in a standing position.

Application of *nage-waza* techniques in *ne-waza* without scoring

The movement of throwing techniques can also be applied in *ne-waza*, without scoring purposes: *sumi-gaeshi, hikikomi-gaeshi, tawara-gaeshi, daki-wakare*, etc. with the purpose of continuing with *osaekomi-waza*, *shime-waza*, *kansetsu-waza* or taking an advantageous *ne-waza* position, thus creating a tactical advantage.

Conclusion

There are many forms and variations of judo techniques and even popular techniques can be presented using a variety of terms. A collaboration between the IJF and the Kodokan, this paper explains some examples of variations, how they align to the current terminology used by both organisations and the value of correct terminology.

The importance of the application of 100 Kodokan Classified Judo Techniques, respecting Japanese tradition and the way of Jigoro Kano, adapted to the current judo development, updated from Kodokan Institute on 1st April 2017 and introduced in the IJF Sport and Organisation Rules (SOR) on 8th July 2020, increases the efficiency of performance through the IJF Data Base, supports teaching judo in the IJF Academy and helps the IJF Media department to present the correct techniques to the entire world.

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Arts and Sciences of *Kuatsu*
A Review of the Historical and Medical Researches

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Abstract: *Although kuatsu is introduced in Sports and Organization Rules of the International Judo Federation as a resuscitation technique for choked-out judokas, basic knowledges of kuatsu have not been fully understood. In this article, old Japanese publications focusing on the practical techniques and accumulated medical researches on kuatsu are reviewed.*

There are several techniques of kuatsu to resuscitate a choked-out judoka. Those include the compression of the chest wall or the abdominal wall, with or without pushing the back of the thoracic spinal bones. Kuatsu stimulates the touch and pain senses which are transmitted along the ascending sensory tract, reticular formation, and finally radiate to the cerebral cortex. This stimulation awakens a choked-out judoka from unconsciousness.

Many physiological researches on Kappo have been reported that showed a merit of kuatsu to shorten the time of unconsciousness while reviving the respiratory function of a choked-out judoka. Therefore, techniques and physiological effects of kuatsu should be fully understood and be used safely worldwide through regular educational workshops among judo community members while establishing its legal system if needed in some country.

Key words: *judo, jujutsu, shime-waza, choking, fainting, kuatsu*

Kuatsu is introduced in Sports and Organization Rules (SOR) of the International Judo Federation (IJF) as a resuscitation technique practiced by judo teachers and referees. Their knowledge is a part of the judo heritage and should not be forgotten (IJF, 2017). However basic knowledge and techniques of *kuatsu* had only been described in old Japanese books in the late 19th century in Japan. In this article, review of old Japanese publications, practical techniques and physiological researches on *kuatsu* are described.

Birth of *kuatsu* in *jujutsu*

Jujutsu was developed in Japan during the civil war era in the 16th century. The first *jujutsu* school, named *Takenouchi-ryu* was born in 1532 as the oldest military school in Mimasaka country which is now Tsuyama city area in Okayama prefecture in Japan. The second *jujutsu* school named *Muso-ryu jujutsu* was developed in 1592 in Sanuki country which is now Kagawa prefecture in Shikoku district. As a famous leading *jujutsu* school, Kito-ryu was born in 1637 in Ibaraki country which is now Osaka prefecture and *Tenjin Shinyo-ryu* in 1822 in Kyoto (Tezuka, 2000; Tohdoh, 2007).

Jujutsu consists of two parts: *Sappo* and Kappo. The meaning of *Sappo* is “Method of killing” and that of *Kappo* is “Method of *kuatsu*”. *Sappo* is martial arts consisting of blowing, locking, choking, throwing, and holding techniques. On the other hand, *Kappo* is oriental medicine consisting of resuscitation techniques for suspended animation as a result of hand-to-hand combat during the civil war era in the 16th century in Japan.

Until the end of Edo period (Samurai’s era, 1600~1868), more than 160 *jujutsu* schools were born in all over Japan, while more than 160 *Kappo* techniques were developed simultaneously as resuscitation techniques for a person with unconsciousness due to strangulation or some other mechanisms in close cooperation with Sappo. However relevant literatures are hardly available as *jujutsu* techniques were confidentially taught orally in the individual school of *jujutsu* during the civil war era and Edo period. They were secretly reserved in each school and were never allowed to be taken out from the school to prevent a leakage of secret arts to surrounding enemies because of the period of the civil war era in Japan. Furthermore, secret arts were usually transmitted from a father to only one elder son without any description. Only some scrolls (Makimono) including an instruction of *jujutsu* techniques with schematic drawings of *Yoshin-ryu*, *Tenjin Shinyo-ryu*, and *Kito-ryu jujutsu* were published in 18th century during the Edo period (Kuboyama, 2014).

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Publications of *jujutsu* with Kappo

Several books of *jujutsu* including *Kappo* were published during the Meiji period (1868-1911). They described instructions and illustrations of secret techniques of *jujutsu* and *Kappo* (Table 1).

Table 1. Publications of jujutsu/*kappo* since the late 19th century.

Year	Title of the book	Authors	Publisher
1892	Secret of *jujutsu* - Kappo	Yoshino MATSUMOTO	Seimeido
1893	*Tenjin Shinyo-ryu*: Instructions and graphic illustrations of secret of jujutsu	Chiharu YOSHIDA Mataemon ISO	Aokikouzando
1894	Detailed explanation of *jujutsu* Kappo	Heiji MORINAGA	Ohkurashoten
1896	Life or death free bonesetting: Physiology of jujutsu	Matsunosuke INOKUCHI	Aokikouzando
1898	Hayanawa/ Kappo: Illustrations of *jujutsu* practice	Matsunosuke INOKUCHI	Aokikouzando
1907	Simplified *jujutsu* - Practical manual	Masamichi YAMAMOTO	Fujitani Soubunkan

Yoshino Matsumoto published a book “Secret of *Jujutsu* Kappo” in 1892 (Matsumoto, 1892). On the cover, an interesting subtitle “Resuscitation of suspended animation” is observed (Figure 1A). In addition, “Techniques of Atemi (blowing)” is noticed beside the title as an appendix. Vital spots for both *Sappo* and *Kappo* are illustrated in this book (Figure 1B).

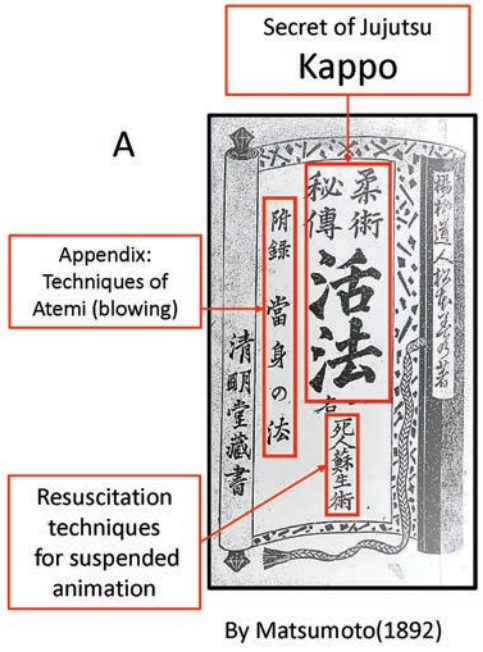


Figure 1A

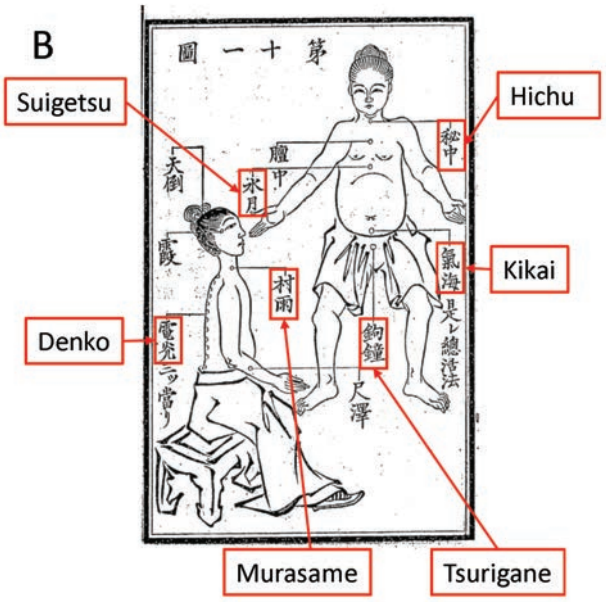
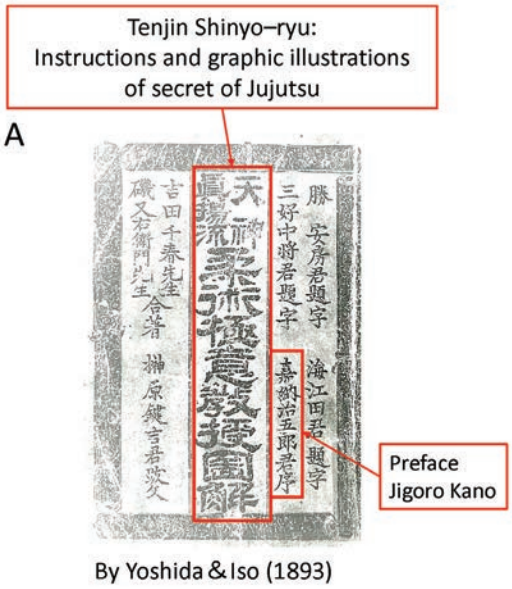


Figure 1B

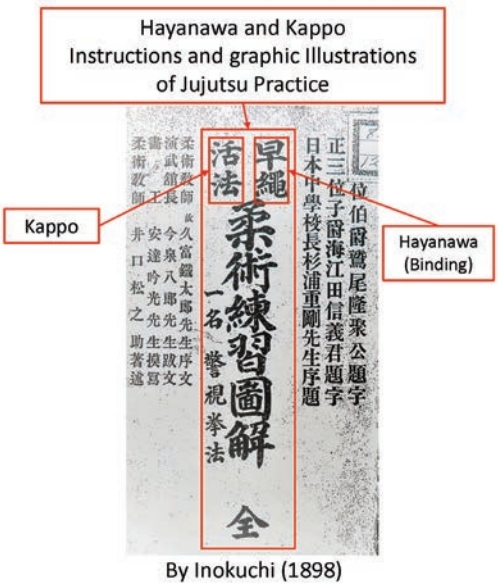


Two men method of artificial respiration

Figure 2

In the next year in 1893, Chiharu Yoshida and Mataemon Iso published a book entitled "*Tenjin Shinyo-ryu*: Instructions and graphic illustrations of secret of jujutsu". A memorial description of preface by Jigoro Kano is noticed on the cover (Figure 2A), and as a part of *kuatsu*, a two men method of artificial respiration is demonstrated to revive the respiratory function of a person in suspended animation (Figure 2B) (Yoshida and Iso, 1893).

In 1898, Matsunosuke Inokuchi published a book entitled "Hayanawa and Kappo□Graphic illustrations of *jujutsu* practice" (Inokuchi, 1898) (Figure 3A). Practical techniques of *jujutsu* were instructed, and technical points of binding were precisely illustrated together with *Kappo* techniques. And Masamichi Yamamoto published a book entitled "Simplified *Jujutsu* — Practical manual" in 1907, and *Kappo* was noticed as an appendix (Figure 3B) (Yamamoto, 1907). As an important basic knowledge, vital spots of the human body in both *Sappo* and *Kappo* were illustrated in the book of *Takenouchi-ryu* and *Tenjin Shinyo-ryu jujutsu* school, respectively.

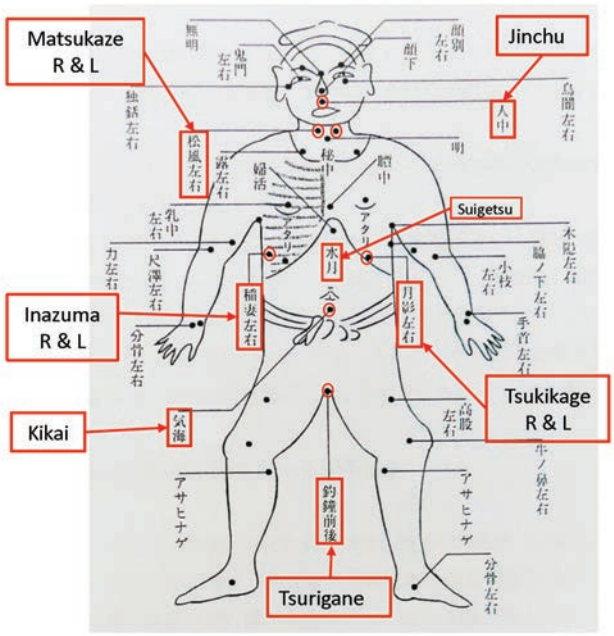


By Inokuchi (1898)

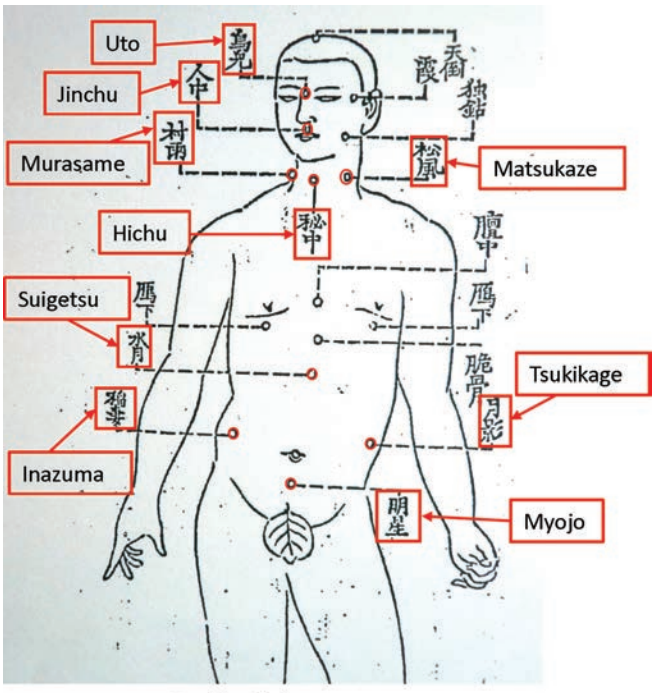
By Yamamoto (1907)

Figure 3

Uto, Jinchu, Murasame, Matsukaze, Hichu, *Suigetsu*, Inazuma, Tsukikage, *Myojo*, *Denko* and Turigane (scrotum) are the representative marks (vital spots) of blowing in Sappo, and *Kikai*, *Myojo* and *Denko* are those in Kappo, while *Kikai* is a point of the meridian in traditional oriental medicine. Among those, *Jinchu, Matsukaze, Suigetsu, Inazuma* and *Tsukikage* are the names commonly used in both schools (Figure 4) (Asami & Matsumoto 1972; Kubota, 1996; Matsumoto, 1892; Morinaga, 1894; Tezuka, 2000).



Takenouchi - ryu



Tenjin Shinyo - ryu

Figure 4 - Anterior views of vital spots in *Sappo* and Kappo

Techniques of *Kuatsu*

Several techniques of *kuatsu* had been developed and been used to resuscitate an unconscious person or choked-out judokas. *Sasoi-Kuatsu* has been used as the most popular method of resuscitation for choked-out judokas in dojo. At the first step, the operator carefully pulls up the shoulder of a fainting judoka to sit up on the *tatami* and pushes hard the anterior chest wall downward to achieve a forced expiration while pushing the back of the fifth to sixth thoracic spinal bone (vital spot of Denko) with the knee of the operator to stimulate the ascending sensory nerve (Figure 5) (Asami; 2000, Matsumoto, 1892; Samura, 1933; Tezuka, 1997).

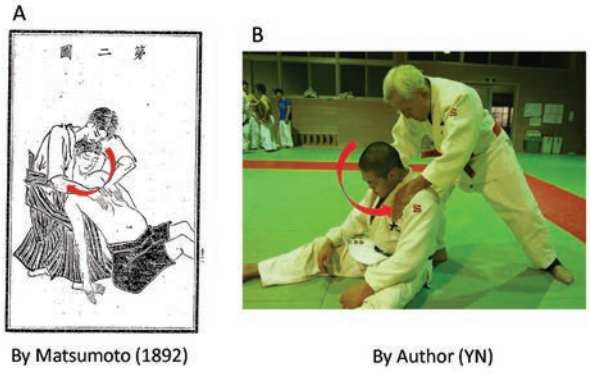


Figure 5 - *Sasoi Kuatsu*

Although this procedure had been used frequently, the author never recommend this method from a view point of modern emergency medicine because of a risk of neck injury due to over anterior flexion of the neck during the procedure to pulling up the fainting judoka to sit up. In case of *Eri-Kuatsu*, it is important to keep the back of a fainting judoka propped up by the left knee and to catch the left anterior lapel with the left hand to support the neck and the upper body, and the operator pushes upward the vital spot "*Myojo*" at the lower abdomen one inch above the pubic bone with the right hand formed like a hand of eagle in a breath to achieve a forced expiration and to stimulate the sensory nerve (Figure 6) (Inokuchi, 1898).

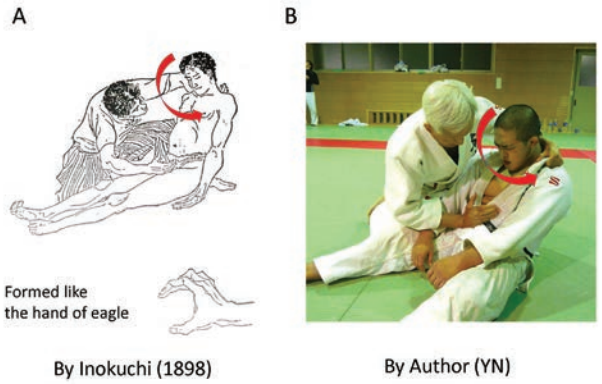


Figure 6 - Eri Kuatsu

This method is also not recommended from a viewpoint of modern emergency medicine because of a risk of neck injury during the procedure. In a case of a fainting judoka in a supine position, *Kikai-Soukatsu* is recommended. "*Kikai*" is one of the name of meridians at the center of the lower abdomen 1.5 inches below the umbilicus near the vital spot of "*Myojo*". The operator puts his both palm bottoms 1.5 inches below the umbilicus and push up the vital spot "*Kikai*" toward the diaphragm in a breath (Figure 7) (Inokuchi, 1898).

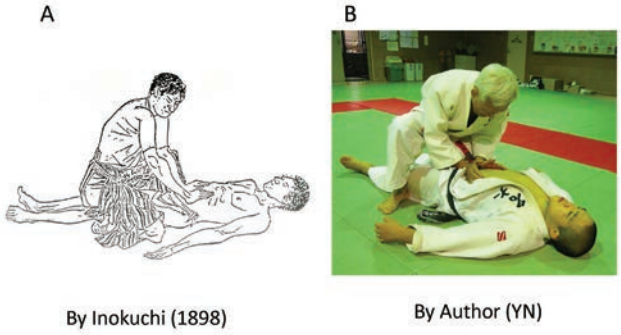


Figure 7 - *Kikai Soukuatsu*

This is a typical procedure to achieve a forced expiration, because the thoracic cavity is compressed by the elevated diaphragm to decrease the respiratory internal pressure of the bronchus which is received by the deflation-sensitive receptors and finally stimulates respiratory function. This technique is the most effective procedure among the several *Kappo* techniques and therefore is recommended to use as the final procedure if an operator failed in awakening the fainting judoka with the other method of *kuatsu*. On the other hand, if a fainting judoka is in a prone position, *Ura-Kuatsu* (or Back-*Kuatsu*) is recommended. The operator sits astride a fainting judoka with one knee raised, and puts his both palm bottoms on the back of the bilateral sides of the nineth and tenth thoracic spinal bones (vital spot of "*Denko* ") behind the epigastric region (vital spot of "*Suigetsu*") and pushes the chest wall toward the lung and the liver in a breath to stimulate the sensory nerve and to achieve a forced expiration (Figure 8) (Ikai et al., 1972; Inokuchi, 1898).

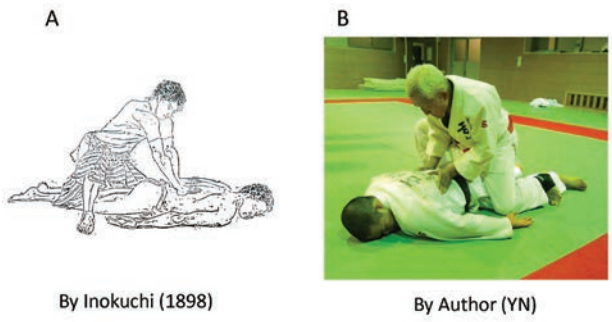


Figure 8 - *Ura Kuatsu* (Back *Kuatsu*)

Education system of *kuatsu*

As shown in the publication list, *Kappo* (*kuatsu*) had been taught by grand master of each *jujutsu* school even after finishing the Edo period (1600 – 1868) and starting the Meiji period (1868 – 1911). Jigoro Kano developed judo to modify *jujutsu* in 1882 and established the Kodokan. Several memorial records are found in the historical calendar described in the appendix of "130 years of historical records in the Kodokan". Master Kano himself organized a seminar or workshop of judo for Yudanshakai (Black belt association) and taught *kuatsu* at the end of his lecture and training course for 8 times from 1899 to 1921 (Kodokan, 2012).

Master Kano sent Yoshitsugu Yamashita 6th dan (later 10th dan) to the United State of America (US) in May 1902 to spread judo in the US. President Theodore Roosevelt arranged for Mr. and Mrs. Yamashita a dojo in the White House, had a lesson 3 times a week and became one of the several students under Professor Yamashita (Brousse & Matsumoto, 2005; Brousse & Messner, 2015; Matsumoto, Abe, Kawamura, Hayakawa, & Morishita, 1970; Murata, 2015). According to the English diary reported by Masujiro Honda (3rd dan), an English literary and student of Kano, Professor Yamashita gave a final lesson in the art of resuscitation (Kappo) to his great pupil, Colonel Roosevelt in the White House Dojo on the eve of returning to Japan on May 3, 1906 (Honda, 1906). President Theodore Roosevelt was the first brown belt holder in the US and must have been the first foreign judoka who learned *Kappo* outside Japan. Jigoro Kano also headed the petition movement asking for the establishment of "Certified judo bonesetter" to support professional judoka financially, and a new law was established in 1920. Afterwards, professional judo teachers could open their private dojo to teach both judo and *Kappo* together with clinical works of bone-setting.

On the other hand, Dai Nippon Butokukai (DNB)(Great Japan Federation of Martial Arts) was established in Kyoto on April 17, 1895 under the authority of the Japanese government by integrating many *jujutsu* schools for the preservation of traditional Budo (martial arts), while establishing together with Training Institute for Martial Arts' Teachers (TIMAT) in 1905. And the graduates were sent to its branches as an instructor all over Japan (Brousse & Messner, 2015; Sakaue, 1989). Judo had a promotion system (dan-ranking) not only in eastern Japan, Tokyo at the Kodokan but also in western Japan, Kyoto at the DNB. After World War II, General Head Quarters of the Supreme Commander for Allied Powers dissolved the DNB as an educational center of militarism and the TIMAT was also closed on November 9, 1946. More than 1,300 leaders and officials of the DNB were purged, ostracized and lost their jobs. And some of them went abroad to teach judo in the foreign countries. In addition, the law of certified bonesetter was also abolished and all martial arts were prohibited in Japan. However only the Kodokan could survive as a center of modern sports judo.

Although modern sports judo practice and competition were permitted in 1952, judoka had less time to learn *Kappo* for a while. Since 1985, annual summer seminar of traditional *kappo* has been held in the Kodokan by Professor Toshihiro Kubota, grand master of *Tenjin Shinyo-ryu jujutsu* and Professor Masataka Tezuka at Meiji University (Kubota, 1996; Tezuka, 2000). Only high-ranking black belt judoka above 4th dan including overseas judokas were eligible for participating the seminar (Figure 9).

Figure 9 - Summer seminar of Kappo at Kodokan

In the case of the authors, YN had a special experience to learn both judo and *Kappo* with bone-setting techniques from grand master Yoshitaro Okano 9th dan (later 10th dan) in Nagoya University Judo Club during undergraduate days in the medical school since 1963. Master Okano had learned *Tenjin Shinyo-ryu* and *Muso-ryu jujutsu* before entering the TIMAT in Kyoto as the first generation students in 1905. This personal experience has been effective to transmit the knowledges and techniques of both judo and *Kappo* to his junior members of the judo club. Although All Japan Judo Federation launched the Certified Judo Coaching Qualification System to improve the qualities and activity of coaches in April 2013, there has been no national qualification system for *Kappo* in Japan. Only limited number of high-ranking black belt judokas above 4th dan have had a chance of learning traditional *Kappo* in the Kodokan.

Physiological responses

Why does a choked-out judoka wake up by *kuatsu*? We should understand the reticular activating system (RAS) to answer this question. The RAS is a component of the reticular formation in the vertebrate brains located throughout the brain stem and play a significant role in coordinating both the sleep–wake cycle and wakefulness. On the other hand, extracorporeal signals including physical senses of pain, touch, temperature, hearing, and sight travel along the peripheral nervous system to reach the spinal cord and pass through the ascending sensory tract, reticular formation, thalamus, and are interpreted by the brain. It is thought that an operator of *kuatsu* pushes up the vital spot to stimulate the touch and pain senses, which pass through the ascending sensory tract in the spinal cord, reticular formation, thalamus, and finally radiate to the cerebral

cortex. Through this process, the choked-out judoka wakes up from unconsciousness (Figure 10) (Magoum, 1958; Moruzzi & Magoun, 1949; Starzl, Taylor, & Magoum, 1951a; Starzle, Taylor, & Magoum, 1951b). In short, only simple action to push the vital spot is necessary to wake up the fainting judokas.

Changes of cardiopulmonary function

Kuatsu maneuver induces forced expiration by compressing the chest wall or pushing up the lower abdomen toward the diaphragm. According to the Hering-Breuer theory, forced expiration by *kuatsu* maneuver decreases the respiratory internal pressure which is received by deflation-sensitive receptors (pulmonary stretch receptors) located in the bronchia and bronchioles. And the impulses from these receptors travel afferently via the vagal nerve and reach the medullary respiratory centers (Hering–Breuer reflex) (Brerer, 1868; Hering, 1868). Then the respiratory function of an fainting judoka revives immediately after application of *kuatsu*.

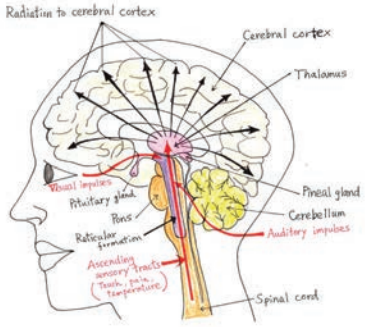


Figure 10 - The Reticular Activating System (RAS) (by Moruzzi & Magoun, 1949)

According to several human experiments with judoka, respiratory volume and rate irregularly decreased during choking and fainting, and gradually revived in one minute during the course of awakening. On the other hand, heart rate increased during the above period and gradually normalized (usually in 12 seconds) after awakening. In addition, expiratory volume increases 2 to 3 times by any form of *kuatsu* without choking or 3 times after choking out followed by *kuatsu* (Table 2).

Table 2. Changes in expiratory volume by *kuatsu* – Human experiments by Ikai, M et al. (1972).

Type of *kuatsu*	Expiratory volume (mL)
at rest	400 ~ 500
Sou-Kuatsu (without choking)	900 ~ 1,000
Eri-Kuatsu (without choking)	700 ~ 900
Sasoi-Kuatsu (without choking)	1,000 ~ 1,200
Sou-Kuatsu after choking	1,200 ~ 1,400

And the respiration rate in 20 seconds increased by 20 ~ 75%, whereas the respiration volume in 20 seconds increased by 33 ~ 86% after an application of *kuatsu*. In a case applying *Sou-kuatsu* after choking, the respiration rate increased by 100% and the respiratory volume increased by 170% (Table 3) (Asami, 2000; Ikai, et al. 1972; Matsumoto & Asami, 1971). According to another human experiment by Asami, et al., expiratory volume by *kuatsu* was 150 ~ 600 ml and inspiratory volume of modern artificial respiration was about 2 times of those by *kuatsu*, however respiratory volume of the latter was 20 ~ 30 % less than those of the two men method of *kuatsu* (Figure 2) (Asami, Matsumoto, & Sasaki, 1972; Yoshida, & Iso, 1893). However, the extent of tidal volume reduction during fainting is not critical and breathing disorder is unusual to occur in choked-out judokas during practice and competition.

Table 3. Respiratory changes in 20 seconds after application of *kuatsu*–Human experiments by Ikai, M et al. (1972).

Type of *kuatsu*	Respiration in 20 seconds					
	Rate			Volume (L)		
	at rest	after *kuatsu*	percent increase after *kuatsu*	at rest	after *kuatsu*	percent increase after *kuatsu*
Sou-Kuatsu (without choking)	4	7	75%	3.6	6.7	86%
Eri-Kuatsu (without choking)	4	6	50%	3	4	33%
Sasoi-Kuatsu (without choking)	5	6	20%	4.2	6.6	57%
Sou-Kuatsu after choking	5	10	100%	4	10.8	170%

Safety management of choked-out judokas by *kuatsu*

If a judoka is choked-out during competition, a referee calls a *tatami* doctor to treat the fainting competitor. The doctor immediately enters the *tatami* and observe the appearance of the choked-out competitor who sometimes develops unpleasant symptoms: oculogyric crisis (upward deviation of eyeballs), convulsion, drooling, and incontinence during unconsciousness. Then the doctor may decide to apply *kuatsu* to shorten the time of unconsciousness and to revive the above symptoms, while observing the expression of the eyes of the competitor to diagnose the recovering condition from fainting. Next the doctor checks the neurological recovery of the waked up competitor lying on the *tatami* and ask him “How do you feel?”, “Are you feeling OK?”, “Where are you now?” and “Can you understand my question?”. If the competitor’s response is good, the doctor can permit and help him to sit up and carefully help him to stand up and get out from the tatami.

Discussion

Kuatsu is an old traditional resuscitation technique developed in Japan during the civil war era in the 16th century as a part of jujutsu. Several resuscitation techniques are described in the old published books: how to support to breathe, how to get down a hanged person, how to spit

out water from a drowning person, and actual techniques of *kuatsu* are illustrated to deal with those serious problems. Those issues, however, should be a heritage from the past and have not been discussed in any event in judo but very important problems remain in modern emergency medicine (Asami, 2000; Matsumoto, 1892; Matsumoto, & Asami,1971; Tezuka 1997). Although many physiological studies on fainting by *shime-waza* have been reported not only in Japanese but also in English journals (Haga, et al.,2016; Ikai, et al.1958; Mitchell, Roach, Tyberg, Belenkie, & Sheldon, 2012; Raschka, Rau, Hubsch, Bunner & Banger, 1998; Rodriguez, et al., 1991), many historical and physiological research papers on *kuatsu* have been published only in Japanese journals by Japanese sports and physical researchers. Unfortunately, many parts of these published papers were found to be duplicated and re-submitted by the same first authors or co-authors in these 50 years (Asami, 2000; Asami & Matsumoto, 1970; Ikai, et al., 1972; Matsumoto & Asami, 1971;Tezuka, 1997; Tezuka, 2000). Only a little scientific investigation of *Kappo* has been attempted. A Japanese anesthesiologist Hyodo recommended *kuatsu* from the viewpoint of modern medicine for cases requiring manual resuscitation as first-aid for an emergency (Hyodo, 1966). On the other hand, negative descriptions about *kuatsu* are shown in SOR : " the *kuatsu* is these days forbidden in some country", " their practice is not allowed but their knowledge is part of the judo heritage". However, the reason why and where *kuatsu* is forbidden is not described in SOR (IJF, 2017). Furthermore, American doctors referred the above Japanese literatures and criticized Japanese traditional resuscitation techniques *kuatsu* unfavorably, because those methods have little scientific benefit as yet untested both medically and legally. However, they did not show any data of comparative studies between *kuatsu* and their own modern medical research on artificial respiration (Lang, 1984; Norton, 1969). From another point of view of daily practice of judo, *kuatsu* do however have an actual merit to shorten the time of unconsciousness of choked-out judokas with or without associated symptoms and to prevent some unfavorable effects due to prolonged choking with delayed recovery from unconsciousness. Therefore, the authors do not refer to the respiratory problems mentioned above but describe the techniques and effects of *kuatsu* used within the limits of resuscitation techniques to revive the fainting judokas by *shime-waza*. However further physiological studies on *kuatsu* should be carried out by medical doctors collaborating with sports scientists to establish the medical scientific evidence and safety performance of *kuatsu*. In addition, seminar and workshop of *kuatsu* should be held regularly among judo community members to educate the medical evidences and basic techniques of *kuatsu*, while establishing its legal system if needed in some country. This may lead to a safer management of choked-out judokas with a help of modern emergency medicine to prevent unexpected neurological injuries due to erroneous performance. Then *kuatsu* can widely be used all over the world after acquiring necessary knowledge and safer technique of the procedure.

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Judo Education: The formation of the IJF Academy

By Envic Galea

Abstract: *The establishing of the International Judo Federation (IJF) Academy was an evolutionary process that started in the 1990s. In this article, we present short historical documentation of this process, starting from medical and educational seminars, to a pilot project with an initial intake of 15 students, to become a multi-lingual, international Higher Education Diploma programme undertaken by hundreds of coaches worldwide.*

Key words: *IJF Academy, history, education, medical seminars, education seminars, academic coach certification, European Qualification Framework*

In 1991, in Athens, the European Judo Union (EJU) Congress elected a new Assistant General Secretary on the Executive. In this role, and later as Head Sports Director and Vice President of the EJU, I started investigating the technical structures of National Federations within the Union and how the European Judo Federations and their clubs functioned. As was anticipated, there was a significant difference in their coach formation and appointment. The better organised a federation was, the more successful it performed. For instance, the French Judo Federation not only had the largest judo membership in Europe but also had better results in competition.

Further enquiries showed that except for some Federations the qualification system for the coaches was an internal process and most federations appointed former competitors as coaches without any formal training in coaching. These coaches therefore based their training methodology on their experience. The national federations certified these coaches directly, some after attending a short course, while others established the certification on the coaches' athletic past results. During the following years, the EJU Directorate had the opportunity to meet many of the national Judo coaches and administrators, to understand better the role and function of these sport structures.

In 1995, the EJU executive committee, with the support of Kurt Kucera, President of the EJU, established an Education/Youth Commission. The Executive confirmed Franco Capelletti, then technical director of the Italian Judo Federation, Jean Luc Rouge, then Technical Director of the French Judo Federation, and I then Head Sports Director of the EJU to chair the Commission. The role of this new Commission was to investigate the situation of youth and children in the EJU and propose projects for the better development of this sector.

Two years later, in 1997, I also became responsible for the Medical Commission of the EJU. The EJU Medical Commission duties were athlete anti-doping and supervision of EJU Championship injuries. I envisaged that doctors could give a better contribution to Judo if we organised a combined scientific seminar together with coaches, mainly because most doctors on this Commission were also judoka. During this year, we held the first joint Medical and Education conference in Rome. This annual conference consisted of seminars analysing specialised judo topics, such as Judo for Children, Judo for different age categories, Judo for Women, and other scientific issues such as avoiding injuries and better knowledge of prohibited substances.

From the very start, we did not limit these seminars to discussions. We organised these seminars also to the tatami (mat). Judo was not only discussed but also practised, while we exchanged ideas on teaching methodologies for various age groups.

EJU Medical & Education Seminars

This new scientific Commission invited the National Federations to explain their national coach qualification structures. The structures and process of the French *Institut National du Sport, de l'Expertise et de la Performance* (INSEP) based and the German Cologne-centered coach qualification stood out from the rest as an excellent example of preparedness. The Commission concluded that judo coaches had to obtain not only a sports qualification from their National Federation but also an academic formation. Coaches were not teaching Judo only in their clubs where the national federation certification was sufficient, but Judo was also starting to be thought in sports centres, universities, and schools. These institutions began asking that coaches are not only experts in their sports skills but also their academic qualifications. Moreover, with the expansion of the European Union, coaches were becoming more mobile; they were travelling from one country to another, and a necessity to standardise the conversion of their qualifications started becoming more relevant. It became necessary that coaches had formal qualifications.

The main hurdle for coaches to attend academic courses and qualify as coaches was time at their disposition to participate in these formation courses. Most national classes, when available, were full time, and most of the judo club coaches already had full-time day jobs, and teaching of Judo was a part-time job. They could not attend full-time or part-time academic classes.

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EJU Academic Coach Certification

Enter the "Blended Learning System", a way of learning that combines traditional classroom teaching with tutoring that uses computer technology, and which delivers this tutoring over the internet (Cambridge dictionary; https://dictionary.cambridge.org/dictionary/english/blended-learning). We found such Blended Systems would be useful for student retention because this approach gave them more flexibility in the planning of the students' studies.

In 2005, with the help of Mike Callan a judoka and lecturer at the University of Bath, the EJU Education Commission got the approval at the EJU Congress. It launched the Foundation Degree in Judo Coaching at the University of Bath in the blended format. We took the already existing coaching course and contextualised the modules to judo. Coaches studied online and attended a twice-yearly week for practical sessions for three years, from the University of Bath. In 2010, we moved this foundation degree in Judo Coaching to Anglia Ruskin University in Cambridge. Students had the option to keep studying for the BSc in Sports Coaching (EJU) at both universities. These developments happened under the EJU presidency of Marius Vizer, who gave his full support in the structuring of the agreements with the universities for the coaching courses.

Following the success of these courses, in 2010 we also reached an agreement with the University of Tor Vergata in Rome and the Italian Judo Federation, to introduce a Master's degree. Attilio Sacripanti, a renowned researcher in judo and professor, specialising in biomechanics, structured and led this course, delivered in a blended format.

This experience proved that the blended format works as the best form to educate the Judo coaches. However, we discovered that the cost and the pre-education entry-level for these courses was prohibitive to many coaches who wanted to join. Also, we did not have control over the Judo and education content, which left us particularly concerned. Although the education content was of an excellent academic level, the teaching material was designed for generic sports not specifically to Judo. A higher judo content in the educational section and an international standard of Judo in the sports content was desirable.

IJF Academy

In November 2012, Marius Vizer now President of the IJF, asked the Education Directorate to start the coordination for the set up an IJF Academy which should be the teaching arm of the IJF. Vizer preferred that the structure of the dedicated Judo teaching institution be under the IJF umbrella. The President entrusted me, in the capacity of member the IJF Education Commission, with this coordination of the formation of the Academy.

I got in touch with Tibor Kozsla, then International Director for the faculty of Physical Education and Sports Sciences at Semmelweis University, Budapest. We had already collaborated on pilot projects for the National Olympic Committee representing Malta when I was the national Youth Director there. In Malta, we had introduced a successful structure for an online project for coaches supported by the National Olympic Solidarity. We used this experience to structure and run the IJF Academy.

Together with the office of the President, we organised an ad hoc IJF Academy commission brainstorming meeting in Budapest. During the meeting, we examined all studies on Sports Coaching Structures, giving primary attention to the advice from the European Sport Coaching Framework (ESCF) (https://www.coachlearn.eu/_assets/files/project_documents/european-sport-coaching-framework.pdf).

"Federations at the national and international levels take the lead in sport-specific certification courses. Institutions of higher education tend to focus on more universal topics such as sports science, coaching methods, and theory. There also is a positive trend for such institutions to include sport-specific components. It is recommended that partnerships be forged between federations and educational institutions to maximise the quality and relevance of the courses offered."

The ad hoc IJF Academy Commission concluded that (i) the IJF Academy would organise three levels of coaching; the Instructor, the Coach, and the Pro Licence; (ii) these courses have to be progressive, no students would be allowed to enter a course unless they did the first and so on. (iii) the introduction of these courses was to be gradual, with an initial concentration on the first pilot course, which would include the basics of Judo; and (iv) balance the tutoring with 50% academic content and 50% Judo content based on the advice of the ESCF.

Professors from Semmelweis University were commissioned to prepare Judo related scientific modules and international Judo experts from the IJF to develop the Judo modules. The IJF agreed with Semmelweis University to certify the course. Both the University and the IJF would issue a certificate to the successful students. The course would run in a blended format, all the academic subjects online and the practical sessions and assessments at one of the Olympic Centres in Budapest. The practical week would include a final exam for the theoretical modules, under the supervision of the IJF Academy directors, called the "paper test", and the practical courses and Judo final practical exams were to be run by IJF approved judoka.

The IJF Academy was to be under the jurisdiction of Mohamed Meridja, the IJF Coach and Education Director, Daniel Lascau, the IJF Academy Sports Director, Tibor Kozsla the IJF Academy Education Director and I would be the Chairman.

During the Ordinary Congress of the International Judo Federation in Rio, Brazil, 2013, IJF President Marius Vizer announced the formation of the IJF Academy, that the Academy would be the teaching arm of the IJF and that the first pilot course of the IJF Academy was starting. The first students registered in August that year to the pilot project, Le-

vel 1 Instructor. In December 2013 the first practical session was held at Tata Olympic Centre in Hungary for 15 students.

The first 15 students of the IJF Academy at Tata Olympic Center Hungary 2013.

IJF Academy in ten languages

One of the fifteen students was Mesut Kapan, the Turkish Federation Olympic Coach. He asked the Academy whether he could translate the course content to the Turkish language so it could become the National Structure for their coach qualification. This request was accepted as there already was a plan to translate the course into French and Spanish languages. More Federations asked to translate the contents into their native language, upon which, today, Level 1 Instructor course runs in ten languages.

IJF President Marius Vizer and members of the IJF Executive visits the IJF Academy Referees course in Budapest 2018.
(IJF Executive from left to right - Spots Director Armen Bagdasarov, Education & Coaching Director Mohamed Meridja, President Marius Vizer, Head Refereeing Director Jun Carlos Barcos. IJF Academy - Academy Expert Mark Huizinga, Education Director Tibor Kozsla, Chairman Envic Galea, Sports Director Daniel Lascau, also on IJF Executive together with Refereeing Supervisor Jeon Ki Young and IJF Referees)

The Kodokan

The IJF Academy structured the Judo classes on the Kodokan official Judo techniques. But after the first few courses, it was discovered that the knowledge of the basic judo techniques, timing and distance in the demonstration of the techniques was low. Therefore, Judo kata was introduced to the curriculum to help improve the standard of Judo. Thus, the Academy added the two most important kata known as Randori Kata, the Nage no Kata to the first level course, and the Katame no Kata was added to the second level course. This decision allowed the Academy to work closely with the Kodokan Institute in Japan, which started sending Kata experts to the practice sessions. The relationship between the IJF Academy and the Kodokan Institute grew stronger over time. In 2019, it was agreed to a joint project to produce educational short films of 100 Kodokan techniques, and made available for students.

National and Regional Courses, Olympic Solidarity support

With the introduction of more languages, more National Federations were interested to see that their coaches receive the IJF Academy certification. The number of students at the Academy was increasing, and it was no longer financially viable to organise the practical sessions in Hungary. Instead, the IJF Academy started visiting those Federations who had a more significant number of students. By this time, the Olympic Solidarity recognised the importance of this coach formation. It started giving financial support to the National Olympic Committees and the National Federations to organise these National and Regional Courses.

The IJF Academy sets up its own LMS

Until 2014 the IJF Academy was using the Semmelweis University Learning Management system (LMS) operating on Moodle (https://moodle.org), an open-source learning platform. However, on September 1, it was decided that the Academy sets up its own LMS, with a new operating system which gave greater flexibility such as the introduction of videos, private and group chat, security systems such as face recognition and other improvements.

The introduction of this dedicated LMS, the management of the course and the use of the learning material was handled more straightforward. Students could study both online or download lessons for offline study. The LMS system also handled efficiently and securely the multiple-choice questions of the exams and the uploading of assignments, which are the basis of the online assessment.

2018 The qualification framework

By 2017, the Academy now counted over 1,737 alumni from 78 countries. The IJF became the only international sports federation with an academic qualification for their coaches. However, the certificates issued from

Hungary university were not pinned within the European Qualification Framework (EQF) https://www.cedefop.europa.eu/en/events-and-projects/projects/european-qualifications-framework-eqf level because their current structures only applied the EQF from the sixth level upwards. EQF is a qualification defined by the European Commission as "the formal outcome of an assessment and validation process obtained when a competent body determines that an individual has achieved learning outcomes to given standards" (http://www.ehea.info/Upload/TPG_A_QFERO_MK_1_EQF_Brochure.pdf).

The lack of EQF recognition meant that if an alumnus wanted to convert their certificate into an educational value, they are required to go to their national education board to have it converted to the national standard. The Academy preferred that all the IJF certificates are recognised by national institutions, thus facilitating the Federation and students to get EQF recognition.

Following a thorough investigation of several European educational qualification systems, the Academy concluded that the Malta National Qualification Framework (https://ncfhe.gov.mt/en/Pages/MQF.aspx)

was more comprehensive because it covers all standard eight levels. The IJF Academy was thus incorporated as a Maltese Foundation and obtained a licence as a Higher Education Institute.

The IJF Academy courses are now pinned at level five and are recognised as a Higher Education level internationally. This licence places the IJF on a distinguished sport-educational status mainly because it is the only international Federation that has on offer academic qualification for its coaches and administrators, and is also a recognised educational institution. At present, the IJF Academy has two courses both at this level: the Higher Education Certificate Judo Instructor (30 Credits) and the Higher Education Diploma Judo management (60 Credits). The awarded credits fall under the European Credit Transfer and Accumulation System (ECTS) in higher education and the European Credit system for Vocational Education and Training (ECVET), facilitating national and international recognition and mobility.

Constant evolution

The IJF Academy is actively involved in accrediting more courses for the IJF members, with plans for Higher Education Diploma Judo Coach (60 credits), Higher Education Diploma Club Judo Coach (60 credits), Higher Education Certificate Judo Nutrition (30 credits), and Higher Education Certificate Judo Sport Psychology (30 credits). As a general guide, a 30 credit course lasts one semester Half a year), and a 60 credit course lasts two semesters (1 academic year). The Academy is also actively involved with other IJF Commissions to provide formation and certification according to their requirements, for instance, offering courses and accreditation for IJF Referees and the Police and Army Commission. Eventually, the Academy aims to combine these courses into a Bachelor of Science degree and Masters degrees in due course.

Conclusion

The founder of Judo was Jigoro Kano; he is famous around the world as being not only the founder of Judo but an educator, he presented Judo as a discipline that went beyond a martial art. Judo was to be the character-forming, the discipline for mind and body. The IJF Academy adopted one of his quotes as the motto of the Academy "*Nothing under the sun is greater than education. By educating one person and sending him into the society of his generation, we make a contribution extending a hundred generations to come.*" This quotation from Kano defines the soul of the Academy. Over the seven years, the Academy was in existence; the Academy saw that the Federations were looking for a formalised coaching structure of their coaches and a harmonised international content of education. The Academy filled in for that education tool.

Education is an ongoing process, and the Academy is in a constant study on how to improve its teaching content. Today the Academy counts 2,258 alumni from over 160 countries from 5 continents. The Academy pays much attention to the feedback forms submitted by every student, presented at the end of their study. Their suggestions are taken into consideration because that is the only way Judo can be continuously improved all over the world.

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Prevention of Injuries Through The Teaching of Judo-Based Falls

By Luis Toronjo Hornillo, Óscar del Castillo Andrés

Abstract: *The consequences of unintentional falls are the second leading cause of death from unintentional injuries worldwide, with a higher incidence in children and older adults. Judo, through the teaching of ukemi, can help eliminate or reduce the severity of injuries caused by such falls in these populations. This article presents two programmes based on judo that are aimed at tackling fall-related injuries: Safe Falls-Safe Schools© and Adapted Utilitarian Judo. The implementation of these programmes has produced significant results for the variables analysed, which indicates that both programmes are useful tools to reduce the risk of injury caused by unintentional falls.*

Key words: *Ukemi, judo, childhood injuries, public health, health promotion, older-adult, falls*

Originally, judo was not conceived by Jigoro Kano as a competitive sport, but as an educational instrument with a high content of values, which should serve as a tool for the integral formation of people. Judo should then contribute, through its practice, to the improvement and benefit of society. For the true benefit of oneself one must also take into consideration the benefit of society. One's greatest prosperity can be achieved through service to humanity" (Kano, in Maekawa and Hasegawa, 1963). Master Jigoro Kano distinguished between "kyogi" or judo in the limited sense, such as that practiced with the sole purpose of physical improvement and better combat technique, and "kogi" which responds to judo in the broad sense, focused on the integral education of people and thus on improving society.

At present, the European Judo Union (EJU) has the following phrase next to its logo, 'Judo - more than sport.' These words are not the slogan of a mere advertising campaign, but they are loaded with meaning that recalls the principles present in the historical roots of judo.

Taking into account this perspective of humanistic vocation present in judo, a collaboration agreement was established between the EJU and the research group 'Physical Education, Health and Sport' of the University of Seville (Spain), with the aim of promoting other social aspects that are linked to the foundation values of judo, such as social judo for the improvement and protection of health, agreeing on the creation and development of the Safe Fall Programme.

The project aims to provide useful judo-based responses to public health problems posed by falls (World Health Organisation, 2018). The consequences associated with falls have become a threat at a global level, with the World Health Organisation (WHO) pointing to school children and the elderly as the main populations at risk. The WHO warns in its fact sheet 344 (2018) that falls have become the second leading cause of death as a result of accidental or unintentional injuries and proposes to establish effective, comprehensive and multi-faceted prevention programmes that are consistent with the creation of safer environments and that eliminate factors that make falls possible. Thus, effective fall prevention programmes should aim to reduce the number of people who fall, decrease the frequency of falls and reduce the severity of fall injuries (WHO, 2018), which could be achieved by teaching people how to fall in a safe way.

Programme Overview

As a response to the approach proposed by the WHO, a research project has been carried out that resulted in the presentation of the Doctoral Thesis: Design, Implementation and Evaluation of Two Proactive Judo-Based Programmes for Teaching Falls in Risk Populations, defended by Luis Toronjo and co-directed by Oscar Del Castillo (2019). It develops the contents and methodologies of two programmes, one aimed at the population of children of school age (Safe Falls-Safe Schools©, CSES©) and the other aimed at older adults. These programmes have the approval and endorse-

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ment of the Portal of Ethics of Biomedical Research of Andalusia (Spain), have been granted several international awards and have research contracts 68/83 with the company Ceroone Technology (2016) and the Andalusian Federation of Judo and Associated Sports (2017).

They are developed by Doctors Del Castillo and Toronjo, from the 'Physical Education, Health and Sport' research group of the University of Seville, who have published thirteen articles on the subject, in high-impact scientific journals, in collaboration with other researchers. Examples of the latest research published in Q1, with high impact rates and scientific relevance are:

- Effects of Fall Training Program on Automatization of Safe Motor Responses During Backwards Falls in School-Age Children. International Journal of Environmental Research and Public Health (Switzerland), doi:10.3390/ijerph16214078, with a JCR impact index of 2.468. November 2019.
- Decreasing the Fear of Falling in Older Adults. The use of Adapted Utilitarian Judo. Chapter in the book Sport Coaching Whith Diverse Population: Theory And Practice. Edited by Routledge (London, UK), to be printed in February 2020.

The results have been presented at 18 international congresses including the EU Safety Congress 2019 (Belgium, Luxembourg), the World Conference on Injury Prevention and Safety Promotion 2018 (Bangkok, Thailand), the 16th Hungarian Sports Science Congress (MSTT, Nyíregyháza, Hungary), International Society for Behavioral Nutrition and Physical Activity (ISBNPA, Prague, Czech Republic), III National Congress and IV International Congress on Quality of Life and Healthy Lifestyles (Chillán, Chile), VII Conference on Ethnography and Qualitative Research (Bergamo, Italy), and the VI International Congress on Education Sciences and Development (Setúbal, Portugal). In addition, the promising results have given the researchers the opportunity to have a meeting at the WHO Office for Europe in Copenhagen (2018), with the director of the injury prevention programmes.

The involvement of the EJU has enabled the international expansion of the research, by organising the 1st International Conference on Training and Research CSES© in Cadiz (Spain, 2018), with the collaboration of the Andalusian Judo Federation and DA. The Seminar was attended by technicians and researchers from 10 European countries: Germany, Denmark, Hungary, Italy, Czech Republic, Russia, Serbia, Sweden, Switzerland and Spain.

For the implementation and research of the CSES© programme, scientific criteria are followed based on an experimental methodology, with a protocol based on the collection, analysis and interpretation of evidence, with intervention and control groups. The international coordination is carried out by the research group of the University of Seville (Spain), with the participation of the University of Studies of Milan (Italy), the University of Pécs (Hungary), and the Southern University of Denmark (Denmark). The research has been carried out on a population of 22,800 schoolchildren, with a research sample of more than 3,000 children. In all cases, collaboration agreements have been signed between the EJU, the Universities and the national judo federations and in all countries the approval of the corresponding national ethics committees have been obtained.

Currently, the data obtained in the implementations carried out by the research teams of Italy (Invernizzi), Hungary (Morvay), Denmark (Henning) and Spain (DelCastillo and Toronjo), are being correlated to present the results and conclusions of the international research.

In safe falls programmes, the teaching methodology and content have been adapted specifically to each of the target populations. The characteristics of each age group have been taken into account in order to offer a useful response, through the creation and implementation of proposals aimed at the prevention and improvement of health and safety in children and older adults.

The programme aimed at children is implemented in schools within physical education classes, with the ultimate goal of helping to reduce the consequences of accidental falls, in which mortality may be the most important result, but not the only one, since there are a high number of cases in which injuries, psychological problems and sequelae with varied significance and types of disability occur.

For the older adult population, judo for health is valued as a tool to promote an active aging of the older population, through a programme designed within the framework of innovation, longevity and quality of life, which uses the adaptation of the technical elements present in traditional judo, adapting them to the needs and characteristics of older adults. Another aim of this programme is to contribute to the reduction of risk factors associated with falls.

The results are significant and very encouraging in both cases, having proven that the implementation of the CSES© program in children significantly reduces the risk of injury in all children, regardless of variables such as BMI, gender, academic year and level of sports practice. In the implementation of the programme of safe falls in older adults, there have been improvements in fundamental variables of the prevention of falls, the most relevant ones being: the re-

duction of the Fear of Falling (FOF), the improvement of all the items analysed by the Falls Efficacy Scale-International (FES-I), both in its social and domestic dimensions.

Conclusion

These programmes contribute to improve the image of judo, positioning it within the space of social responsibility, as a sport activity that contributes to the protection and prevention of the physical integrity of children and to the active aging and improvement of the quality of life and health of the older adult population. Judo, through the use of an adapted and utilitarian methodology of *ukemi*, can be a holistic activity, aimed at preventing falls and reducing the risk of injury, adding a unique and innovative element in the strategy of treating falls in at-risk populations. Therefore, it is an ambitious project that requires thoughtfulness and social commitment from all the parties involved in the practice and diffusion of judo, as its primary objective is to increase protection for vulnerable groups in society, contributing to the maintainance and improvement of their safety, health and quality of life.

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Kinematic Comparison of the *Seoi-Nage* Technique Between Top-Elite and Sub-Elite Judo Athletes

By Takanori Ishii[1], Michiyoshi Ae[2], Sentaro Koshida[3], Yuta Suzuki[4], Yasuto Kobayashi[5], Norihisa Fujii[6]

Abstract: *This study sought to identify biomechanical factors that determine highly skilled seoi-nage technique by comparing kinematics between top-elite and sub-elite judo athletes. Three-dimensional motion data were captured using a Vicon-MX system with 18 cameras operating at 250 Hz as 3 male top-elite and 16 male sub-elite judo athletes performed seoi-nage. No significant difference was found in motion phase time of the kuzushi/tsukuri phase between the two groups, indicating that motion phase time is not necessarily a factor distinguishing between the seoi-nage performed by top-elite judo athletes and that performed by sub-elite athletes. The peak relative velocity of the whole-body centre of mass along the anterior-posterior direction appeared to be greater in the top-elite athletes (median: 2.62 ± 0.25 m/s) than in the sub-elite athletes (median: 1.62 ± 0.28 m/s) during the kuzushi/tsukuri phase (p = 0.05). The overall angular velocity of the body part lines was similar in both groups; however, the timing at which the peak values appear may distinguish between the top-elite and sub-elite judo athletes. The results imply that the velocity of the thrower relative to the uke in the forward drive and turning motion reflects a high-skill seoi-nage. Coaches should recognise relative forward velocity as a factor that may contribute to a successful seoi-nage when teaching this judo throwing technique.*

Key words: *three-dimensional motion analysis, martial arts, judo throwing technique, nage-waza*

Seoi-nage in judo is categorized in group one of the *gokyo no waza* (five groups in judo teaching paradigm) and has been the most frequently used techniques in judo practices and matches. According to statistics from major international judo events, judo athletes were most likely to acquire points with the *seoi-nage* technique. For example, in the 2016 Olympics Games in Rio de Janeiro, Brazil, *seoi-nage* and *uchi-mata* techniques acquired the most frequent scores, each of which consisted of 7.5% of all the scores in men's match. In the 2018 World Judo Championships in Baku, Republic of Azerbaijan, *seoi-nage* scored the most among all the throwing techniques, consisting of 8.8% of all the scores (Judo Scientific Research Team of the All Japan Judo Federation, unpublished data, 2018). These must explain why resourse guides for coaches and athletes have illustrated the structure of the *seoi-nage* technique (Nomura, 1999; Sato, 2005). Although the information gives us great insights for coaching, the descriptions are usually experiential and, therefore, diverse, potentially causing confusion for coaches as well as athletes. Technical factors of skilled *seoi-nage* need to be identified by using the knowledge of biomechanics to develop an effective teaching paradigm of *seoi-nage*.

Most judo experts, including former gold medalists in the Olympic games, have pointed out that elite judo athletes who are skilled at *seoi-nage* are able to execute the throw much more quickly than their opponent can issue a response. Therefore, the quickness of *nage-waza* is believed to be one of the most important factors to determine the skill level of *seoi-nage* (Nomura, 1999; Jeon, 2001; Hosokawa, 2005; Suzuki, 2005; Yoshitaka, 2005). In the recent study of Ishii et al. (2018), however, the motion time during the *kuzushi/tsukuri* phase was not significantly different between the elite and college judo athletes, suggesting that simple objective measures that encompass the entire motion are not able to represent the quickness of *seoi-nage* appropriately. In the case of judo, making the defense of an opponent delay by providing little or false signs (i.e., fake) of execution plays an essential role in the high performance of judo throw (nage-waza). According to the principle of judo, athletes need to prepare for *nage-waza* execution by breaking the balance of an opponent during *kuzushi* phase. Simultaneously, the judo athlete utilizes the opponent's movement as well as their strength to move the opponent and him/herself into a favorable position for *nage-waza* in the tsukuri phase (Matsumoto, 1975). These indicate that the quickness of *nage-waza* partially depends on the biomechanical characteristics of each judo specific movement that the athlete engages in the *kuzushi* and tsukuri. Therefore, the biomechanical analysis of the judo-specific movements in the phases is crucial to establish effective teaching programs for high-level judo throws.

The study of Ishii et al. (2018) compared *seoi-nage* biomechanics between college and elite judo athletes; however, the difference may result from a combination of physical and technical factors. Comparing the *seoi-nage* biomechanics between top-elite and sub-elite judo athletes (e.g., medalists between international and national

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competitions) may give us a better chance to elucidate the crucial technical factors that determine the skill of *seoi-nage*. Therefore, the purpose of this study was to investigate factors associated with skilled *seoi-nage* by comparing the biomechanics of the technique between the top-elite and sub-elite judo athletes. Based on the previous study of Ishii et al. (2018), we hypothesized that there would be little difference in the motion time of the *kuzushi/tsukuri* of *seoi-nage* between top-elite judo athletes and sub-elite judo athletes. Moreover, the second hypothesis was that the linear velocities of the whole body in only anterior direction would be higher in the top-elite athletes. Finally, we hypothesized that the angular velocity of the thrower's turning motion would increase sequentially from the lower to the upper body in top-elite judo athletes, but not in sub-elite judo athletes.

Data collection

The biomechanical data for the top-elite judo athletes, as well as some of the sub-elite athletes, were previously published by Ishii et al. (2018). Three-dimensional coordinate data were collected for 94 reflective markers of 14mm diameter on the participants' body (47 markers per athlete) while they performed *seoi-nage* in pre-arranged sparring drills. Data were captured with 18 cameras of a VICON-MX system (VICON Motion Systems, Ltd., Oxford, UK) operating at 250 Hz for the *tori* (the person throwing) and the *uke* (the person being thrown). The participants wore a special judo gear designed to improve the visibility of the placed markers (Figure 2), and the judo gear was individually adjusted so that they had a similar feeling to an actual judo gear (judo-gi). The participants performed *seoi-nage* the *seoi-nage* throw on experienced and weight-matched (±3kg) *uke* as similar as possible to that in their usual sparring drills. For safety reasons, we recruited the *uke* who had more than a seven year-experience with a black belt rank.

Table 1. Participant characteristics

Participants	Body mass [kg]	Height [m]	Age [y]	Athletic career
Top-elite athlete A	70.3	1.60	26	Silver, 2009 and 2011 WJC Bronze, 2010 WJC Silver, 2012 OG
Top-elite athlete B	76.8	1.69	25	Gold, 2010 WJC Gold, 2010 AG
Top-elite athlete C	77.8	1.69	22	Bronze, 2010 WJC
Junior-elite athletes (n=5)	68.0 ± 6.0	1.64 ± 0.04	19.8 ± 2.5	12.4 ± 4.0 years, medallists in the Japan judo junior championships
College athletes (n=11)	69.5 ± 6.9	1.66 ± 0.05	19.6 ± 1.3	10.2 ± 3.3 years, competing at Japanese college level

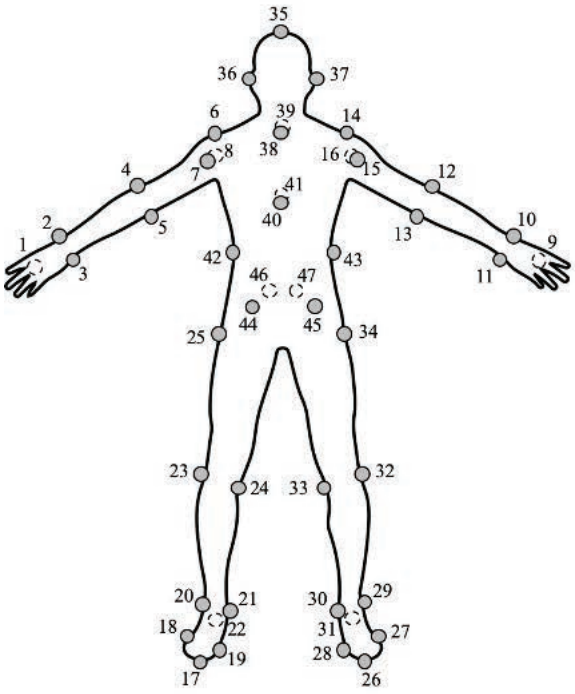
WJC; World Judo Championships; OG, Olympic Games; AG, Asian Games

Methods

Participants

The participants were three male top-elite judo athletes who were medallists in the World Judo Championships, five male junior-elite judo athletes who were medallists in the Japan Judo Junior Championships, and 11 male college judo athletes, as shown in Table 1. All of the college athletes were active collegiate judo athletes at the time of data collection and were considered to have advanced levels of judo skill. The average numbers of practice/training were 6.2 [4-10] sessions per week in the college judo athletes. We assigned the 3 top-elite judo athletes into the top-elite group and the remaining 16 judo athletes (comprising both the junior-elite and collegiate judo athletes) into the sub-elite group. This study was approved by the Research Ethics Committee of the Faculty of Health Sciences, Ryotokuji University. Documents explaining the purpose of this study and methods for data collection were handed out, details of the data collection procedure were explained to the participants and written informed consent was obtained from participants who agreed to participate in the data collection.

The participants rated their own performance on a scale of 1 to 5 (1 = poor, 2 = below average, 3 = average, 4 = good, 5 = excellent). They were asked to repeat *seoi-nage* until 5 trials rated 4 or 5 had been captured successfully. After all, averaged numbers [max-min] of the attempts were 11 [8-15] times. In addition, five experienced coaches rated the participants' selected performance using the same evaluation scale. All the five raters had master's degrees, belonged to college or semi-professional judo teams as coaches, and have produced national champions. The *seoi-nage* throw rated highest by the coaches for each subject was chosen as the best trial from the five trial selected by the paritipant for motion analysis. The inter-rater agreement was Kendall's W = 0.73 – 0.92 ($P < 0.01$), which is considered to be in good agreement.



1: Right hand
2: Lateral aspect of right wrist
3: Medial aspect of right wrist
4: Lateral aspect of right elbow
5: Medial aspect of right elbow
6: Right acromion
7: Anterior aspect of right shoulder
8: Posterior aspect of right shoulder

9: Left hand
10: Lateral aspect of left wrist
11: Medial aspect of left wrist
12: Lateral aspect of left elbow
13: Medial aspect of left elbow
14: Left acromion
15: Anterior aspect of left shoulder
16: Posterior aspect of left shoulder

17: Right toe
18: 5th metatarsal bone of right foot
19: 1st metatarsal bone of right foot
20: Right heel
21: Right malleolus lateralis
22: Right malleolus medialis
23: Lateral aspect of right knee
24: Medial aspect of right knee
25: Right greater trochanter

26: Left toe
27: 5th metatarsal bone of left foot
28: 1st metatarsal bone of left foot
29: Left heel
30: Left malleolus lateralis
31: Left malleolus medialis
32: Lateral aspect of left knee
33: Medial aspect of left knee
34: Left greater trochanter

35: Vertex
36: Right tragus
37: Left tragus
38: Suprasternal notch
39: 7th cervical vertebrae
40: Xiphoid process
41:10th thoracic vertebrae

42: Lower end of right rib
43: Lower end of left rib
44: Right anterior superior iliac spine
45: Left anterior superior iliac spine
46: Right posterior superior iliac spine
47: Left posterior superior iliac spine

Figure1: Locations of 47 reflective markers

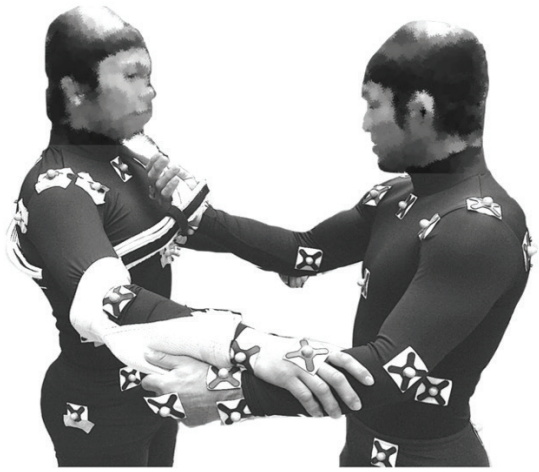


Figure 2: Participants wearing specially designed judo gear for motion data capture

The anterior-posterior (A-P) axis is defined as the directional line from the *tori* to the *uke* in the starting position, the vertical axis as the vertical direction and the medial-lateral (M-L) axis as the direction perpendicular to both the A-P and vertical axes. The range covered by motion capture cameras was 2.5 m in the M-L axis, 4 m in the A-P axis and 3 m in the vertical axis (Figure 3).

Data processing

Three-dimensional coordinate data of the *tori* and *uke* were smoothed by a Butterworth digital filter at a cut-off frequency ranging from 4.8 to 9.3 Hz, as determined by the residual method (Winter, 2009). Figure 4 shows the phases of *seoi-nage* used in the present study, which were defined by Ishii et al. (2018). The *kuzushi/tsukuri* phase started when the pivot foot (right foot for a right-handed athlete) lifted off, and it ended when both feet were in contact with the mat. The *kake* phase was defined from the end of the *kuzushi/tsukuri* phase to the instant that a part of the *uke* body was in contact with the mat. Event 1 (E1 in Figure 4) represents the instant that the *tori*'s pivot foot was lifted off for the first forward step, which was identified as the instant that the toe maker reached 0.02 m higher than the standing position, and Event 2 (E2) represents the instant that the pivot foot came in contact with the mat, as confirmed by the ground reaction force data.

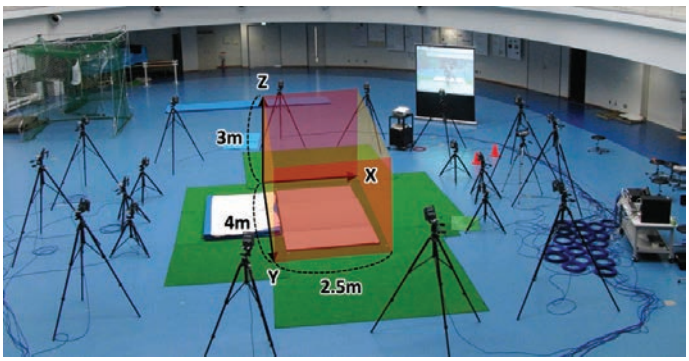


Figure 3: The experimental setup

Event 3 (E3) denotes the instant that both of the *tori*'s feet are in contact with the mat, and Event 4 (E4) denotes the instant that the *uke*'s body part was in contact with the mat

in the *ukemi* breakfall motion. The moment of E4 was also identified by ground reaction force data with a threshold of 10 N. Analysis was done between E1 and E4 (completion of throwing technique). Data were normalized by the time of each motion phase. In this study, the focus was on the *kuzushi/tsukuri* phase. The coordinate data for eight left-handed athletes were treated as right-handed ones by mirroring their coordinate data.

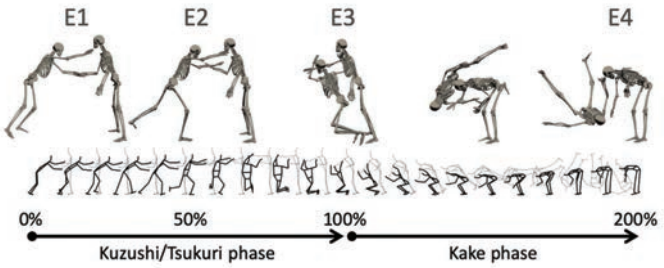


Figure 4: The events (E) and phases of *seoi-nage* (Ishii et al, 2018)

Calculated parameters

1. Motion phase time

The motion phase time (s) between the events were obtained as an index of the quickness of *seoi-nage*.

2. Velocity of the centre of mass (COM) of the *tori* and *uke*

The COM of the *tori* and *uke* were estimated using the body segment parameters for Japanese athletes (Ae, 1996). Three-dimensional COM velocity was calculated by differentiating displacement of the COM with respect to time. Relative COM velocity (RV) of the *tori* to the *uke* was defined as the difference in the COM velocities between the *tori* and the *uke* (V_{tori} - V_{uke}).

3. Overall angular velocity of the body part lines (Figure 5)

A shown in Figure 5, the line connecting the COMs of the right and left arms was defined as an arm line, the line connecting the right and left shoulders as a shoulder line, the line connecting the right and left hips as the hip line and the line connecting the COMs of the right and left legs as a leg line. The mid-points of the markers affixed to the anterior and posterior aspects of the shoulder were used as the shoulder joint centre. The hip joint centre was estimated using the method recommended by the Japan Clinical Gait Analysis Forum (1992) as the most suitable for Japanese individuals. The angular velocity vector of the body part lines ω was calculated by the following equation (Ae & Fujii, 2003).

$$\boldsymbol{\omega} = \frac{\mathbf{r} \times (\mathbf{V_2} - \mathbf{V_1})}{|\mathbf{r}|^2},$$

where **V1** and **V2** represent velocity vectors of the right and left sides of the body part line, and r is a vector from the right side to left side of the body part line. The resultant angular velocity (AV) of the body part line was calculated as an index of the overall angular velocity of the body part.

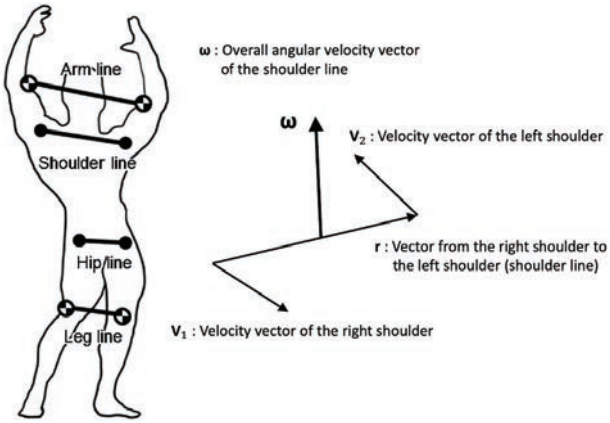


Figure 5: Body part lines used in this study and an example calculation for overall angular velocity of the shoulder line (Ishii et al, 2018)

Statistical analyses

The one-sample Kolmogorov-Smirnov test rejected the normality of the variance of the kinematic parameters in the present study. Therefore, the Mann-Whitney U test from non-parametric statistics was conducted to test differences between the two groups in the motion phase time, the absolute COM velocity, the relative COM velocity, and the overall angular velocity of the body part lines. Effect sizes were calculated using r proposed by Cohen (1988). Based on that study, the effect sizes were assessed as trivial (<0.1), small (0.1–0.3), medium (0.3–0.5), and large (0.5-). MATLAB and its statistics toolbox (The MathWorks Inc., R2019b, Version 8.6, Natick, MA, USA) were used for calculation, and the level of significance was set at less than 5%.

Results

There were no significant differences between the top-elite and sub-elite athletes in the motion phase times of the early phase (E1-E2), late phase (E2-E3) and whole *kuzushi/tsukuri* phase (E1-E3) in *seoi-nage*, as shown in Figure 6.

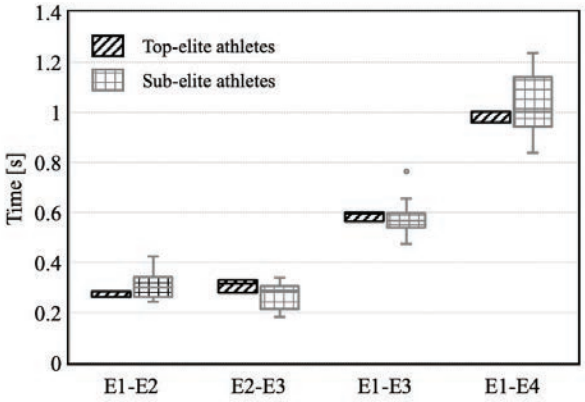


Figure 6: Motion phase times for the *tori* in *seoi-nage*

Table 2. Maximum absolute and relative velocity of the whole-body centre of mass and maximum overall angular velocity of the body part lines

	Top-elite athletes (n=3)		Sub-elite athletes (n=16)		Significance	ES
	Peak	% mark	Peak	% mark		
Absolute velocity of whole-body centre of mass (m/s)						
V_{M-L}	0.31 ± 0.04	107 ± 30	0.41 ± 0.09	108 ± 23	N.S. (P = 0.050)	M (0.45)
V_{A-P}	1.36 ± 0.05	102 ± 7	0.98 ± 0.20	94 ± 24	N.S. (P = 0.131)	M (0.35)
$V_{Vertical}$	-1.51 ± 0.09	101 ± 2	-1.15 ± 0.19	101 ± 3	N.S. (P = 0.083)	M (0.40)
Relative velocity of whole-body centre of mass (m/s)						
RV_{M-L}	0.54 ± 0.05	110 ± 5	0.58 ± 0.07	110 ± 8	N.S. (P = 0.199)	S (0.29)
RV_{A-P}	2.62 ± 0.25	119 ± 6	1.62 ± 0.28	105 ± 9	N.S. (P = 0.050)	M (0.45)
$RV_{Vertical}$	-1.42 ± 0.15	101 ± 2	-1.13 ± 0.19	100 ± 2	N.S. (P = 0.288)	S (0.24)
Overall angular velocity (rad/s)						
AV_{Arm}	9.62 ± 1.08	98 ± 5	9.63 ± 1.35	90 ± 9	N.S. (P = 0.696)	T (0.09)
AV_{Sh}	9.46 ± 0.82	91 ± 4	9.27 ± 1.57	90 ± 7	N.S. (P = 0.696)	T (0.09)
AV_{Hip}	11.76 ± 0.70	87 ± 2	10.59 ± 1.00	78 ± 7	N.S. (P = 0.467)	S (0.17)
AV_{Leg}	10.27 ± 0.57	77 ± 2	10.60 ± 1.33	79 ± 4	N.S. (P = 1.000)	T (0.00)

Notes: Median ± quartile deviation.

*, significant; N.S., not significant; TE, top-elite athletes; SE, sub-elite athletes.

Times of appearance of the maximum values are shown in % of normalised time.

ES, effect size: T, trivial (<0.1); S, small (0.1–0.3); M, medium (0.3–0.5); L, large (0.5-).

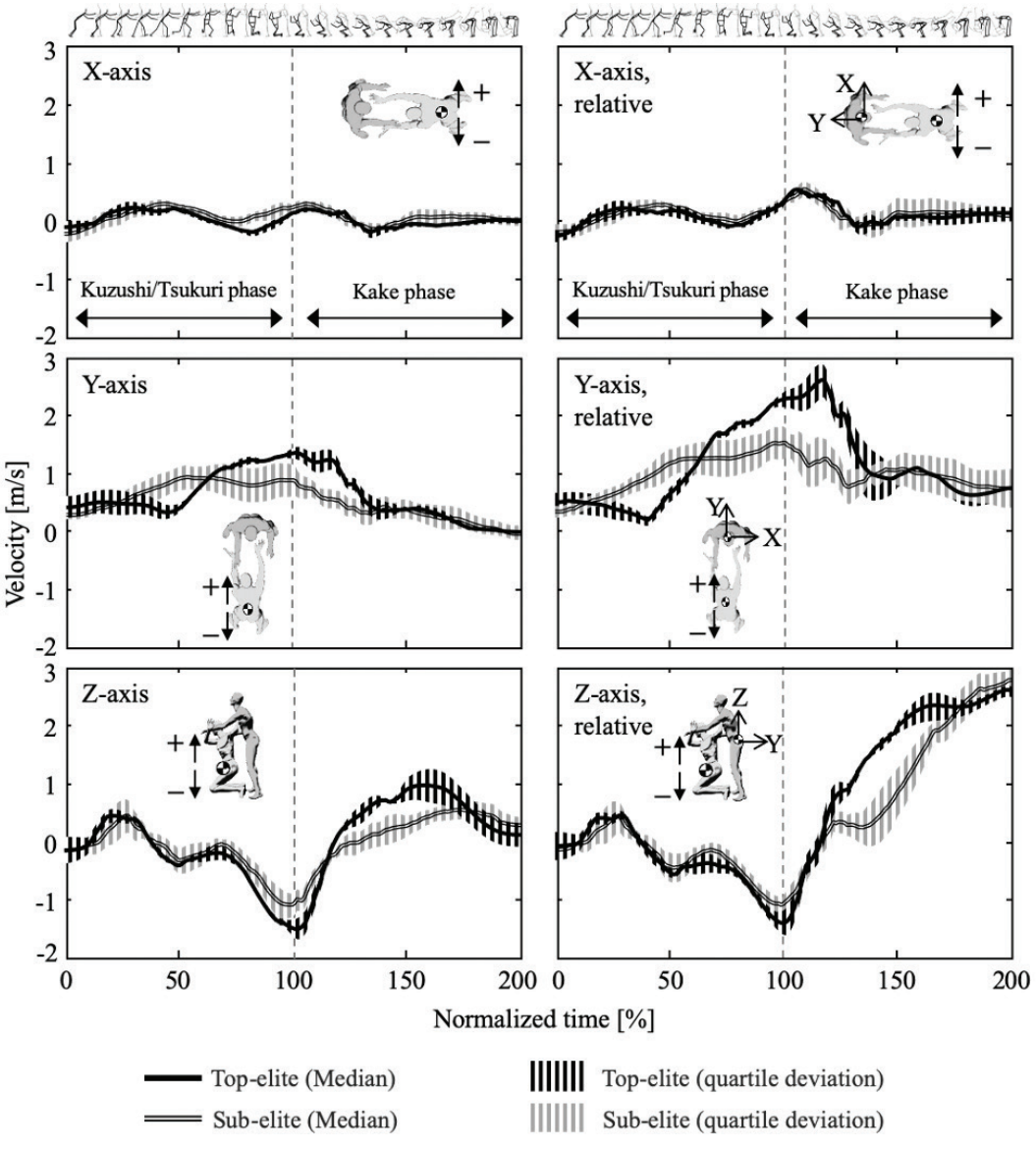


Figure 7: Changes in velocity of the whole-body centre of mass for the *tori* in *seoi-nage*

Table 2 shows the maximum absolute and relative velocity of the whole body COM and maximum overall angular velocity of the body part lines of the *tori* for both athlete groups, with normalised times of their appearance. Although there was no significant difference in the absolute, relative and angular velocity between the two groups, RV_{A-P} tended to be greater in the top-elite athletes than in the sub-elite athletes, and V_{M-L} tended to be greater in the sub-elite athletes than in the top-elite athletes.

Figure 7 shows changes in velocity of the whole body COM of the *tori* in *seoi-nage* for both groups. The left column gives absolute velocity and the right column gives relative velocity of the whole body COM. The *tori*'s V_{M-L} and RV_{M-L} of the whole body COM was small throughout the whole phase in both groups. V_{A-P} gradually increased in the sub-elite athletes from the beginning of the *kuzushi/tsukuri* phase to the 50% mark in the *kuzushi/tsukuri* phase and then gradually decreased during the *kake* phase. V_{A-P} in the top-elite athletes showed no remarkable increase until the 50% mark in the *kuzushi/tsukuri* phase but quickly increased thereafter in the *kuzushi/tsukuri* phase. RV_{A-P} was larger in the sub-elite athletes than in the top-elite athletes until the 50% mark in the *kuzushi/tsukuri* phase. However, RV_{A-P} in the top-elite athletes increased remarkably and was larger than that in the sub-elite athletes from the second half of the *kuzushi/tsukuri* phase to the 120% mark in the *kake* phase. The difference in relative velocity was larger than the difference in absolute velocity between the two groups.

The $V_{Vertical}$ decreased in the top-elite athletes from the 70% to 100% mark and rapidly increased from the 100% to 130% mark. Furthermore, the downward velocity of the absolute and relative velocity in the top-elite athletes was larger during the second half of the *kuzushi/tsukuri* phase than that in the sub-elite athletes.

The median AV_{Leg} in the sub-elite athletes increased from the 50% mark to reach a maximum value; that in the top-elite athletes also rapidly increased from the 50% mark but the peak appeared earlier than that in the sub-elite athletes. Changes in AV_{Leg} followed a similar pattern between the top-elite and sub-elite judo athletes. The AV_{Hip} rose earlier and the peak value was larger in the top-elite athletes than in the sub-elite athletes. The median AV_{Hip} in the top-elite group was lower than that in the sub-elite at the 50% mark; however, the top-elite group's AVHip increased abruptly after the 50% mark and its peak was higher than that of the sub-elite group. AV_{Sh} in the top-elite athletes quickly increased from the 40% to 100% mark, whereas that in the sub-elite athletes started to increase towards the maximum value between the 10% and 80% mark. The increased AV_{Sh} in the top-elite group occurred 10% later compared to the sub-elite athletes. Finally, AV gradually decreased in the *kake* phase in both groups.

In both groups, the AV_{Arm} showed similar changes to AV_{Sh}. However, AV_{Arm} in the top-elite group clearly differed compared to that of the sub-elite group at approximately the 60% to 70% time marks, and the timing of the peak values differed within a 20% time period between the two groups. Both groups maintained high AV_{Arm} line in the *kake* phase.

In the top-elite athletes, the maximum AV_{Hip} and AV_{Arm} appeared in sequential order moving from the lower to upper parts of the body.

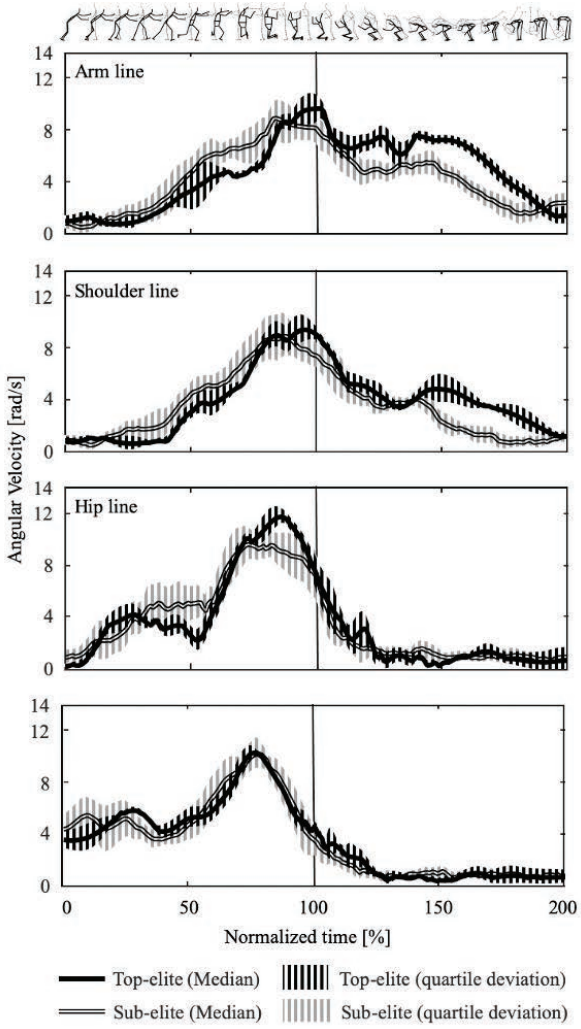


Figure 8: Overall angular velocity of the body part lines

Discussion and Implications

Performing judo-specific actions in a quick-coordinated manner plays an essential role in high-level judo throwing performance. Ishii et al. (2018) attempted to identify biomechanical factors that determine the quick and skillful execution of *seoi-nage* by comparing the kinematics of elite and college judo athletes. The previous result suggests that the relative forward drive velocity and angular velocity of the turning motion reflect the skill level of *seoi-nage*. In the present study, we compared the kinematics of *seoi-nage* performed by top-elitee and sub-elite judo athletes to obtain findings that may help coaches design better training programs for the judo throwing technique. The absolute velocity in the left and right direction of the top-elite COM tended to be smaller than that of the sub-elite judo athletes. Also, the relative velocity of COM in the A-P direction tended to be higher in the top-elite judo athletes. We also found differences in the pattern of the relative velocity of COM and the body part

lines' angular velocities in the *seoi-nage* motion between the two groups. However, there were no significant differences in the motion time, maximum absolute and relative velocity of the whole-body COM or angular velocity between the two groups.

Unlike some previous studies (Jeon, 2001; Suzuki, 2005; Yoshitaka, 2005), this study found no significant differences in the motion phase times in *seoi-nage* between top-elite and sub-elite judo athletes, which supports our first hypothesis. In addition, there were differences between the two groups in the absolute velocity of the whole-body COM in the M-L direction, indicating that the top-elite athlets showed less unnecessary movements in the direction.

Our finding of a statistically significant in the maximum RV_{A-P} between groups indicates that relative velocity in the A-P direction does reflect the skill level of *seoi-nage* (Figure 7). The RV_{A-P} rapidly increased in the top-elite athletes from when the *tori*'s pivot foot was in contact with the mat (ca. 50% mark) to when both the *tori*'s feet were in contact (100% mark), whereas that in the sub-elite athletes was smaller and increased earlier. Thus, the top-elite athletes drove themselves toward the *uke* more quickly during the *kuzushi/tsukuri* phase, suggesting that this quicker forward movement in the latter half of the *kuzushi/tsukuri* phase may enable top-elite athletes to complete *seoi-nage* before the opponent responds defensively. These biomechanical features may differentiate the skill of *seoi-nage* between top-elite and sub-elite judo athletes.

The overall angular velocity of the body part lines, particularly AV_{Arm}, demonstrated different timing in the appearance of peaks between the top-elite athletes and the sub-elite athletes (Figure 8), suggesting that there may be practical differences in the angular velocities between the two groups. It is also noteworthy that the maximum overall angular velocity of the body part lines in the top-elite athletes began from the lower body, moving through to the upper body in sequential order. In contrast, there was no clear sequential order in the sub-elite athletes. This sequence of body rotation seen in the top-elite athletes, particularly the time lag in the rotation between the lower and upper body, may delay the opponent's defensive reaction because clear and sufficient sensory and visual signals would not be clearly broadcast, increasing the chance of successfully throwing the opponent.

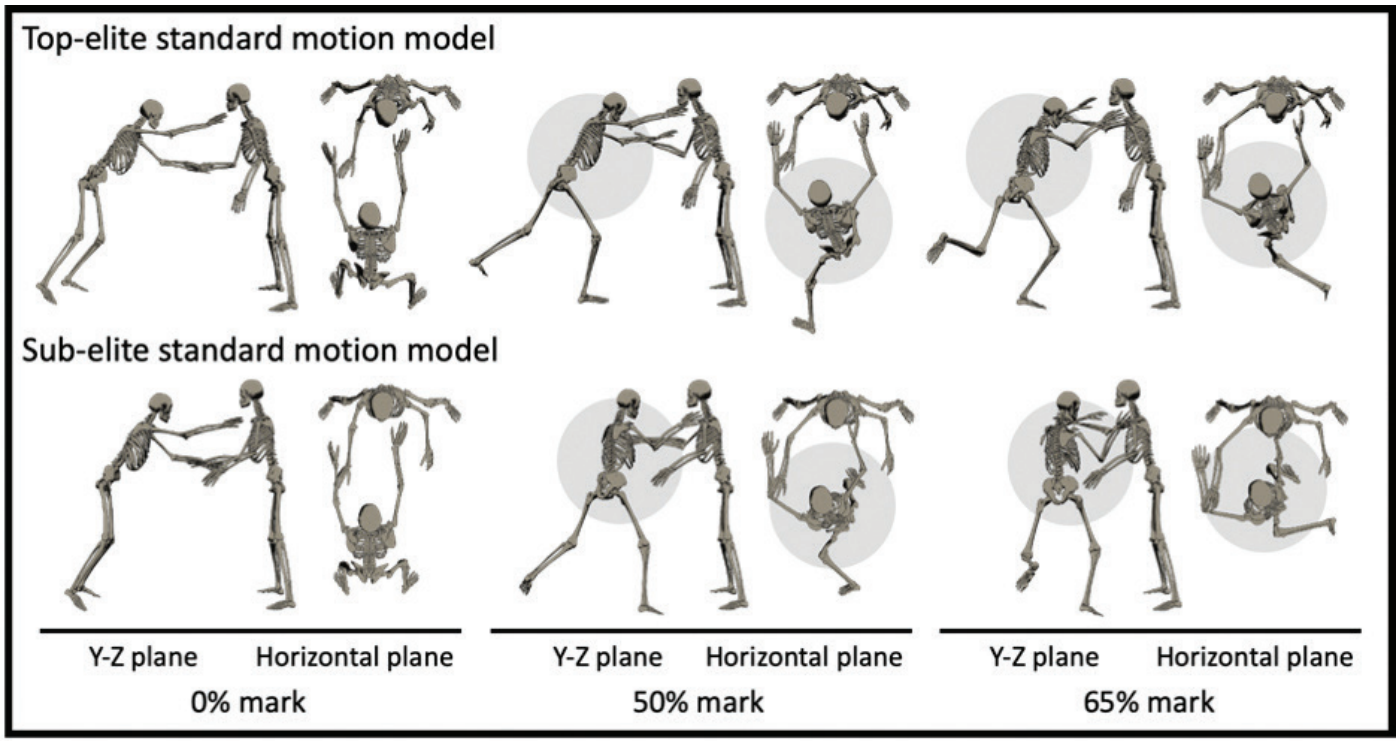


Figure 9: Differences in upper body position between the standard motion models of the top-elite and sub-elite athletes

Although statistical differences were not found, our findings regarding the maximum vertical component of the COM velocities during the *kuzushi/tsukuri* phase suggest that this component may be an important factor for the quickness of *seoi-nage*. The large downward velocity of the whole body leads to an increase in its downward displacement during the *kuzushi/tsukuri* phase, which may allow the judo athlete to raise and rotate the opponent effectively during the *kake* phase.

Figure 9 shows the standard motion model of the top-elite and sub-elite judo athletes when the 0%, 50%, and 65% marks of the *kuzushi/tsukuri* phase are reached. The present result demonstrated that there was little difference in the trunk position between the two groups at 0% mark. At 50% mark, although the top-elite athletes still maintained the position, the sub-elite athletes already started turning their trunk with a more upright position. The sub-elite athletes more rotated their trunk at 65%mark, while the top-elite rotated only their lower limb and maintained the forward leaning position, delaying the start of trunk rotation. The results

suggest that maintaining the forward leaning posture and delaying the start of trunk rotation has the tactical benefit that delays transmitting force or the sense of pulling to the opponent, thus making the sensory and visual inputs indistinct for the opponent to start a defensive response. In judo practice, throwing drills that focus on only the pre-throw actions have frequently been used to improve quickness in throwing techniques. Some coaches have claimed the importance of shortening of the turning motion in practice drills. However, the present results suggest that coaches might need to more emphasize to the forward drive of the body in the latter half of the *kuzushi/tsukuri* phase and the kinematic sequence of body rotation, rather than the motion time.

The standard motion models were proposed initially by Ae et al. (2007) and Murata et al. (2008), represent the averaged biomechanical models of each participant's group. There are a few limitations to the present study. We defined the motion time and events (E1 to E4), based on contact of the feet and of the body, as well as the change in ground reaction force, not on whole-body COM velocity or angular velocity. This may be one reason why the short *kuzushi/tsukuri* phase was not the result of high quickness (COM and angular velocities). Soft tissue artifacts may have reduced the accuracy of motion analysis, although the influence of soft tissue artifacts was minimized by using specially designed tight judo gear and data reduction processes (e.g., filtering). The *uke* wore a special judo outfit designed to improve the visibility of the attached markers and was thrown in a controlled situation. Therefore, the motion characteristics might have differed from that in a real grappling situation. Moreover, we used a single representative data of each participant for analysis, which may introduce the possibility of sampling bias. However, participants were asked to evaluate the quality of their trials subjectively and to select trials that they rated as a good performance. In addition, five experienced judo coaches evaluated the trials and a single trial that both the participant and the coaches rated as the best trial was chosen for further analysis. These steps would minimize bias in trial selection and ensure that the single data point well reflected the characteristics of the *seoi-nage* skill of each participant. The present study also includes a small sample size. The statistical analysis may have overlooked actual differences in the measurement variables between the top-elite judo athletes and sub-elite judo athletes due to the low statistical power. The study aimed to elucidate the *seoi-nage* biomechanical parameters that characterize the *seoi-nage* skill of top-elite judo athletes, following the research of Ishii et al. (2018), and the obtained findings further advance our knowledge of *seoi-nage* biomechanics. For further studies, more varieties of judo athletes and a larger number of participants should be analyzed, as well as the kinetics of the lower limbs, to increase our knowledge on the biomechanics of *seoi-nage*.

Conclusions

To investigate factors contributing to skilled execution of the *seoi-nage* judo throw, kinematic parameters were compared between top-elite and sub-elite judo athletes. The top-elite athletes had a greater peak A-P component of the relative centre of mass velocity, and the timing of the peak angular velocity differed between the top-elite and the sub-elite athletes. The forward relative centre of mass velocity during the turning motion might be a biomechanical factor contributing to the skill level of *seoi-nage*. Coaches should pay more attention to the velocity of the body of the *tori* relative to the *uke* for the proper evaluation of *seoi-nage* skill. The peak values of the overall angular velocity of the body part lines were similar between the top-elite and sub-elite athletes. However, the peak values in the peak angular velocity, particularly in the arm line in the top-elite athletes, appeared during a relatively later phase in the turning motion compared to those in the sub-elite athletes. The knowledge gained from this study may inform coaches' instruction of judo techniques. Future studies should examine a wider category of judo athletes and a larger number of participants.

Acknowledgement

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The authors declare that there are no conflicts of interest in the authorship or publication of this contribution.

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Judo Combat: Time-Motion Analysis And Biomechanical Approach

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Abstract: *The aim of this work is to connect time-motion analysis of judo combats and biomechanical classification of throwing techniques differenced as lever based and couple-based techniques.*

The connection of time contest analysis and biomechanical approach made this study punctual, nomothetic and useful for training input. The study sample included 104 judo combats and the collection of 6 time-motion indicators, namely: average combat time, locomotion, technique, ne waza, defense in standing, defense in groundwork phases.

The study results showed that the locomotion phase is longer than the other combat phases, while technique phase is the shortest one. Average time durations increased after first round till to final combats. Lever based techniques were used a little bit more than couple-based techniques and this may be taken into account in training process. The semifinal combats, and combats for bronze medal lasted longer than other rounds. Also, the majority of the combats ended before regular time and 19% of the combats finished with golden score.

The results of this work give information about time-motion characters of the judo contests that could be connected to the order of magnitude of the energy demands of the real judo competitions, by one heuristic combating equation, for example. The judo coaches may use these findings to plan their training process and improve strategic skills of judokas.

Key words: *judo, competitive activity, time-motion phase, judo biomechanics*

This work is the start of a middle term development research focalized at improving judo skills and effectiveness in Uzbekistan. The findings of this first analysis will be utilized as input for the improvement of specific training load or methods, the results of which will be evaluated afterwards, both in the course of controlled training sessions and in national and international competitions.

Normally it is important to analyze competitive activity of athletes in various sports. Over the last several decades, competitive activity of athletes played an important role in preparing a system. Different scientific works were researched in many sports on this problem. For example, basketball, rugby, soccer and other sports, the features of the competitive activity were studied (Bangsbo et.al., 1991; Brewer et.al., 1995; Ekblom, 1986; Reilly et.al., 1976). Also, other specialists studied competitive activity of complex-coordination sports such as synchronized swimming and figure skating (Rudovskaya et.al., 2016; Lysova, 2001). In combat sports, and specific for karate, taekwondo and free-style wrestling, this kind of studies were carried out (Beneke et.al., 2004; Marcon et.al., 2010; Cipriano, 1993). For judo on the same topic there is a plethora of very advanced studies, which we will analyze in detail below.

Judo is high-intensity combat sport in which during contests various technical-tactical actions are used by the athletes. It consists of many actions and activities. These are considered non-linear actions and these factors influence the analyzing process (Franchini et.al., 2009; Franchini et.al., 2008). Previous studies show that in judo contests different parameters and phases are identified such as time, motion, structure and technical, tactical actions. According to the current IJF refereeing rules [www.ijf.org] the following classification of techniques can be used:

throwing techniques – *nage-waza* (subdivided into *ashi-waza*-leg techniques, *te-waza*-hand techniques, *koshi-waza*-hip techniques and *sutemi-saza*-sacrifice techniques) and grappling techniques – *katame-waza* (subdivided into *osae-waza*-hold-down techniques, *shime-waza* – strangling techniques and *kansetsu-waza* – joint lock techniques).

Research in this field has a long tradition. For decades, one of the most popular studies is that of analysis of judo competitions. In many scientific studies, judo combat activity was divided according to following phases: total combat time, standing combat time, displacement without contact or approach, gripping, technique, groundwork combat and pause time (Miarka et.al., 2014; Giovani et.al., 2010). In other studies judo combat phases were analyzed as break, preparation, grip, technique, fall, and groundwork phases. The various time characteristics were identified for different

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combat phases. Research results showed that the combat phases are not similar for all weight, age and sex categories (Miarka et.al., 2012; Sterkowicz-Przybycień, K. et.al., 2016). The studied literature showed that there are enough differences between the combat phases time in accordance the specific bases of the athletes (example, age, weight, sex, qualification and others).

The small details of the combat phases can give more crucial information about the athletes and general competition trends. For these reasons, some researchers studied small details of the contests. Particular measuring criteria were proposed such as: activeness index, effectiveness of attack, counterattack effectiveness index, defensive effectiveness index and offensive activeness index. Measuring processes according to these criteria were successfully used in practical work. The contest dynamic indicators of the champions and vice-champions were compared through these evaluating methods (Kalina, 2000; Boguszewski, 2014).

Physiological bases of the judo contests were studied in some research. The authors confirm that this approach can provide the specialists and coaches with more reliable information than others. In the simulated judo combats some physiological indices were used. The previous findings present that during the contests the maximal HR was 176±16 bt/min (Sanchis et.al., 1991). Other studies confirm that athletes' maximal HR was 180±11bt/min for men, and 176±6 bt/min for women immediately after contests (Sbriccoli, et.al., 2007). In contrast, some studies have compared VO_2 expenditure and Blood Lactate concentration during the judo contests (Bonitch-Domínguez et.al., 2010; Gariod et.al., 1995; Sikorski, 1985). The HR indicators are not equal with Blood Lactate concentration and VO_2 intakes of the athletes. It is important to point out that approach is needed that explains all features of the judo combats.

Earlier studies have been done by researchers to connect the energy expenditure and contest activity of judo athletes (Ogawa et.al., 1958). Later, new approaches were developed such as biomechanical principles of judo biomechanics (Sacripanti, 1987). Thanks to biomechanical approaches, the opening of useful new connections can be seen in judo research. Judo biomechanics helped coaches to develop a deeper understanding of the physical principles of judo.

In fact every judo throw can be grouped under two only general principles: 1) application of a Physical Lever, 2) application of a Couple (see Appendix), and this criterion was choose because it can give useful information to coaches on the combat strategy method of the adversary. For example, the biomechanical analysis of the London Olympics technique, (Sterkowicz, et.al., 2013) provided interesting information, not about the most effective technique, which on the other hand is not significant, but about: the combating styles, the forms of projection preferred by the various weight categories both for athletes than world-class athletes and indirect news on the training methods used.

In the case of National Uzbekistan Championship, that we have information about: type, number, and execution time of throw types; potentially with that could be performed a gross evaluation about mean energy consumption per combat due to throwing. If we add the complete description like locomotion time, *ne-waza* time, etc. it is possible to model our results to propose a range between minimum and maximum of the gross mean energy wasted in competition by each athlete. Biomechanical analyses show that during the use of the two different classes of throwing techniques the energy expenditure differs from each other.

These conclusions were based both on theoretical and experimental research, some of them connecting oxygen consumption and thermal emission from athletes' bodies (Sacripanti, et.al., 2015). However, in practical work and judo combat analysis process, the time-structure and biomechanical approaches have not been used at the same time to have information pulled out from judo contests.

There is no previous research using the time-motion and biomechanical approach at the same time for analyzing the judo contests. Furthermore, our previous analysis and observations show that judo athletes are not combat equal in all rounds. It can be hypothesized that time-motion characteristics, type of throws and their ratios, technical-tactical indices, durations of combat phases and other competitive indicators differs from round to round (Sterkowicz et.al., 2000; Calmet, 2002; Calvo et.al., 2014).

This factor plays significant role on planning training process and preparing of the athletes to main competition. Knowing all "times" evaluated during the contest and the championship phases, we can evaluate the "Strategic Optimization" (Sacripanti, 2016) (see Appendix) that is connected both to the time of a whole contest and to a sequence of contests.

When we consider the two classes of Leverage and Torque throwing techniques, it is interesting to note, that the same physical equation corresponds to two semantically different principles (Lever and Couple).

In fact, both the actions of the Lever and that of the Couple simply produce a rotation of the body that undergoes them.

With a difference: shift in space of the center of mass of *Uke*'s body is connected to the Lever, which implies a greater work than that of the Couple, who should produce, for *Uke*'s body, only a rotation around its center of mass, when considering theoretically the opponent as a non-deformable beam.

It is possible to write in formulas:

$F_L = F_c = F \wedge dr = Fdr \sin\theta$ {1} which is the information sought.

It is interesting to note that Uzbekistan judokas show, as main characteristic, during the execution of complex movements high degree of coordination, quality suitable for the Lever group throws, and less timing capability, specific instead of the Couple group. On the basis of this information it is possible to formulate a theoretical behavioral hypothesis for the Uzbek judoka in competition, which must be validated by experimental observations.

Therefore, it is logical to hypothesize that Uzbekistan athletes will prefer techniques of the Lever group, over those of the Couple group, thereby using a slower combat pace.
However, strictly referring to Uzbekistan National Championship, the difference in percentage utilization between Lever and Couple techniques is not so important.

Therefore, the aim of this paper is threefold, the first is: analysis of the time-motion characteristics of judo contest activity; the second - analysis of the throwing techniques by biomechanical approach and to connect them to the strategic approach to a contest; the third is to analyze what are Uzbekistan judoka preferences. It is assumed, when this approach is used in practical work, that it is useful in determining the order of magnitude of the contest load and the time-motion characteristics.

This thesis is applied to analyzing judo contests as the main subject of this study.

Materials and Methods

The research papers whose results were analyzed in this paper were collected via the electronic search engines Scopus, PubMed, Academia.edu, Google Scholar. The search selected papers by use of key words: judo, combat activity, combat-phase, judo biomechanics, analysis.

Athletes volunteered to participate in these championships and results are anonymous in the analysis and interpretation of the data used as these were obtained from other sources and were not generated by experimentation on athletes. The 104 analyzed judo contests were taken from the Uzbekistan National Championships. Overall, there were participated 631 judo athletes. 411 of them male athletes and 220 were female athletes from 14 regions of the Republic of Uzbekistan, but we gave our focus to analysis of athletes of Samarkand region. After regional qualification (February, 2020), the 38 male athletes from Samarkand region participated at the National Championship of Uzbekistan.

Table 1. Anthropometric indicators, sport qualification, Lever-based

Weight category	Weight (M±SD) Kg	Height (M±SD) cm	Age (M±SD) yr	Lever-based throws Mean number	Couple-based throws Mean number	Sport qualification		
						Master of sports	Candidate of master of sports	Other qualifications
-46kg	47.1±0.6	145.5±1.1	16.5±0.5	5	5	-	3	1
-50 kg	50.8±0.8	150.6±1.0	16.6±0.4	4	5	-	3	2
-55 kg	56.7±0.8	158±0.6	16.6±0.4	4	4	-	1	4
-60 kg	61.5±1.0	163±0.7	16.2±0.4	3	5	1	1	2
-66 kg	66.9±0.6	168±0.6	16.6±0.4	3	4	1	2	2
-73 kg	73.6±1.1	175.6±2.1	16.4±0.4	3	4	1	3	1
-81 kg	81.5±1.4	183±1.8	16.7±0.4	3	4	-	1	3
-90 kg	91.6±0.4	188±1.0	17±0.0	2	3	-	-	2
+90 kg	97.0±1.2	193.2±1.5	16.5±0.5	2	3	-	2	2
Total	-	-	-	-	-	3	16	19
%	-	-	-	-	-	8%	42%	50%

The Table 1 shows the information about analyzed athletes' mean anthropometric indices (weight, height and age), sport level, type and number of throws according to biomechanical throws class performed during the competition in each weight categories.

The main focus of the experiments was to calculate time-motion phases of judo contests, connected to biomechanical characteristic of throws.

The analyzed combats were distributed through all the elimination rounds. The average time indicators were identified for each round separately. Furthermore, ratios of bouts ending by golden score, before regular time and at the end of regular time were determined for each round and collected for all contests.

The following combat actions were classified during the match:

1) mean combat time – which is the spent time for real struggle;
2) locomotion phase – the time from the command of "*hajime*"(start) to start the combat and try grasp;

3) technique – the time spent for implementing the technical action (attack);
4) *ne-waza* attack – the time spent for implementing ground attack;
5) defense in standing – the time of defensive actions in standing position of *uke*;
6) defense in groundwork – the time of defensive actions in groundwork situations.

All throws were classified regarding to biomechanical classification as Lever-based or Couple-based throws. In order to clarify this division in two groups as Lever and Couple-based techniques, with well-known Japanese names: *seoi nage, tai otoshi, sode tsurikomi goshi* and *o-goshi* are all lever-based techniques with different stop points and different lengths of lever arm, while: *uchi mata, osoto gari, ko uchi gari* and *okuri ashi barai*, are couple-based techniques, with different application plans of the Couple.

Biomechanical approach, according to Sacripanti classification (Sacripanti, 1987), is used to find other indicators during the analysis of combat activity:

a) total throwing techniques (effective and ineffective) and their ratios by biomechanical classification (Lever-based and Couple-based). This specific approach is more general and not connected to specific technique, but rather to a specific class of throwing:
   - ratios of effective and ineffective Lever-based throwing techniques;
   - ratios of effective and ineffective Couple-based throwing techniques;
b) time-motion indices and rate of occurrence of Lever-based technique, Couple-based technique and *ne-waza* period durations were compared by rounds.

Statistical analysis

All analyzed findings were collected and generalized. The normality of data was assessed by Kolmogorov-Smirnov test. The statistic result (D) of the K-S test, provides a measurement of the divergence of the sample distribution from the normal distribution. The higher the value of D, the less probable it is that data is normally distributed. The p-value quantifies this probability. In the present case the value of the K-S test statistic (D) is 0.29017, the p-value connected is 0.43069.

The data does not differ significantly from the normal distribution. Because the evaluation was deliberately focalized on round, this means only 8 values, to evaluate any differences using one-way analysis of variance (ANOVA) and the student's t-test for differences between pairs, was considered overdone. The mean and standard deviation (Mean± SD) and Minimal and Maximal indicators were also set. P values was set at 0.05.

Results

Analyzed combats by rounds

From the results, most of the analyzed contests take place in the first and second rounds. Obviously, the number of combats analyzed decreases with each successive round. In Figure I there are the percentages of analyzed combats by rounds. The large numbers of combats were analyzed in first and second rounds, 27% and 29%, respectively. Also, the third round and quarter final contests were studied more than semifinal, repechage and bronze medal contests. The final meetings contained only 3% of all analyzed contests. It is interesting to note that the first two rounds have significant differences from other rounds. They collect more than the half number of combats 56 % than the six following rounds 44%.

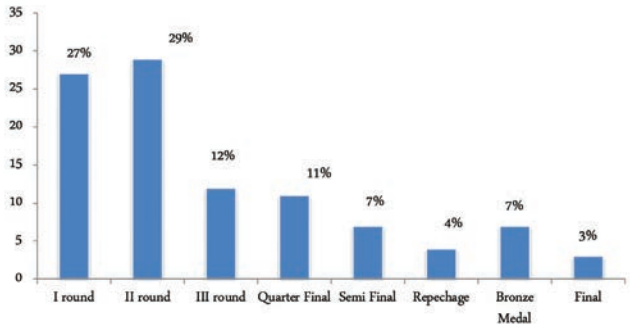

Figure I. Analyzed combats by rounds (%). n=104

Time limits and mean durations of combats of judo athletes by rounds

Time characteristics of combat activity of judo athletes and their ratios by rounds are presented in Table 3. There were remarkable differences found between the contests which finished with Golden Score, those which finished before regular time and the others which finished at the end of regular time. 72% of contests were finished before regular time, while 19% of analyzed contests were finished with Golden Score. Only 9% of the contests continued to full regular time.

It can be seen from Table 2, the mean time duration for each round. The observations for determining the time limitation of every round showed that there are significant differences between the mean time duration of rounds. The bronze medal combats and semifinal contests were lasted more than other round combats. The average combat time for bronze medal contests were 239±81 s and 241±12 s for semifinals. No significant differences were observed between the mean time for I, II, III, Quarter final, repechage, and final combats. The first rounds lasted 135±10 s, the least mean time value comparing to all contest rounds. Not considering bronze medal and semifinals the mean time value of the contests increases very slowly from the first-round till to finals. This indication is worthy of consideration for coaches in planning the right physical conditioning before a determined contest (see Table 2).

Table 2. Time limits and mean durations of combats of judo athletes by rounds (n=104)

Rounds	End with Golden Score#	End before regular time	End with## regular time	Mean±SD In sec.
I round	4	20	4	135±10
II round	4	24	2	153±98
III round	3	10	-	179±15
Quarter Final	3	8	1	180±88
Semi Final	2	4	1	241±12*
Repechage	1	3	-	183±14
Bronze Medal Combat	3	4	-	239±81**
Final Combat	-	2	1	185±57
Total	20	75	9	-
%	19	72	9	-

**Significant differences between I round and combats for bronze medal; **Significant differences between I round and Semifinal combats; #Significant differences between end with Golden Score combats and end before regular time; ## Significant differences between combats end before regular time and with regular time.

Time-motion characteristics of different combat phases

The combat phases and time characteristics were divided as shown Table 3. It can be seen from the results; the mean contest time was 178±11 seconds for all analyzed combats. The quickest contest time was 11 s, and the longest contest time was 470 s. It is interesting to note the high percentage of contests ending before regular time and those ending with golden score. This observation is a clear indication for coaches about the need to prepare athletes very well for dynamic contests whilst also providing specific high aerobic preparation to face the golden score extended contest time.

The most time spent on a particular contest phase was for locomotion time when compared to the other combat phases. The mean locomotion phase time was 11.52±6.1 s. was equal to 0.82 s and maximum time was 24.6 s. The defensive actions for both standing and groundwork situations are equal for standing technique and *ne-waza* combat time durations (see Table 3).

It is necessary to briefly explain the concept of average duration of the three main standing phases of the combat.

“Standing“: the locomotion phase starts from the "*hajime*" command to the begin of the throw and includes walking, grips situations, avoiding grips, unbalancing and so on.
The following phase defined as "throw" is logically the real attack time. It is often very short. The throwing technique can be effective (with score) or ineffective (without score).

Table 3. Time-motion characteristics of different combat phases (n=104)

Time indices	Combat phases (in seconds)					
	Mean combat time	Locomotion	Standing Technique#	Ne waza##	Defense in standing	Defense in ne waza
Mean±SD	178±11	11.52±6.1	1.86±0.9#	7.01±4.5	1.86±0.9	7.01±4.5
Minimum	11	1.30	0.28	0.82	0.28	0.82
Maximum	470	38.8	6.72	24.6	6.72	24.6

#Significant differences between locomotion and standing technique; ## Significant differences between locomotion and Ne Waza phase.

Minimal value of locomotion was 1.30 s and maximal indices were 38.8 s. While, the least time spent for the technique phase was 1.86±0.9 s. The minimum time spent for this phase was only 0.28 s and the maximum time was 6.72 s. It is clear from Table III, the average *ne-waza* phase time was 7.01±4.5 s. We found that the minimum time duration

“Groundwork”: the *ne-waza* combat phase is the phase where the athletes start the ground combat. This phase begins when the athletes start the fight on the ground until the referee stops the combat or *Tori* performs a groundwork technique.

"Defenses in standing and ground": they are very difficult to evaluate, then in a first simplified calculation approach, it is assumed that the time of *tori*'s attack techniques are equivalent to the time of *uke*'s defenses in both situations.

However, all phases determine different energy consumption which is part of the total load that the athlete consumes during the combat.

Effective and ineffective throwing techniques according to biomechanical classification.

Figure II illustrates ratios of effective and ineffective throwing techniques according to biomechanical classification. There were registered 555 (100%) throwing techniques by the judokas in our observation. There were not found significant difference between the two classification of techniques (Lever vs Couple). The Lever-based throws were 51%, while couple-based throws were 49%. It was consisted 284 throws by using Lever-based and 271 throwing techniques were couple-based.

The mean number of attacks were 5.33±1.6, the mean number of Lever techniques were 2.73±1.5, and Couple-based were 2.60±1.7: almost 6 techniques per combat with an equal distribution (3 lever techniques and 3 couple techniques). Overall, 29% of attempts were rewarded with a score. 24% of Lever-based throws obtained effective scores during the competition. Whereas, 33% of the couple-based throws finished with scores (see Figure II).

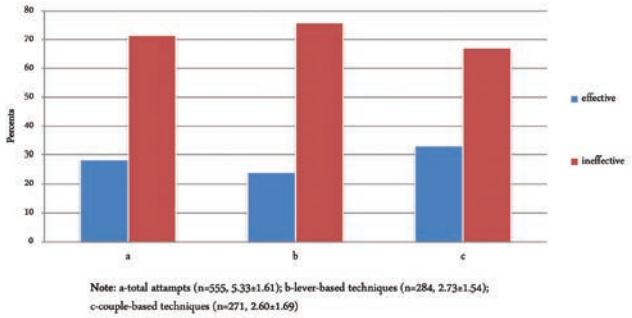

Figure II. Ratios of effective and ineffective throwing techniques according to biomechanical classificaton

Time-motion characteristics of *ne-waza* combat phase, lever-based and couple-based throws by rounds

The results of the time-motion characteristics and rate of occurrence of *ne-waza* contest phase, Lever-based and Couple-based throwing techniques are shown in Table 4. Overall, the mean time of *ne-waza* phases were 8.17±3.4 in the first round and the amount of *ne-waza* contest time decreased slowly until Quarter final contests. Then average time was fluctuated between the Quarter final and repechage combats and reached a peak at 9.13±3.1 s in Bronze medal contests. The maximum and minimum time differences were observed in second rounds and bronze medal combats.

From round 1 to Semifinal contests, the rate of lever-based throws stayed stable. While there were observed fluctua-

Table 4. Time-motion characteristics of ne waza combat phase, lever-based and couple-based throws by rounds

Rounds	Mean±SD	Max	Min	Mean±SD	Max	Min	Mean±SD	Max	Min
	Ne Waza phase, n=220 (in seconds)			Lever-based, n=284 (number)			Couple-based, n=271 (number)		
I round	8.17±3.4	18.11	9.44	2.85±2.0	8	1	2.67±2.2	9	1
II round	6.76±1.9	21.37	1.35	2.56±1.8	8	1	2.6±2.1	9	1
III round	5.72±2.8	13.19	1.43	2.53±1.7	6	1	1.15±0.3##	2	1
Quarter Final	4.76±1.6	11.28	1.79	2.75±2.1	8	1	2.61±1.6	6	1
Semi Final	6.74±3.7	13.49	2.19	2.57±1.6	5	1	4.71±2.7#	9	1
Repe-chage	5.19±2.6	11.39	1.22	3.75±2.5	8	1	1.75±0.8	3	1
Bronze Medal Combat	9.13±3.1	24.6	1.08	2.28±1.7	6	1	2.57±1.7	6	1
Final Combat	8.71±7.3	24.47	2.13	4±1.4	6	3	4±1.6	6	2
#Significant differences between III round and semifinal combats ## Significant differences between III round and final combats									

tion rates using the Lever-based throws till final combats. It rose to a peak of 4±1.4 in final contests. The maximum number was 8 for majority of the rounds and in the final contest it occurred 6 times. Minimal volume of this type of throw was 1 until the final contests, while it was 3 in final contest (See Table 4).

The mean time application of couple-based throws was 2.67±2.2 and 2.6±2.1 in the first and second rounds, respectively. In the third round, the average occurrence of couple-based techniques fell to 1.15±0.3, while, in semifinal combats it rose to 4.71±2.7. In the final there was a substantial rise and the average occurrence of couple-based techniques was 4±1.6. It can be seen from Table 4 that the maximal number of couple-based throws were 9 times in I, II and Semifinal combats, while, in the third round the maximum number of throws was 2. Also, the minimum numbers of throws were 1 for all rounds and it consisted of 2 in final contest.

It is interesting to note between the first two rounds 56% of the total combats were performed, against the 44% of the last six rounds. In the first two rounds, average *ne-waza* time was 7.46±2.6 s against 6.7±3.8 s, while the average number of techniques was practically constant for Lever and for couple, instead the average maximum number decreased from 8 to 6.5 for lever and from 9 to 5.3 for couple.

Assuming the validity of the order of magnitude of some mean values both of lever (2,3 KW) and couple techniques (1,7KW) evaluated as mean energy consumption (Sacripanti, 2015).

We can indicate that in the Uzbekistan National Championship gross mean power consumption, related to throwing action only; ranges between a minimum of 2.3 KW till to maximum of 18.4 KW for lever, respect to 1.7 KW and 15.3 KW for couple.

This information might be useful for anaerobic and aerobic training of judoka. The biomechanical approach usefulness, can be underlined as example by the biomechanical analysis of throwing techniques during London Olympics. In the London Olympics case, certainly more than in National Uzbekistan; Couple techniques were used less frequently (39.6%) than the Lever techniques (60.5%) (Sterkowicz et.al., 2013).

The general preference in both tournaments: National Championships of Uzbekistan and London Olympic of the lever techniques over those of the couple indicates that athletes preferred, a more cautious, and slow race pace.

Discussion

In this study the time-motion characteristics of Uzbekistan National Judo Championships contest phases were analyzed. The ratios of throwing techniques were divided according to biomechanical classification. The ratios of both throwing techniques and time characteristics of contest phases were analyzed.

The results show that most contests finished before the end of regular time. Also, the percentage of the contests which finished with golden score was slightly increased. Other research confirms that most of the contests finished before the end of regular time (72%, Table 2). Also, it is noticeable that in our study there was an increase of golden score contests observed. Compared to previous studies, it was confirmed that the contests which ended in golden score were 3.2% and 2.4% for males and females respectively (Segedi et.al., 2014).

The results showed that 19% of combats were finished with additional time (golden score). It can be deduced that coaches should give their attention to aerobic training during the preparation process. During a golden core situation, the aerobic capacity of the athletes plays an important role. Additionally, the results of this work would confirm that time duration of each rounds was extended to final combats.

The mean time durations were increased approximately from 135±10 s to 241±12 s when compared to the earlier rounds. Other authors have presented similar results, but not on a round by round basis. It was identified that the time durations were 233±78 s, for male and 202.2±88 s, for female athletes respectively (Soranigo, et.al., 2019). The mean contest time for all rounds was 178±11 s in our study. By contrast in the research by other studies (Miarka et.al., 2014), the overall mean time was 179±13 s. Therefore, our results reflect previous studies. When comparing this with other studies, the overall average was 284±17 s, and the results for women and men were 289±21 s and 279±14 s respectively (Soranigo, et.al., 2019).

In biomechanical terms, some internal and external factors influence contest style such as Referee rules, changing in Competition structure, preferred pace of competition, changing in *kumikata*, the types of throws utilized (classic, innovative, chaotic), type of throwing techniques (lever or couple), training methodology, skill of athletes, high dynamical situations and so on (Sacripanti, 2013). In other studies, the mean contest times were divided in to two main periods such as activity and pause. It was noticed that activity period was similar for both men and women (Franchini et.al., 2013).

Locomotion phase is one of the most crucial parts in judo contests. It can be underlined that in locomotion phase judokas plan their combat strategy for next attack. Also, locomotion in judo combats plays a significant role in recovery and this phase can be different for home and visiting athletes as shown in other studies (Brito et.al., 2017). In our study, this phase took more time than the other phases of the combat. Furthermore, some studies

have showed that the locomotion phase is divided into two types according to biomechanical approach: *ayumi ashi*: normal locomotion and *tsugi ashi*: foot follows foot (Sacripanti, 2010).

We obtained an average technique execution time 1.86±0.9 s. Also, it was confirmed by previous studies that in three matches there were found similar results to those obtained in this study (Match 1 - 1.4±0.3 s; Match 2 - 1±0.4 s; and Match 3 – 1.7±0.5 s) (Marcon et.al., 2010). In addition, other researchers have identified the differences among the different levels of athletes. Average technique time was 1.1±1.4 s for expert judokas, 2±2 s for intermediate judoka, and 2.6±2.3 for beginners. While, this is confirmed by the fact that overall attack phase varies according to competitive level, with high level athletes perform more complex combinations before applying a throw than the novice (Calmet et.al., 2010). This phase seems to demand anaerobic a-lactic capacity from the athletes during the contests.

In judo, combating in ground (*ne-waza*) has a particular base. In our research we have found differences compared to previous studies (Miarka et.al., 2014; Giovani et.al., 2010). As particular example, some researches have showed distinct results from the present study, when observing the visually impaired judokas and differences between genders of standing combat and groundwork combat time. 57.7% of male combat time and 39.1% of female combat time corresponded to standing situation, while 42.2% and 60.9% to a groundwork situation.

The average groundwork time was 52s for men (Castarlenas et.al., 1997), while, it was observed by the other studies that then *ne-waza* techniques were used less than standing techniques during the International competitions including Olympic Games (Sterkowicz et.al., 2013).

Also, Maldern et.al. (2006) confirmed that according to their results that the mean times of groundwork phases were 32s. Previous studies have showed different findings compared to current results. It is noticeable to discuss the rate of occurrence of *ne-waza* contest phases till final combats. The average time duration of a groundwork phase was 7.01±4.5 s for all rounds combined, while, average time was fluctuated between rounds.

Most groundwork phases occurred in round 1, bronze medal combats and final combats. These were registered with an average of 8.17±3.4 s, 9.13±3.1 s and 8.71±7.3 s, respectively. It was reported by the other studies that groundwork phase lasted 17±12 s, 9±5 s and 13±6 s in three consecutive matches (Sacripanti, 2013) we must not forget that groundwork times are strongly influenced by both the referees and the referee rules.

According to biomechanical principles, throwing techniques are divided into two groups: lever-based and couple-based throwing techniques. It was confirmed by practical experiments and theoretically that couple-based throwing techniques are energetically less expensive than the lever-based judo throwing techniques (Sacripanti, 1987; Sacripanti et.al., 2015). Our observations have showed no statistical significance between lever and couple throwing techniques used effectively during the competition.

Our work confirmed previous studies, effective couple throwing techniques were 28.7% for males and 39% for females, while 24% and 26.4% of lever techniques were finished with scores for men and women, respectively (Sterkowicz et.al., 2013).

These results are in very good accord with the efficiency evaluated in a paper on the London Olympic (Sterkowicz et.al., 2013) in which authors calculated efficiency for lever throws: 24% for male and 26.4% for female, while for couple techniques respectively 28.7% and 39%. Efficiency of the attacks is very low, which means that coaches, carefully, need to increase attack effectiveness.

It is important to explain of occurrence of throws round by round. The mean volumes of throwing techniques were almost equal in round 1 and round 2 rounds. Using the lever techniques stayed constant until the semifinal, while, application of couple-based techniques fluctuated after the second round until the final combats. Implementation of the lever and couple based techniques in final contests increased to 4±1.4 and 4±1.6, respectively. Minimum attempt was 1 for both throws, while, maximum attempts using the lever-based throws were 8, and 9 for couple-based throws.

Conclusion

The present research examined the time-motion phases of judo contests combined with biomechanical classification of throwing techniques. The average time durations of contests can be used by coaches and athletes to improve their contest strategy. Increasing the length of activity time until final contests are a key factor in the preparation period. This indicates the need for aerobic and anaerobic training specific intercourse before the competitions.

Comparative analysis of throwing techniques according to biomechanical classification requires to apply them in a practical situation. This approach can give a rough indication of energy consumption in real competition.
Research results are specific ratios of aerobic and anaerobic training needs. The results of this work provide information about time-motion characters of the judo competitions that could be linked to the order of magnitude of the energy demands of the real judo competitions, by a heuristic combating equation (see Appendix).

Judo coaches may use these results to plan their training process and improve strategic skills of judokas. The results of this study can be used as rough indication of load

for the training process. We have to be careful about the generalization of these results (38 judokas from the same region of the same country and aged 16 to 17 years old), but coaches have some information to train judoka. A judoka must be able: to combat 5 or 6 times with a duration between 120 s to 240 s (table II; average 178±11 in table III) with complete recuperation between the combats; to do around 10 explosive efforts during a combat ≈180 s (6 attacks; 3 lever throws and 3 couple throws in Figure II); to do 3 intensive efforts (*ne-waza*) around 8 s (authors should precise the number of *ne-waza* phases). The number of combats (5 or 6) needs a good training in aerobic. Authors did not precise the ratio effort/pause but with data in Table 3 [locomotion + standing technique + *ne-waza* (11.52 + 1.86 + 4.5)] one can think that the ratio is the same found in literature (20 s / 10 s) to train in anaerobic lactic.

Future research

This assumption might be addressed in future studies. Future research would examine the usage of this study's results in a practical way to evaluate judo contests' physical load and athletes' physiological indices during contests. They will be utilized as input for the improvement of specific training load or methods, the results of these training applications will be evaluated both in the course of controlled training sessions or controlled combat sessions and in national and international competitions.

Appendix on the Usefulness of Biomechanics in Judo and in Judo combat analysis

1) Judo

Kano has done some very interesting work in his well-known classical classification, however there are some inconsistencies. For example, if the first three classes are based on the tools that transfer energy or strength from *tori* to *uke* (*te, koshi, ashi*) while, the two *sutemi* groups are classified on the parts of the body that touch the tatami (*ma* and *yoko*) with a clear methodological inconsistence.

Many techniques can belong to several classes due to the variability of execution, for example: *uchi mata* (of legs, or hips, and in *makikomi*) will belong to the Kano classification in three classes.

The application of biomechanics groups the five Kano classes into only two classes, while considering *Uke* a non-deformable rigid beam, like a stick, (incidentally this trick was also used by Kano to explain the concept of unbalance (*Roppo No Kuzushi*) (Yokoyama et.al., 1911).

So also for the biomechanical classification, even if the techniques are applied differently from their basic standard form, they will always belong to one of the two classes, e.g. *uchi mata* of leg, hip, applied to the reverse leg (okurikomi), with sacrifice (*makikomi*) etc., will respectively be classified as: a couple, a lever, a rotational lever.

The use of biomechanics, identifying the fundamental universal physical principles of the techniques, allows at the same time to simplify the subject (2 classes instead of 5) and to better understand the correct mechanics of the throwing techniques.

Considering the energy consumption connected to a single throwing technique, biomechanics also divides the techniques into two energy classes: techniques lever-based, more expensive, techniques Couple-based, less expensive.

Furthermore, following the well-known Kano Principle: *seiryoku zen'yō*, (maximum efficiency) we see that it is, from the biomechanical point of view, an Energy Optimization principle, based on the minimum consumption of mechanical energy.

Moreover, if we consider the throwing techniques during standing training practice (*uchi komi*), in the *dojo* (gym) in the light of the biomechanical analysis, we immediately notice that *Uke*'s projected body moves along the geodesics of only two symmetries (spherical and cylindrical) (Sacripanti, 1987). According to the Maupertuis principle, these are the trajectories of least energy consumption in space. Therefore, physical action and judo throws are effectively optimized.

In 1740, Pierre Louis Moreau de Maupertuis (1698-1759) stated that, in analogy with Fermat's Principle of Least Time for light, a body of mass m under the influence of a force

$$F = -\nabla U \quad \{2\}$$

moves along a path which satisfies the Principle of Least Action:

$\delta S = 0$ {3}

where the Action integral (*Uke* body trajectory produced by throwing technique) is defined as:

$$S(x) = \int_a^b mv(s)ds = \int_a^b m\sqrt{\frac{2}{m}(E - U(s))}\,ds \quad \{5\};$$

the variation of trajectory $\delta S = 0$ means that it is the shortest one.

In formula simply:

$$\delta S = \int_a^b mv(s)ds = 0 \quad \{6\}$$

On a closer inspection of mechanics the throwing techniques, it turns out that the techniques Couple-based are, not only less expensive, but also fully optimized, while some of Lever-based techniques can be further optimized, decreasing the energy consumption, by lengthening the lever arm (for example: going from standing *seoi nage*, to *seoi otoshi*, till to *suwari seoi nage*, where *tori* is sitting in the Japanese style (*Seiza*) on the tatami) (Sacripanti, 2015).

2) Combat analysis

The knowledge of all the "times" evaluated during the competition and championship phases, is useful to evaluate the "Strategic Optimization".

"Strategic Optimization" is based on the minimum mechanical work consisting of choice of throws, tactical tools to improve throws effectiveness, use of *ne-waza*, locomotion, defensive work and active recovery among combats, all evaluated as oxygen consumption.

Theoretically we can construct a "Heuristic Energy Equation of the Combat Energy" by means of a Constitutive Algorithm, which it is an algorithm that builds the final solution by iterations based on a partial (incomplete) solution.

A heuristic equation for a combat or a sum of combats (championship) could have the following general form:

$$\overline{E(O_2)} \approx \sum_{i,k} (A_i^{O_2} + A_k^{O_2}) + \sum_i D_i^{O_2} + \sum_n G_n^{O_2} + \sum_m L_m^{O_2} - \sum_s \frac{t_s}{\tau} RMR \quad \{6\}$$

$A_i^{O_2} = Tachi\ waza\ attacks\ with\ lever\ throws\ as\ O_2 = lever$ *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*

In the case of "Strategic Optimization", the optimization is not linked to a single throw but to a complex of movements and situations typical of a combat or an entire tournament.

It is possible to find an optimal solution for the contest by minimizing an energy equation like the previous {6}. With this Objective Function the optimization is connected to the minimum on average of each contribution.

In practice, for coaches during the tournament, finding a minimum point through measurements is impossible; the best way to achieve strategic optimization in real competition is visual observation and expert vision (knowing previously the average experimental measurements of athletes' consumption in training contest) and then consider a reasonable range of competing conduct in which the consumption of energy will be acceptably low. However, this type of theoretical construction is able to provide interesting information, in term of the order of magnitude, on the overall energy needs of athletes.

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