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Pulling forces in different judo stances in laboratory conditions

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Abstract

Background & Study Aim: By constructing a judo specific force measurement device, the total pulling force in relation to left/right force components and stance variations of judo techniques was analysed. The aim of this study is knowledge about the global pulling force in relation to left/right force components and laterality of judo techniques measures in laboratory conditions (mimicked acting on the opponent as close as possible to the competition technique).

Material & Methods: Forty male elite judo athletes (age 20.1 ±0.9 years, weight 79.1 ±18.7 kg, height 174.2 ±8.1 cm). All were members of the national youth team. Athletes performed successively four different stance-pulling techniques all based on *shizen-tai* (natural standing posture) on the judo specific device. Three Load Cells (LC) recorded total and right/left side applied forces on the judogi. Force patterns were analysed according to technique, weight category, and body mass.

Results: For the whole group, in all four stances the produced total force was nearly equal ranging between 13.56 N/kg and 14.40 N/kg. The absolute force values increased with increasing body weight ($p<0.05$), the normalized forces values increased with decreasing body weight ($p<0.001$). In all four stances, the pulling force on the sleeve was greater than the pulling force on the collar independent from arm preference ($p<0.05$). Lightweight judokas showed a more balanced left/right force production, whereas for the heavy weight category the left-right difference was significant ($p<0.05$).

Conclusions: Body weight influenced force magnitudes as well as left/right balancing of force application. Heavier judokas implemented left/right asymmetries by greater force application on the sleeve regardless of arm preference of the *tori* during the technique. Adding rotational technique components by foot stance variations did not change force magnitude and pattern.

Key words: biomechanics • body posture • judo technique • Load Cells

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Shizen hontai – in *shizen-hontai* you stand naturally with your feet spread to a distance almost equal to the distance between your shoulders, so that the centre of gravity lies at a point on the vertical line passing through the centre of the base thus formed for your body.

Load Cells – measurement device which records pull and pressure forces.

Hidari ai-yotsu – same left grip used by both persons.

Kuzushi – unbalancing the opponent.

Migi ai-yotsu – same right grip used by both persons.

Tai sabaki – body control, turning.

Tusukuri – entry into a technique, positioning.

Tori - person performing a technique.

Uke – person receiving the technique.

INTRODUCTION

Judo techniques separate into actions of gripping, pulling, unbalancing, and throwing which all require forceful gripping of the judogi. During all the technique phases first all involved muscles in the kinetic chain develop the required force to mobilize the opponent, and then this force is applied on the opponent via the grip on the judogi [1].

In judo the two main postures, the standard stance (*shizen hontai*) and defence stance are categorized according to foot laterality as right (*migi*) or left (*hidari*) sided. Further nomenclature is based on which side of the judogi of the opponent is used for the grip [2-4].

All judo techniques begin by gripping the judogi, which is of foremost importance for the following pulling actions [5]. During a proper judo technique, adequate forces should be applied on the opponent to disturb his balance and orientate his centre of body mass suitable to the aimed throw [6, 7]. The opponent has to withstand these forces and try to maintain balance [8, 9].

Analysis of kinematic and kinetic indicators of judo techniques will not only provide scientific insight into biomechanical aspects of judo, but will also enhance tactical and technical knowledge of trainers and athletes. For these purpose researchers have developed judo specific measurement devices and tried to evaluate biomechanical aspects of different judo techniques as close as possible to the natural competition. Beginning with the measurement of global pulling forces such analysis has also tended to include left and right grip force patterns [10-14].

The aim of this study is knowledge about the global pulling force in relation to left/right force components and laterality of judo techniques measures in laboratory conditions (mimicked acting on the opponent as close as possible to the competition technique).

MATERIAL AND METHODS

Participants

Forty male elite judo athletes participated voluntarily in this study (age 20.1±0.9 years, weight 79.1±18.7 kg, height 174.2±8.1 cm). All participants had practiced judo over 10 years and all were members of the national youth team. Evaluation of the athletes was performed individually as well as according to three weight categories; light weight category (66 kg and below), middleweight category (67-89 kg) and heavy weight category (90 kg and above). The Ethics Committee of the Medical Faculty of Marmara University approved the protocol.

Measuring tools

A judo-specific setup was constructed to record pulling forces applied during judo techniques. Three Load Cells (six-directional, strain gauge-based, 50 Hz; CAS Corp., Korea) were mounted on a steel construction. These load cells provide constant force values in a range of 30 degrees. One load cell was directly mounted in the middle of the steel construction and fixed to the wall (LC1). The left and right load cells were attached to the sleeves of the judogi by special fixators (LC2 and LC3) (Figure 1 and 2).

This setup enabled us to record the total force applied on the steel construction by LC1, and also the right and left sided applied forces on the judogi by LC2 and LC3.

An indicator and special software (Kyowa Corp, PCD Model 30 A) transferred data coming from the load cells to a computer. The system was calibrated using the calibration factors recommended by the Load Cell manufacturer. A balance adjustment was performed before each impact with the relevant software for each of the load cells.

Procedure

Prior to the testing the judokas had 10 minutes for free warm-up and preparations. Then they performed successively the four posture-pulling techniques all based on *shizen-tai* (natural standing posture).

Posture 1: *shizen-hontai/hidari ai-yotsu* (basic natural standing posture – left grip); stance naturally and mildly, the feet parallel and shoulder width apart; the judoka grips with his left hand the right collar of the judogi, and with his right hand the left sleeve of the judogi. The pulling is executed synchronously with both arms (*kuzushi*);

Posture 2: *shizen-hontai/migi ai-yotsu* (basic natural standing posture – right grip); stance naturally and mildly, the feet parallel and shoulder width apart; the judoka grips with his right hand the left collar of the judogi, and with his left hand the right sleeve of the judogi. The pulling is executed synchronously with both arms (*kuzushi*);

Posture 3: *hidari-shizen-tai/hidari ai-yotsu* (left natural standing posture – left grip); stance with left foot

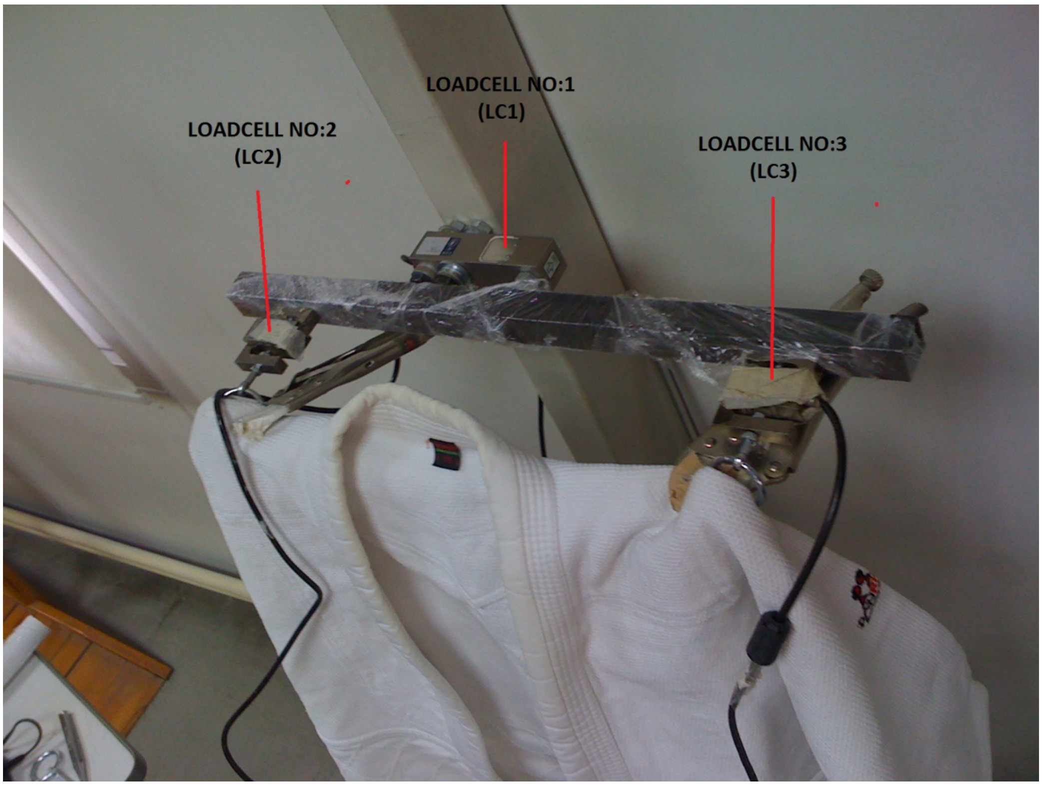

Figure 1. Experimental setup showing steel construction, load cells and judogi; one load cell was directly mounted in the middle of the steel construction and fixed to the wall (LC1). The left and right load cells were attached to the sleeves of the judogi by special fixators (LC2 and LC3).

advanced a bit leftward and forward from basic natural standing posture; the judoka grips with his left hand the right collar of the judogi, and with his right hand the left sleeve of the judogi. The athlete take his right foot to the front, and accompanied by a rotational movement of the body executes the pulling synchronously with both arms (*kuzushi*, *taisabaki*, *tusukuri*);

Posture 4: *migi-shizen-tai/migi ai-yotsu* (right natural standing posture – right grip); stance with right foot advanced a bit rightward and forward from basic natural standing posture; the judoka grips with his right hand the left collar of the judogi, and with his left hand the right sleeve of the judogi. The athlete take his left foot to the front, and accompanied by a rotational movement of the body executes the pulling synchronously with both arms (*kuzushi*, *taisabaki*, *tusukuri*).

Statistical analysis

All results were expressed as mean ± (SD). Absolute and normalized values ("force per kg body weight" and "force as % of body weight") were calculated for the analysis. Left and right force values were compared statistically by the paired t-test. Pearson's correlation was used to relate the pull test variables with the athletes' body mass. The difference was set significant at the $p<0.05$ level.

RESULTS

For the whole group, in all stances the produced total force was nearly equal (Table 1 and 2). The absolute force values increased significantly with increasing body weight ($p<0.05$), but the normalized forces values increased highly significantly with decreasing body weight ($p<0.001$). Furthermore, in all postures the pulling force at the sleeve of the *uke* was greater than the pulling force at the collar of the *uke* ($p<0.05$, see table 3-6). All recorded force values in the four different stances, and especially those of the related postures (1 ÷ 3 and 2 ÷ 4) showed strong significant correlations (Table 7).

In posture 1, the absolute force values increased with the increasing weight categories, whereas for the normalized force values the opposite was true: the lightweight category produced the highest normalized force values, and the heavy weight category

Figure 2. Pulling on the system using the adequate judo technique.

the lowest ones. For all weight categories, the right-handed pull by the *tori* on the sleeve produced higher force values than the left-handed pull on the collar (only significant for the heavy weight category $p<0.05$). The ratio of the normalized forces of both arms was 0.87 for the lightweight category, 0.85 for the middleweight category, and 0.77 for the heavy weight category (Table 3).

In posture 2, an identical pattern was observed for the force differences between the weight categories: the absolute force values increased with the increasing weight categories, whereas for the normalized force values again the opposite was true. For the middle- and heavy weight categories, the left-handed pull by the *tori* on the sleeve produced higher force values than the right-handed pull on the collar (only significant for the heavy weight category $p<0.05$). The ratio of the normalized forces of both arms was 0.78 for the middleweight category and 0.58 for the heavy weight category. Interestingly, for the lightweight category, the right-handed pull by the *tori* on the collar produced higher force values than the left-handed pull on the sleeve, but the difference of the normalized forces of both arms was small and their ratio was 0.93 (Table 4).

The lightweight category *tori* produced both in posture 1 and 2 nearly identical forces with the right and left arm (which means nearly identical loading at the sleeve and the collar of the *uke*).

The force values and patterns recorded in posture 3 reproduced those of posture 1 but with minimal decrements of all forces (Table 5). Left right differences were again only significant for the heavy weight

Table 1. Force per kg body weight in all stances/postures

		Force per kg body weight (N/ Kg)		
	N	Load cell (LC1) Mean ± SD	Load cell (LC2) Mean ± SD	Load cell (LC3) Mean ± SD
Posture 1	40	14.40 ±3.92	6.66 ±2.16	7.92 ±2.97
Posture 2		14.22 ±3.32	7.95 ±2.36	6.69 ±2.87
Posture 3		13.56 ±3.42	6.14 ±2.43	7.49 ±2.63
Posture 4		13.75 ±3.14	7.89 ±2.53	6.29 ±2.65

Table 2. The absolute forces in all stances/postures

		The absolute forces (N)		
	N	Load cell (LC1) Mean ± SD	Load cell (LC2) Mean ± SD	Load cell (LC3) Mean ± SD
Posture 1	40	1094.72 ±223.98	509.16 ±142.10	608.21 ±190.25
Posture 2		1090.60 ±227.81	621.55 ±210.84	487.49 ±186.23
Posture 3		1041.66 ±236.73	468.07 ±175.74	577.32 ±188.58
Posture 4		1050.98 ±200.25	616.15 ±214.77	471.41± 177.11

Table 3. The absolute and normalized value (force as percentage of body weight) of forces according weight categories in the stance/posture 1.

Weight categories	N	Absolute Force (N)			Normalized Value (%)		
		Load cell (LC1) Mean ± SD	Load cell (LC2) Mean ± SD	Load cell (LC3) Mean ± SD	Load cell (LC1) Mean ± SD	Load cell (LC2) Mean ± SD	Load cell (LC3) Mean ± SD
Light	11	1017.73 ±227.32	480.13 ±188.11	543.09 ±216.24	172.96 ±36.62	80.93 ±29.30	92.60 ±37.09
Middle	19	1107.96 ±242.03	515.14 ±121.70	599.77 ±178.09	148.59 ±38.67	68.59 ±15.60	80.42 ±26.81
Heavy	10	1154.34 ±177.01	529.95 ±131.70	696.08 ±165.73	114.55 ±21.58	52.18 ±13.03	68.10 ±13.45

category ($p<0.05$).

Similarly, the force values and patterns recorded in posture 4 reproduced those of posture 2 but again with minimal decrements of all forces (Table 6). Left right differences were again only significant for the heavy weight category ($p<0.05$).

The lightweight category *tori* produced both in posture 3 and 4 nearly identical forces with the right and left arm (which means nearly identical loading at the sleeve and the collar of the *uke*).

DISCUSSION

the main purpose of this study was to compare pulling loads produced by the attacking judo athletes (*tori*) during different stance techniques (*shizen-hontai* and *jigo-hontai*). Although different studies have evaluated such biomechanical force indicators [11-13,15] this setup had the advantage to mimic techniques and stances more closely to the real judo encounter.

Detanico et al. [16] have recorded pulling forces in a similar experimental setup and investigated techniques and stances being applied in competition. Although the *tori* used a combat grip for both the right and left hand, one major divergence from the natural encounter in judo was their experimental

Table 4. The absolute and normalized value (force as percentage of body weight) of forces according weight categories in the stance/posture 2

Weight categories	N	Absolute Force (N)			Normalized Value (%)		
		Load cell (LC1) Mean ± SD	Load cell (LC2) Mean ± SD	Load cell (LC3) Mean ± SD	Load cell (LC1) Mean ± SD	Load cell (LC2) Mean ± SD	Load cell (LC3) Mean ± SD
Light	11	1035.58±225.95	496.71±152.40	533.29 ±179.27	175.81±34.87	84.45±25.46	90.38±29.51
Middle	19	1052.94±186.33	609.09±181.33	483.37 ±181.03	139.66±20.97	81.23±25.10	63.69±21.91
Heavy	10	1222.79±269.49	782.37±226.93	444.93±210.65	120.90±29.44	76.82±22.24	44.25±23.02

Table 5. The absolute and normalized value (force as percentage of body weight) of forces according weight categories in the stance/posture 3

Weight categories	N	Absolute Force (N)			Normalized Value (%)		
		Load cell (LC1) Mean ± SD	Load cell (LC2) Mean ± SD	Load cell (LC3) Mean ± SD	Load cell (LC1) Mean ± SD	Load cell (LC2) Mean ± SD	Load cell (LC3) Mean ± SD
Light	11	906.72±233.01	467.38±164.75	470.52±160.44	153.60±35.77	78.65±24.69	80.33±27.74
Middle	19	1085.60±205.55	483.57±177.30	594.48±207.02	144.88±30.47	63.31±20.21	80.06±30.94
Heavy	10	1106.78±258.99	439.44±198.49	662.24±130.92	108.77±25.19	43.53±21.28	65.10±12.32

Table 6. The absolute and normalized value (force as percentage of body weight) of forces according weight categories in the stance/posture 4

Weight categories	N	Absolute Force (N)			Normalized Value (%)		
		Load cell (LC1) Mean ± SD	Load cell (LC2) Mean ± SD	Load cell (LC3) Mean ± SD	Load cell (LC1) Mean ± SD	Load cell (LC2) Mean ± SD	Load cell (LC3) Mean ± SD
Light	11	992.83±182.99	499.45±183.38	511.61±143.47	168.47±26.08	84.96±31.38	86.65±22.42
Middle	19	1040.39±166.42	597.52±196.33	472.48±160.53	138.56±23.03	79.87±26.61	62.44±19.75
Heavy	10	1135.22±262.43	779.82±195.84	425.22±239.09	111.93±27.21	76.50±18.28	42.34±26.03

Table 7. The correlation results for the recorded total force values in the four different stances/postures of all subjects

N=40		P1-LC1	P2-LC1	P3-LC1
P2-LC1	Pearson Correlation	**.378***		
	Significance (2-tailed)	.016		
P3-LC1	Pearson Correlation	**.619****	**.538****	
	Significance (2-tailed)	.000	.000	
P4-LC1	Pearson Correlation	**.520****	**.777****	**.711****
	Significance (2-tailed)	.001	.000	.000

restriction to have used only one site of the judogi for force data acquisition (they used one single load cell fixed on the judogi).

In the present experimental design, such analysis was extended to simulate judo techniques closer to real competition by recording pulling forces from a three-point data acquisition setup. Pulling forces of the attacker (*tori*) applied on the right and left side, as well as on the whole judogi of the *uke* were recorded by this three-point data acquisition system. This experimental setup allowed for evaluating forces acting synchronously and bilaterally on the opponents (*uke*) torso. This experimental setup also differs from that of Blais et al. [15] who also used a two-point data acquisition system. These authors were able to record the forces of the *tori* produced by the combat grips at the collar and sleeve, but not the resulting forces on the torso of the *uke*.

Recorded forces were analysed as absolute values as well as normalized values to the body weight of the subjects either as "force per kg body weight" [11, 13, 14, 16]. As expected the absolute force values increased significantly with increasing body weight ($p<0.05$). On the contrary, the normalized forces values increased highly significantly with decreasing body weight ($p<0.001$). This is an extension of the findings of Detanico et al. [16], who found only a significant correlation between the absolute maximal force and body mass, but not between the relative maximal force and body mass in the judogi pull test.

Researchers have reported force values during judo techniques obtained by different experimental approaches. Detanico et al. [16] used only one arm for pulling which resulted in absolute force values between 418-478 N and normalized force values ranging from 5.41 to 6.16 $N\cdot kg^{-1}$. Blais et al. [15] reported relative pulling forces of 4.8-6.1 $N\cdot kg^{-1}$ which declined to 2.5-2.7 $N\cdot kg^{-1}$ when applied to the partner. Hassman et al. [6] measured relative pulling forces around 4.29-5.91 $N\cdot Kg^{-1}$ by using a fixed system. Nowoisky [17] reported in elite judokas maximal pulling forces up to 1800 N. In this study higher total relative force values between 13.75 and 14.40 $N\cdot kg^{-1}$ were measured. Factors as using only one arm [16] or employing mobile systems with constant weight [15] may account for these differences. In the present experimental setup, the only part that could be strained was the judogi. Employing such a fixed setup resulted in higher force values.

Regarding the analysis of the different postures, in the standard stance (*shizen hontai*), the athletes were able to apply pulling forces approximately 114-175% of their body weight. With the "foot in front" stance (*migi shizen tai- hidari shizen tai*) pulling forces were in the range of approximately 108-168% of their body weight. These results show that the stances/postures with one foot in front do not provide any advantage in force application.

Generally, the amount of the total force production was nearby equal for all the four postures, which also denotes to the good reliability of the measurements, as all participants were highly motivated. A further support comes from the finding that the force values showed significant and highly significant correlations between the four postures; especially the related postures were highly correlated (Pearson correlation coefficient 0.619 for 1-3, and 0.777 for 2-4).

For all subjects and for all stances/postures the amount on force applied to the sleeve was greater than that on the collar. Although this difference reached statistical significance only for the heavy weight class ($p<0.05$), it may indicate the superior influence of the sleeve pull to drive the *uke* into a rotational trajectory.

The comparison of collar and sleeve grip forces has yielded different patterns for the three weight categories. In the heavy weight category there were significant differences between the grip forces at the collar and sleeve ($p<0.05$), but not in the other two weight categories. The heavy weight category judokas applied greater force magnitudes at the sleeve. This finding was valid for the force application of the *tori* using either the right or left arm. In contrary, the lightweight group judokas applied nearly identical forces at the collar and at the sleeve for each arm combination.

Blais et al. [11] reported also identical forces at the collar and sleeve for elite lightweight women judoka, which were higher when measured by a judo specific machine than those obtained while performing with a partner. This important difference of force development may have practical consequences for competition. In the heavy weight, class the *uke/tori* has to focus on defending/attacking arm techniques targeting the sleeve, whereas in the lightweight class a more symmetrical attack/defence strategy may be employed. The heavy weight *tori* will apply primarily rotational forces on the *uke*. This line of thought is supplemented by findings of the in depth biomechanical analysis of judo techniques by Imamura et al. [1]. Whereas the shoulder throw (*seio-nage*) created a small impulse onto *uke*, the hip throw (*harai-goshi*) and leg throw (*osoto-gari*) techniques required greater impulses on the *uke*, emphasizing the importance for strength rather than skill of the *tori*.

In this context, Nowoisky [17] summarized his biomechanical analysis of judo throwing techniques in over 1000 top athletes in the pivotal finding that explosive pulling force development (quicker than in 400-800 ms) in the arms is required to be technically effective on the *uke*. He used testing and training devices, which transferred two arm-pulling forces during adequate judo techniques to a single rotating mass. This study extended such fundamental analysis by a three-point force capture system accounting for left-right symmetries/asymmetries. This data acquisition allowed to scrutinize force development of the *tori* as well as to reflect on the forces acting on the torso of the *uke*. This approach enables comprehension of the dynamic interaction between the *uke* and *tori* and to monitor training induced enhancements in force production.

CONCLUSION

Measuring force production of judokas with a fixed three-point judogi-pulling device showed that force application on the sleeve of the *uke* was always greater than on the collar. This pattern was independent of the *tori's* arm preference for pulling. Lightweight judokas showed a more balanced force production in this regard. A further important aspect was that positioning the foot in front of the body (*hidari shizen tai* and *migi shizen tai*) did not increase force application on the *uke*.

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COMPETING INTERESTS

The author declares no conflicts of interest.

REFERENCES

1. imamura RT, Hreljac A, Escamilla RF et al. A three-dimensional analysis of the center of mass for three different judo throwing techniques. J Sport Sci Med 2006; 5(CSSI): 122-131
2. Kano J. Kodokan Judo. Tokyo: Kodansha International Ltd.; 1986: 37-55
3. Watanabe J, Avakian L. The secrets of judo: A text for instructors and students. Tokyo: Tuttle Publishing; 1990: 40
4. Mifune K. Canon of Judo. Tokyo: Kodansha International; 2004
5. Ache Dias J, Wentz M, Külkamp W et al. Is the handgrip strength performance better in judokas than in non-judokas? Sci Sports 2012; 27(3):e9–e14
6. Hassmann M, Buchegger M, Stollberg K-P et al. Motion analysis of performance tests using a pulling force device (PFD) simulating a judo throw. Procedia Eng 2010; 2(2): 3329-3334
7. Eric M, Thierry P. Teaching balance for judo practitioners. IDO Mov Cult J Martial Arts Anthropol 2011; 11(1): 42–46
8. Perrot C, Mur JM, Mainard D et al. Influence of trauma induced by judo practice on postural control. Scand J Med Sci Sports 2000; 10(5): 292-297
9. Perrin P, Deviterne D, Hugel F et al. Judo, better than dance, develops sensorimotor adaptabilities involved in balance control. Gait Posture 2002;15(2): 187-194
10. Blais L, Trilles F. The progress achieved by judokas after strength training with a judo-specific machine. J Sport Sci Med 2006; 5(CSSI): 132-135
11. Blais L, Trilles F, Lacouture P. Validation of a specific machine to the strength training of judokas. J Strength Cond Res 2007; 21(2): 409-412
12. Kim E, Nam D, Kim S et al. Development of a pulling-reaping training & measurement instrument to enhance judo performance. ISBS - Conference Proceedings Archive 2008 July 14-18, 2008, Seoul, Korea; 2008: 362–365
13. Hassmann M, Buchegger M, Stollberg K-P. Judo performance tests using a pulling force device simulating a Seoi-Nage throw. IDO Mov Cult J Martial Arts Anthropol 2011; 11(3): 47-51
14. Monteiro L, García García JM, Carratala V. The balance and the ratio of pulling-reaping-pushing in elite judokas. In: Proceedings (editors Figueiredo AA, Gutiérrez-García C.) Scientific Congress on Martial Arts and Combat Sports. Associação para o Desenvolvimento e Investigação de Viseu, Instituto Politécnico de Viseu Escola Superior de Educação de Viseu, Viseu – Portugal, 13th–15th May 2011: 77–81
15. Blais L, Trilles F, Lacouture P. Three-dimensional joint dynamics and energy expenditure during the execution of a judo throwing technique (Morote Seoï Nage). J Sports Sci 2007; 25(11): 1211-1220
16. Detanico D, Budal Arins F, Dal Pupo J et al. Strength parameters in judo athletes: An approach using hand dominance and weight categories. Hum Mov 2012; 13(4): 330–336
17. Nowoisky H. The biomechanics of loss of balance in Olympic sport judo, possibilities of measurement of biomechanical parameters. ISBS - Conference Proceedings Archive. 23rd International Symposium on Biomechanics in Sports, Beijing-China, 22nd – 27th August 2005: 600-604

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