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The knee joint extensor and flexor strength indicators in judo female athletes

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

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Abstract

Background & Study Aim: Muscle strength, namely the capacity for overcoming the external resistance or counteracting it at the expense of muscular effort, plays an unquestionably essential role in judo competitor's training. The objective of this study has been knowledge about the values of torques, torque gradient and muscle strength deficit released by knee joint extensors and flexors at rest by judo female competitors, taking up specialist strength training.

Material & Methods: Two female study groups were selected: judo female competitors (n = 15); aged 22.20 ±1.32 years, body weight 67.47 ±13.58 kg, competitor seniority 11 ±1.60 years; reference sample (n = 15) non-full-time in any sports discipline female students of the University of Physical Education (AWF) in Wrocław, Poland: aged 22.20 ±1.26 years, body weight 64.33 ±8.25 kg. A study of knee joint extensors and flexors torque was performed at rest. The measurement was made at 30 and 70 degrees. The properties of a lever in equilibrium were applied: 1) sum of torques acting on a lever equals zero; 2) sum of forces acting on a lever equals zero.

Results: Judo female competitors generate: higher values of torques of both right and left knee joint extensors and flexors at 30°; higher values of torques of both right and left knee joint extensors at 75°; higher mean value of torque gradient of knee joint extensors and flexors at 30 degrees; higher mean value of torque gradient of knee joint extensors and flexors at 75 degrees.

Conclusions: Due to higher maximum values of torque and the torque values being generated within a shorter time than the AWF female students, the competitors show a greater capacity of the muscle for developing higher strength values and a greater capacity for a fast release of strength. The difference must be conditioned by many years of adaptation of the muscle and nervous systems to the effects of sports training as well as a specific nature of that sports discipline; the dynamics of releasing muscle strength, to some extent, determines the speed of performing an action and its effectiveness.

Keywords: deficit value • flexor muscles • muscle strength • strength training • tokui waza

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INTRODUCTION

Physical training activates nervous mechanisms which control the work of skeletal muscles by a multiple repetition of the same movements. Such activation concerns both the processes of triggering and inhibiting and it probably covers neural ensembles involved in the control of movements at all the levels of the central nervous system. As a result it leads to facilitating the neuromuscular coordination, expressed by an increased precision and the speed of movements, a decreased work energy cost due to an improved technique of movements and increased strength acquired during the maximum volitional contraction [1].

Muscle strength, namely the capacity for overcoming the external resistance or counteracting it at the expense of muscular effort, plays an unquestionably essential role in judo competitor's training. Due to the fact that a judo fight involves overcoming external forces by the opponent or opposing him or her, judo competitors face high requirements in terms of the development of that motor characteristic [2].

In the process of control of the effects of strength training in judo competitor, the key test applied by coaches is the measurement of torques of selected muscle groups at rest. In sports the measurements facilitate determining the strength value as the characteristics of fitness, used to evaluate the state of competitors being trained and evaluation of their preparation for the participation in competitions. The result recorded in those tests will significantly inform about what values of relative strength (values of the recorded absolute strength to the body weight) the competitor will be able to develop under dynamic conditions which occur in a judo fight. Since judo represents the group of sports limited by weight categories, most often in those competitors the strength is recorded in terms of the body weight and expressed in units [N* m/kg].

Besides, in judo the measurement of torque gradient is widely applied in studies of the effectiveness of strength training process. Torque gradient determines the ratio of increment in torque to the time in which the increase occurred. Its value thus shows the capacity of the muscle to a fast release of strength [3].

Due to a specific nature of competition in judo (a dynamic way of fighting), that indicator next to the measurement of maximum torque, is an essential indicator demonstrating the adaptation of the muscle and nervous systems in strength training. Higher values of strength gradient revealed in the test inform that very quickly the competitor can reveal the maximum values of strength which will surely enhance the dynamics of a throw, and thus its more effective performance [4].

One of the symptoms of the nervous system adaptation to training is also a decrease or increase in the so-called muscle strength deficit. The term stands for the difference between the values of strength generated by agonists and antagonists (flexors and extensors) of the limb tested separately. Symmetric motor actions are movements which are identical for both parts of the body (e.g., butterfly or breaststroke swimming) [5]. Whenever the sportsmen's limbs, in most of the exercises and during the start movement, are involved symmetrically (e.g. weight lifters), no symmetrical deficit is found [6].

Asymmetrical are such motor actions which are different for each body part (e.g., playing the violin), as well as actions performed once with a single limb (e.g., shot put, discus throw) [7]. In combat sports, such as judo, in which competitors specialise mostly in unilateral fighting, that phenomenon is quite common thus determining its values is also one of the studies performed in this work. Besides muscle strength deficit can become pathological, pointing to the occurrence of focal point of disease in muscle tissue as well as mechanical damage to other structures of the locomotor system. Performing studies of respective muscle groups at rest, one can state or exclude any differences in muscle strength, developed by a group of flexors and extensors of respective limbs.

The objective of this study has been knowledge about the values of torques, torque gradient and muscle strength deficit released by knee joint extensors and flexors at rest by judo female competitors, taking up specialist strength training.

The specific objectives are to answer the following questions:

- is the torque (per kilogram of body weight) of knee joint extensors and flexors generated at 30°higher in judo female competitors?
- is the torque of knee joint extensors and flexors generated at 75° higher in judo female competitors?

Neuromuscular – *adjective* referring to both nerves and muscles [17].

Torque – the application of a force that generates a rotation. As a synonymous of moment of force it would be the product of a force and the distance between the axis of rotation and the force line of action or direction.

Torque – *noun* the force that an object such as a lever exerts on something to cause it to rotate [17].

Strength – *noun* the fact of being strong [17].

Strength training – *noun* training that aims to build muscle strength, usually resistance training [17].

Performance – *noun* the level at which a player or athlete is carrying out their activity, either in relation to others or in relation to personal goals or standards [17].

AWF (is an abbreviation in **Polish Academy of Physical Education)** – an institution of university type providing education in the field of sport science, having full academic rights (from bachelor to a professor with the right to confer a "***doctor honoris causa***" title). In Poland, there are six academies of physical education: the Academy of Physical Education in Katowice, Krakow, Poznan, Warsaw, Wroclaw and the Academy of Physical Education and Sport in Gdansk [18].

Tokui-waza – "favourite" or "best" technique. It's the throw that fits naturally to athlete body type.

Randori – sparring in judo in which both participants practice attacking and defending [19].

- is the time of increment in torque of knee joint extensors and flexors (measured at rest) at 30° higher in judo female competitors?
- is the time of knee joint extensor and flexor strength increment (measured at rest) at 75° greater in judo female competitors?
- does lateralization affect the value of the released muscle torques, and thus the values of muscle strength deficit?
- does, as a result of damage to lower limb structures, the muscle strength deficit value change?

MATERIAL AND METHODS

Participants

For the study two female study groups were selected; 15 people each. The first sample included judo female competitors, aged 22.20 ±1.32 years (Table 1). The second, reference, sample was made up of female students of the University of Physical Education (AWF) in Wrocław; non-full-time in any sports discipline – aged 22.20 ±1.26 years (Table 2).

Study design

The study was performed at the Lab of Function Testing in Internal Diseases at the Department of Physiotherapy in Non-Invasive Medicine and Surgery, the University of Physical Education in Wrocław. To measure the muscle torques in lower limbs, the Biodex System 3 Pro Set Multi-Joint Rehabilitation System, provided by Biodex Medical Systems, was applied.

Biodex, the device which includes the chair and measurement head the adequate tips are fixed to. The selection of the tips depends on what muscle body parts we make the measurement for. The head and the chair are mounted on a sliding rail and mechanically controlled. The second part of the device is made up of the measurement indicator values settling console. The console is connected to the computer which collects the measurement results and facilitates their further analysis.

To measure the muscle torques at rest, the properties of a lever in equilibrium were applied: 1) sum of torques acting on a lever equals zero; 2) sum of forces acting on a lever equals zero.

Table 1. Detailed characteristics of the judo female athletes (n = 15) – ordinal variable: sport class (then: age; body weight; competitors seniority).

Code of judo athlete	Age [years]	Body weight [kg]	Competitor seniority [years]	Sport class	Lateralization		
					two-sided	right-sided	left-sided
J01	23	75	13	master	X		
J02	23	63	11	master		X	
J03	23	52	12	master			X
J04	22	68	13	master			X
J05	22	68	10	master		X	
J06	22	57	12	master		X	
J07	21	88	8	master	X		
J08	21	58	11	master			X
J09	20	62	8	master	X		
J10	25	54	13	first	X		
J11	24	55	12	first	X		
J12	23	64	11	first		X	
J13	22	64	10	first			X
J14	21	97	11	first		X	
J15	21	87	10	first		X	
M	**22.20**	**67.47**	**11.00**	**master (n = 9) first (n = 6)**	**n = 5**	**n = 6**	**n = 4**
SD	**1.32**	**13.58**	**1.60**				
min÷max	**21÷23**	**52÷97**	**8÷13**				

Table 2. Detailed characteristics of the judo female competitors (n = 15) – ordinal variable: age (then: body weight).

Code of person	Age [years]	Body weight [kg]	Lateralization		
			two-sided	right-sided	left-sided
S01	25	55	X		
S02	24	60		X	
S03	23	63		X	
S04	23	61		X	
S05	23	59		X	
S06	23	58			X
S07	22	81	X		
S08	22	79		X	
S09	22	57		X	
S10	21	72			X
S11	21	71			X
S12	21	67		X	
S13	21	65		X	
S14	21	63		X	
S15	21	54			X
M	**22.2**	**64.33**			
SD	**1.26**	**8.25**	**n = 2**	**n = 9**	**n = 4**
min÷max	**21÷25**	**54÷81**			

Prior to the test, the subjects got to know the device structure and operation and before the measurement, a short 15-minute warm-up was made. The subject, having taken her seat in the Biodex chair, was secured with stabilising belts to make a change in the location of the axis of rotation of the joint (translational motion) impossible and to exclude the effect on the result of acting of torques of the other muscle groups. Having stabilized and explained all the procedures, the subjects made three successive test maximum concentric contractions by an extension and flexion in the knee joint. Stabilization was made at the height of arms (the chest), waist and the upper part of the thigh. The limb was supported with a special tip pad, fixed with a Velcro belt. A necessary condition to receive objective results was to balance the device arm. Then the position of the axis of the joint (the joint axis overlapped with the device lever axis) was located and the lever arm length was adjusted to the shin length in the subject. The test involved a measurement of the right and left lower limbs at two angles, successively 30° and 75° for knee joint extensors and flexors. Each measurement was made three times. Each test was 20 sec long, namely 10 seconds of work and 10 sec of rest (Figure 1). For each subject, the testing method was exactly the same.

Statistical analyses

The study results were recorded and statistically processed. The measurement data series were separated for flexors and extensors. For each series the inapplicable data (zero measurements and delay periods) was removed. For such data the maximum values of torques and sections of a linear increment in torque, further used to calculate the torque gradient, were determined. With the partial values, mean values for respective characteristics were reported. The data facilitated performing the analysis of biomechanical features.

RESULTS

A higher mean value of torque generated at 30° per kilogram of body weight was identified for judo female competitors. Higher mean values were recorded in knee joint flexors and extensors in right and left lower limbs. The greatest

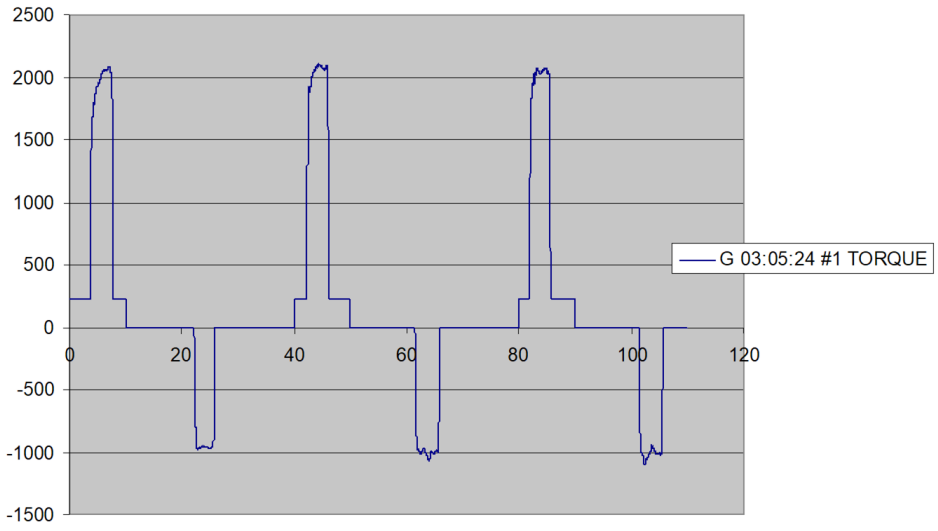

Figure 1. Muscle torques testing pattern in lower limb.

difference between mean values of torque, 37.75 Nm/kg, was noted in extensor muscles in the left lower limb and 27.53 Nm/kg in flexor muscles in the right lower limb. In judo female competitors recorded a 19.26 Nm/kg higher mean value of torque in extensor muscles in the right lower limb, whereas in left lower limb flexors 12.24 Nm/kg higher (Figures 2 and 3).

Considering the results of mean values of torques of knee joint extensors and flexors at 75°, it was found that judo female competitors generate a higher value of strength measured in [Nm/kg] in those muscles, both in the right and the left lower limb. The difference between mean values of torque of extensors in the right lower limb is 86.84 Nm/kg, while in the left lower limb 89.22 [Nm/kg]. The difference in torques generated by flexor muscles is lower, as compared to the above values; in right lower limb flexors 27.06 [Nm/kg] and in left lower limb flexors 18.69 [Nm/kg] (Figures 4 and 5).

The judo competitors generate higher mean values of torque gradient that the AWF students. This is true both at 30 and 75 degrees. The greatest differences in the values of that indicators were noted at

Figure 2. Mean value of torque per kg of body weight [N* m/kg] generated at 30°.

Figure 3. Mean value of torque per kg of body weight [N* m/kg] generated at 30° in percentage values.

75 degrees, in the left and right lower limb extensors; 147.97 [Nm/s] and 112.33 [Nm/s] successively. The difference in mean values at 30 degrees by extensor muscles in the right lower limb was 104.32 [Nm/s] and left lower limb 89.95 [Nm/s]. In flexors slightly smaller differences were reported. At 30 degrees the differences were 40.06 [Nm/s] in the right lower limb, 27.61 [Nm/s] in the left lower limb. At 75 degrees the mean gradient value for right knee joint flexors was 71.08 [Nm/s] higher in judo female competitors, and 27.29 [Nm/s] higher in left knee joint flexors (Figures 3, 5, 6, 7).

The muscle strength deficit value in judo female competitors (Table 3) and non-full-time in any sports discipline AWF female students (Table 4) are analysed in the discussion section.

DISCUSSION

Empirical data confirmed that lateralization affects the muscle strength deficit value. This thesis can be confirmed by the results reported by judo athletes **J07**, **J09**, **J11** in whom, while training and in a

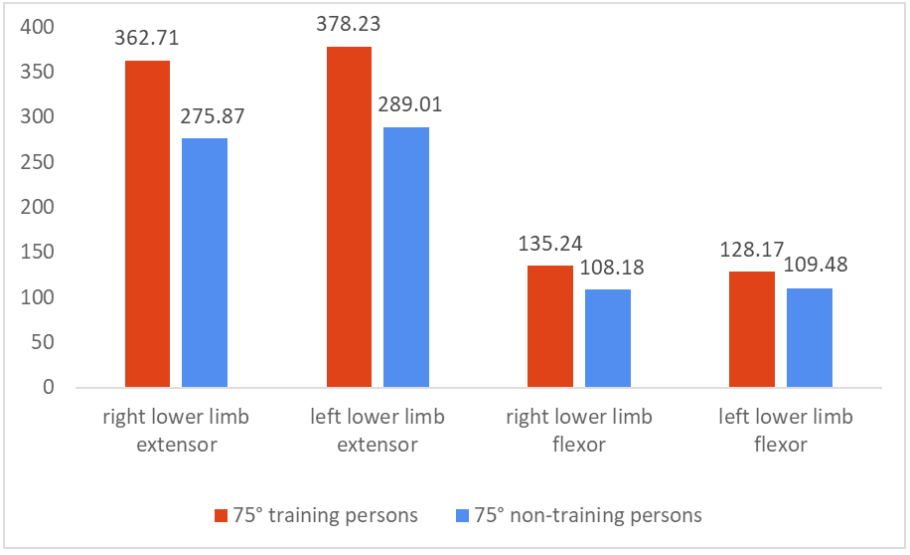

Figure 4. Mean value of torque per kg of body weight [N* m/kg] generated at 75°.

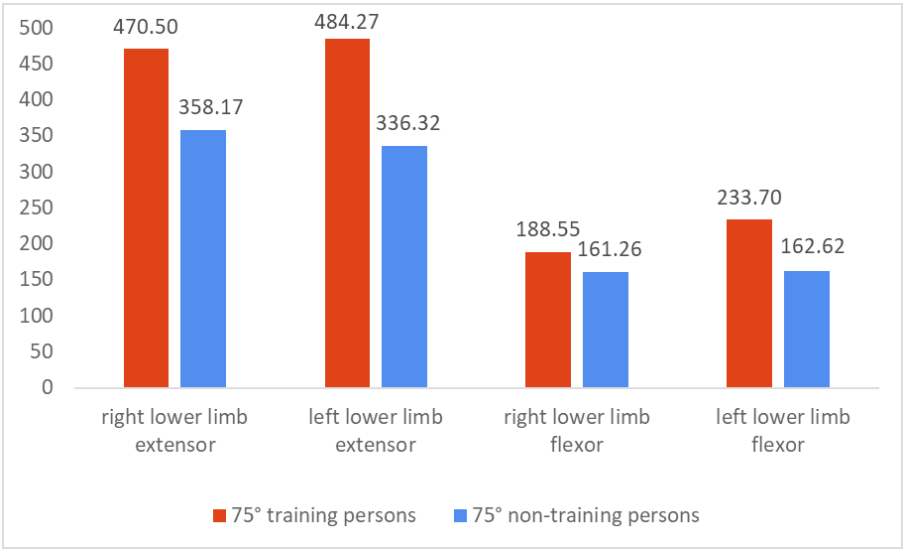

Figure 5. Mean value of torque per kg of body weight [N* m/kg] generated at 75° in percentage values.

sports fight, with the kind of techniques performed and performing them on both sides (both right and left), symmetrically two lower limbs are involved. As a result, the value of muscle strength (at all the angles studied) considered as dependence of flexors to extensors and the other way around, does not show any significant differences. Those female competitors are thus identified with a correct harmonious development of muscle strength. Athlete **J10** demonstrates similar dependencies in terms of strength values, however, due to testing flexors at 75° contraction of the biceps femoris occurred, and the deficit accounted for 15.8%.

The second argument for the justifiability of the thesis are the results reported for the other subjects. Those female competitors in their sports career focused on unilateral (dominant) method of fighting. One can therefore claim that due to many years of muscle and nervous systems adaptation, considerable differences in the values of muscle strength between the right and the left lower limb occurred. In judo athletes **J02, J05, J06, J07, J12, J15** a higher value of strength generated by the left lower limb is recorded, which is due to the function of that limb in throw techniques preferred by the competitors. It is indeed a support

Figure 6. Mean value of torque gradient generated by knee joint extensors and flexors at 30 degrees in percentage values.

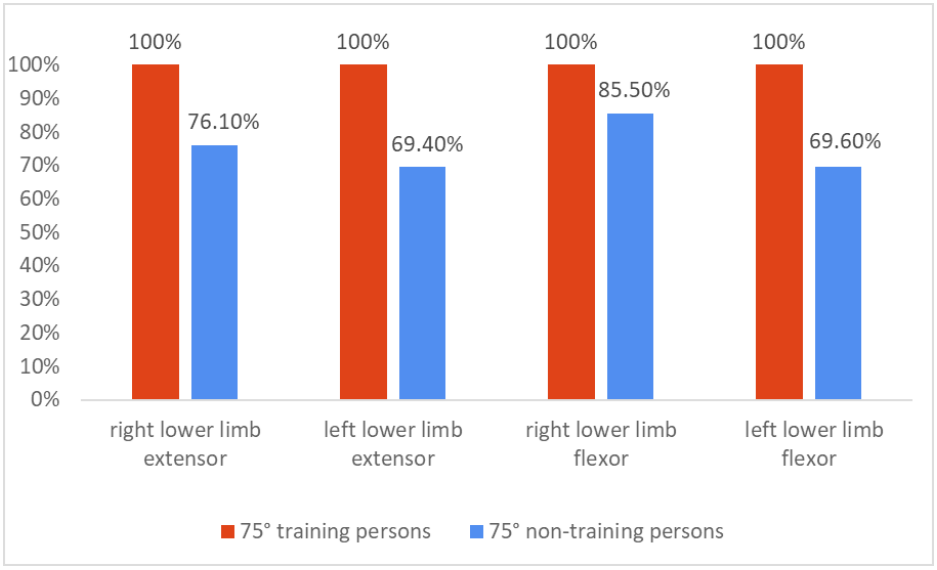

Figure 7. Mean value of torque gradient generated by extensors and knee joint flexors at 75 degrees in percentage values.

for a throwing competitor who carries the weight of both her own body and the resisting opponent. A similar situation was observed in judo athletes **J03, J04 J08, J13** where due to the left-side style of fight and the type of techniques performed, the right limb became the strength-value dominant.

With the data provided in Table 3, one can claim that lateralization affects the muscle strength deficit value, which can be confirmed by the results recorded female students **S01, S02, S04, S05, S06, S09,-S10, S11, S12, S13, S14.** Students **S03, S07, S15** are an exception; their results were not considered since, due to the injury of the lower limb apparatus, they could result in a non-objective final interpretation of the study. In subjects **S01, S02, S04, S06, S09, S10, S11, S12, S13, S14** one finds the muscle strength development compliant with the regularities in ontogeny; lateralization. Student **S08** is an exception to the rule. The subject revealed a right-sided lateralization in her history, whereas her results demonstrate that the right lower limb is weaker than the left one: the extensors at 30 degrees by 16.3%, the extensors at 75 degrees – by 9.4%.

Analysing those results, it was found that female students 2**S14** and 14**S140** showed a considerable muscle strength deficit exceeding the upper extreme limit (more than 25%). Student 2**S14** showed the deficit of 26.7% in extensors at 30 degrees, subject no 14 – the deficit accounting for 21.6 % in knee joint flexors at 30 degrees. That fact reveals that the subjects, to avoid any potential future pathological changes in locomotor system, should enhance their muscle strength in the weaker limb.

The argument in favour of the thesis of this study, in terms of the effect of damage to lower limb structures on the muscle strength deficit value, are the results reported by training judo athletes 7**J01**, 10**J08**, and 11**J12** and non-training students **S03, S07, S15**.

A judo female competitor **J01** showed a strength deficit value ranging from 11% to 25%, at 30° and 75° for left lower limb flexors, which points to weakening of left knee joint flexor muscle strength and which can be accounted for the subject's history (injury of the left knee joint 6 months before). A similar situation is reported forjudo athletes **J04** and **J12**.

As for the non-training persons; **S15**, due to biceps femoris tear (2 years before), reported the strength deficit value of 32.6% in the right lower limb flexors at 30 degrees; student **S07**, as a result of broken fibula in the right lower limb (2 years before), demonstrated a considerable muscle strength deficit at 30 and 75 degrees of flexors and extensors. Similarly **S07**, due to the injury of the right knee joint (1.5 years before), found also a considerable muscle strength deficit at 30 and 75 degrees of flexors and extensors in that lower limb. Besides we recorded that students **S03, S07,**

Table 3. Muscle strength deficit value in judo female competitors (n = 15).

Code of judo athlete	Judo female competitors' muscle strength deficit value								Lateralization	Throw techniques performed (tokui-waza)/ injury
	extension 30°		flexion 30°		extension 75°		extension 75°			
	direction of changes	deficit value	direction of changes	deficit value	direction of changes	deficit value	direction of changes	deficit value		
J01	-	3.0%(I)	R >L	21.2%(II)	-	–7.3%(I)	R >L	19.1%(II)	two-sided	left knee joint injury (6 months before)
J02	L >R	–23.8% (II)	-	3.5% (I)	-	–0.9% (I)	-	–7.1% (I)	right-sided	harai-gosi; uhi-mata; osoto-gari; te-guruma;
J03	-	7.6%(I)	R >L	17.1%(II)	-	–1.3%(I)	-	8.0%(I)	left-sided	taio-toshi; kouchi-gari; osoto-gari;
J04	R >L	26.2%(III)	R >L	11.2%(II)	-	–6.1%(I)	-	3.9%(I)	left-sided	harai- gosi; uhi- mata; ouchi-gari; tani-otoshi; / left knee joint injury (a year before)
J05	L >R	–16.6% (II)	L >R	–10.3%(I)	-	–8.2%9(I)	-	9.2%(I)	right-sided	uhi-mata; ouchi-gari; sasae-tsuri-komi-ashi;
J06	-	–2.2%(I)	-	7.2%(I)	L >R	–12.7%(II)	R >L	16.4%(II)	right-sided	uhi-mata; ouchi-gari; osoto-gari;
J07	-	–2.9% (I)	-	3.2%(I)	-	2.1%(I)	-	–1.7% (I)	two-sided	seoi-nage; harai-goshi; morote-gari; o-goshi;
J08	-	0.6%(I)	R >L	-12.2%(II)	R >L	–25.8%(III)	-	–8.0%(I)	left-sided	harai-gosi; uhi-mata; osoto-gari; kouchi-maki-komi;
J09	-	–5.4% (I)	-	8.7%(I)	-	0.2%(I)	-	–3.6%(I)	two-sided	seoi-nage; sode-tsuri-komi-goshi; kouchi-maki-komi;
J10	-	–2.1%(I)	-	2.9%(I)	-	6.8%(I)	R >L	15.1%(II)	two-sided	seoi-nage; kouchi-maki-komi; during examination, the right lower limb biceps femoris cramp occurred
J11	-	2.1%(I)	-	–2.1%(I)	-	7.7%(I)	R >L	10.9%(I)	two-sided	seoi-nage; kouchi-maki-komi; kata- otoshi;
J12	L >R	–34.7%(III)	L >R	–13.4%(II)	L >R	–17.6%(II)	-	4.7%(I)	right-sided	harai- gosi; uhi- mata; osoto-gari; te-guruma; right knee joint injury (a year before);
J13	R >L	12.0%(II)	-	–1.0%(I)	-	–4.3%(I)	-	0.9% (I)	left-sided	harai- gosi; uhi- mata; tani-otoshi;
J14	L >R	–20.5%(II)	-	–2.1%(I)	-	–6.8%(I)	-	7.9%(I)	right-sided	harai-gosi; osoto-gari;
J15	L >R	–35.1%(III)	-	3.3%(I)	-	–7.0%(I)	R >L	19.8%(II)	right-sided	osoto-gari; ouchi-gari;

I deficit scope 1-10%, a deficit not showing considerable differences between the muscle groups; **II** deficit scope 11-25% , a deficit pointing to considerable disproportions in the muscle strength values informs about a necessity of taking actions to increase the value of strength of weakened muscle group to avoid any potential injuries; in competitors it demonstrates the adaptation due to training process; **III** deficit scope >25%, a deficit informing a necessity of taking actions aiming at eliminating a pathological loss in the muscle strength value; **L >R** left lower limb strength value higher than the right lower limb strength; **R >L** right lower limb strength value higher than the left lower limb strength; **"–"** shows deficit with the turn opposite to lateralization

S15 showed a considerable muscle strength deficit exceeding the upper extreme limit (over 25%) and that, to avoid any future pathological changes of the locomotor system, they should undergo the adequate rehabilitation process.

To recapitulate, the analysis of the material facilitates making an observation that high values of torque, torque gradient and the discrepancies in the strength of right and left lower limb knee joint flexors and extensors, referred to as muscle strength deficit,

Table 4. Muscle strength deficit value in AWF female students' (n = 15).-

Code of students'	AWF female students' muscle strength deficit value									
	extension 30°		flexion 30°		extension 75°		flexion 75°		Lateralization	Lower limb injury/ comments
	direction of changes	deficit value	direction of changes	deficit value	direction of changes	deficit value	direction of changes	deficit value		
S01	-	9.8%(I)	-	3.6%(I)	-	5.6%(I)	-	2.8%(I)	right-sided	-
S02	R >L	13.7%(II)	R >L	16.8%(II)	-	–9.3%(I)	R >L	17.3%(II)	right-sided	
S03	L >R	–11.0%(II)	L >R	–33.6%(III)	L >R	–39.2%(III)	L > R	–33.7%(III)	right-sided	right knee joint injury (1.5 years before)
S04	-	5.1%(I)	-	7.7%(I)	-	-3.9%(I)	R >L	21.8%(II)	right-sided	-
S05	R >L	8.2%(I)	L >R	–24.9%(II)	R >L	11.4%(II)	-	0.3%(I)	right-sided	
S06	-	9.5%(I)	R >L	13.9%(II)	-	2.3%(I)	-	3.4%(I)	right-sided	
S07	L >R	–24.1%(II)	L >R	–34.5%(III)	L >R	–26.1%(III)	L >R	–28.2%(III)	right-sided	broken fibula in the right lower limb 2 years before
S08	L >R	–16.3%(II)	-	3.6%(II)	-	–9.4%(I)	R>L	24.9%(II)	right-sided	-
S09	L >R	15.7%(II)	L >R	12.7%(II)	-	6.8%(I)	-	0.1%(I)	left-sided	-
S10	R >L	12.1%(II)	L >R	21.6%(II)	L >R	20.5%(II)	L >R	40.6%(II)	left-sided	-
S11	-	7.5%(I)	-	7.9%(I)	L >R	6.9%(II)	L >R	15.2%(II)	left-sided	
S12	R >L	15.8%(II)	-	0.9%(I)	R >L	11.9%(I)	R >L	9.4%(I)	right-sided	
S13	R >L	22.1%(II)	R >L	13.2%(II)	-	–5.6%(I)	R >L	10.9%(I)	right-sided	-
S14	R >L	26.7%(III)	R >L	20.8%(III)	-	2.3%(I)	-	1.5%(I)	right-sided	
S15	R >L	15.5%(II)	L >R	–32.6%(III)	-	5.3%(I)	R >L	12.6%(II)	right-sided	biceps femoris tear in right lower limb 2 years before

I deficit scope 1-10%, a deficit not showing considerable differences between the muscle groups; **II** deficit scope 11-25% , a deficit pointing to considerable disproportions in the muscle strength values informs about a necessity of taking actions to increase the value of strength of weakened muscle group to avoid any potential injuries; in competitors it demonstrates the adaptation due to training process; **III** deficit scope >25%, a deficit informing a necessity of taking actions aiming at eliminating a pathological loss in the muscle strength value; **L >R** left lower limb strength value higher than the right lower limb strength; **R >L** right lower limb strength value higher than the left lower limb strength; **"–"** shows deficit with the turn opposite to lateralization

are associated with the judo female competitor's strength training. The term "strength training" is used very generally in this work. In fact, this many years of training consisted of thousands of repetitions of judo athletes preferred for specific judo techniques – *tokui waza* (last column in Table 3) [8-10]. In our opinion, these specific techniques (also preferred during tournament and training fights – *randori*) are often the cause of injuries. In the case of students from the reference group, the causes of body injuries were certainly other circumstances (abstracting from the situation when judo athletes suffered an injury off the mat). In addition, the results of our unique research expand our knowledge about the relationship between lateralization and many health-related phenomena not only for judo athletes [11-13], but also for optimizing training in combat sports [14-16].

CONCLUSIONS

Judo female competitors generate: higher values of torques of both right and left knee joint extensors and flexors at 30°; higher values of torques of both right and left knee joint extensors at 75°; higher mean value of torque gradient of knee joint extensors and flexors at 30 degrees; higher mean value of torque gradient of knee joint extensors and flexors at 75 degrees.

Due to higher maximum values of torque and the torque values being generated within a shorter time than the AWF female students, the competitors show a greater capacity of the muscle for developing higher strength values and a greater capacity for a fast release of strength. The difference

must be conditioned by many years of adaptation of the muscle and nervous systems to the effects of sports training as well as a specific nature of that sports discipline; the dynamics of releasing muscle strength, to some extent, determines the speed of performing an action and its effectiveness.

Due to lower limbs structures damage, the muscle strength deficit value changes. The change deteriorates the injured limb and so the deficit shows a considerably exceeded value in the healthy limb strength.

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