Knee strength ratios in male judokas: age-related differences

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Abstract

Background and Study Aim: Asymmetries and muscle imbalances are associated with increased risk for lower limb injuries. This study aimed to verify the hypothesis that there is a significant difference between judokas of different age categories in the maximum muscular force, as well as in the functional ratio (H/Q_{func}) of thigh muscle for both legs.

Materials and Methods: The sample of participants consisted of 25 judo athletes of senior, junior, and cadet age categories, which were roughly equal by body weight. A sample of the variables used in the study was composed of isokinetic indicators for estimating the muscular force of the flexors and extensors of knee joint at two angular velocities and two contraction modes. To analyze differences between samples included in this study univariate analysis of variance (ANOVA) and LSD Post Hoc test were used.

Results: There were statistically significant differences in the maximum muscular strength between the examined groups and that there were no statistically significant differences in the H/Q_{func} ratio of the thigh muscles of the examinees. A trend of growth of muscular force from cadet to senior age category was observed, as well as the decline of muscular symmetry with the increase in the age category of examinees.

Conclusions: Although no differences were confirmed in each variable for the assessment of muscle strength, there was an evident trend of increasing muscle strength from cadet to senior age category. In many cases of assessed angular velocities and types of muscle contractions, the symmetry of thigh muscles decreased as the age category increased. Based on the results obtained in this study, it can be concluded that judo does not lead to functional asymmetry of the thigh muscles of athletes who belong to different age categories.

Key words: dynamic asymmetry • injury • isokinetic training • velocity

Conflict of interest: Authors have declared that no competing interest exists

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H/Q ratio – unilateral ratio of thigh muscles. This agonist/antagonist ratio is reliable to indicate an insufficiency of particular muscle group [9, 10].

H/Q_{func} – represents eccentric antagonist to concentric agonist strength ratio [8].

H/Q_{conv} – represents antagonist to agonist strength ratio in the same contraction mode [21].

Judo – ***noun*** a Japanese martial art in which opponents use balance and body weight, with minimal physical effort, to throw each other or hold each other in a lock [1].

Isokinetic training – ***noun*** weight training in which the muscle contracts at a constant speed, requiring specialized equipment [1].

Velocity – ***noun*** the rate of change of position in given direction, composed of both speed and direction [1].

Tactics – ***plural noun*** the art of finding and implementing means to achieve immediate or short-term aims [1].

Technique – ***noun*** a way of performing an action [1].

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

Tachi-waza – judo throwing techniques executed from a standing position. These include ***te-waza*** (hand techniques), ***koshi-waza*** (hip techniques), and ***ashi-waza*** (foot and leg techniques) [30]; including also sub classification ***sutemi-waza*** (rear-fall and side-fall judo throws; synonym – "dedication throws").

Tatami – traditional straw mats used in jūdō and aikidō training halls [30].

INTRODUCTION

Judo is a dynamic, high-intensity intermittent sport that requires the possession of complex skills and the exceptional tactical preparedness that is necessary for success [1, 2]. Also, on this topic Franchini et al. [3] stated that competitive judo can be described as a highly intense sport in which competitors try to throw their opponent on the back or control their opponent in a ground battle (fight in a horizontal posture – *ne waza*). Many of the attempts and actions performed during judo fight are highly explosive and require strength and coordination to outwit the opponent through quick technical maneuvers [4, 5]. Judokas need to perform many tries and techniques during each match, which means a physical pressure is placed during each match for every judoka.

The movement structure in judo is hugely demanding. Therefore, the forces of muscular contraction play a crucial role in the performance of throwing techniques in this martial art [6]. Accordingly, the strength of the thigh muscles, as well as the shoulder muscles, can make a difference between successful and less successful judo competitors. These facts indicate that judo is a complex sport with requirements that contain many specific characteristics that are necessary to achieve a high competitive level. Understanding the characteristics of elite athletes can provide beneficial information about what is necessary to achieve competitive success. During the techniques training (*tokui waza*), the athletes improve their performance and prefer the dominant side, which in turn results in differences in strength when testing and comparing dynamic asymmetry. Of course, top athletes differ from those who are less successful precisely in that they strive to equalize the capabilities and abilities of both sides of the body, concerning the longitudinal axis. The mentioned strength imbalance is a risk of injuries, so in many studies, the emphasis is on assessing the imbalance and tendency to symmetry, not only muscular but generally the psycho-physical balance of the athlete.

Drid et al. [7] in their study showed that isokinetic dynamometry could provide beneficial information regarding the detection of the strength of a particular muscle group as well as the timely detection of imbalance between muscle groups in judo. Therefore, isokinetic dynamometry is the optimal way to determine unilateral and bilateral asymmetry between the thigh muscles and thanks to the torque data obtained, relationships within the extremities are easily estimated [8]. Unilateral ratio of thigh muscles is most commonly referred to as the "H/Q ratio" in literature. The aforementioned ratio (agonist/antagonist) can very reliably indicate an insufficiency of a particular muscle group. H/Q ratio is particularly significant in acyclic sports as well as in sports where there is a dominant muscle group in terms of strength [9, 10].

There are two described ratios in the literature for the unilateral asymmetry evaluation, namely conventional (H/Q_{conv}) and functional (H/Q_{func}) ratio. Functional ratio which is considered as more relevant can be calculated by dividing the value of the maximal strength of the knee flexor muscle performed in eccentric contraction mode and the value of the maximal strength of the knee extensor muscle performed in concentric contraction mode, thereby assessing the relative ability of the hamstring muscles to act with eccentric contraction and stabilize the knee in specific actions [8], while the conventional ratio can be calculated by dividing the value of the maximal strength of the knee flexor muscle with the value of the maximal strength of the knee extensor muscle and both performed in concentric contraction mode. Furthermore, the assessment of bilateral asymmetry of the lower extremity musculature is of great importance both for the prevention of injuries and for maximum performance in competitions, and mainly for the dominant use of the left or right side of the body in performing techniques for judo or for example change movement directions in other sport disciplines.

This study aimed is the verification of hypothesis that is there a significant difference between judokas of different age categories in the maximum muscular force, as well as in the functional ratio (H/Q_{func}) of thigh muscle for both legs.

MATERIAL AND METHODS

Three groups of subjects were involved in this study, and the total number of examinees was 25. The first subsample consisted of 8 judokas of the senior age category, the second subsample consisted of 9 judokas of the junior age category, and the third subsample consisted of8 judokas of the cadet age category. All participants involved in this study were morphologically similar (Table 1). All participants were active competitors and medal winners on national and international competitions. All

Table 1. Physical characteristics of the participants.

Variable	Seniors (n = 8)	Juniors (n = 9)	Cadets (n = 8)
	mean ±(SD)	mean ±(SD)	mean ±(SD)
Age (years)	22.50 ±1.85	18.33 ±0.50	16.50 ±0.53
Body height (cm)	182.81 ±10.48	183.72 ±8.53	183.88 ±6.22
Body mass (kg)	82.30 ±17.03	82.22 ±17.40	82.95 ±20.04
BMI	24.37 ±2.28	24.11 ±2.94	24.34 ±4.49

measurements were conducted by ethical rules, and each examinee who participated in the assessments was presented with an explanation of the survey and a predicted measurement procedure to conduct the survey without any disturbing factors and to obtain valid and reliable results.

Finally, the examinees and their parents signed an agreement confirming that they were aware of the purpose and objectives of the measurement, the measurement protocol, and the possible risks of measurement and that they approached the measurement voluntarily. The study was approved by the local Institutional review board of Faculty of Sport and Physical Education, University of Novi Sad (Ref. No. 554/2018; approved at 1 October 2018).

Procedures

This study belongs to the transversal type of studies, and all measurements have been done at the diagnostic center of the Faculty of Sport and Physical Education in Novi Sad. To get valid and reliable results in the variables mentioned above in this research an isokinetic dynamometer was used, from the HUMAC NORM company. The isokinetic dynamometer was calibrated before each test. The range of motion of the examined extremity was 90 degrees. The same person conducted the instructing of the subjects before testing and measuring. A dynamometer was set for each subject according to protocol. Testing began with warming up, followed by a rest period of 2 minutes before performing maximal contractions. Maximal muscle strength of the subjects was performed at an angular velocity of 60°/s and muscle endurance at 180°/s. During the testing protocol, four maximal contractions were performed in a row. The same procedure was performed for both legs in concentric mode, whereas after rest, testing was repeated in eccentric mode.

Statistical analysis

All analyses were performed using the statistical software package IBM SPSS v. 20.0. In the first part of the analysis, descriptive statistics were calculated for all applied indicators. Then, the normality of results distribution was analyzed using the Shapiro-Wilk test, since the formed subsamples were small (7-11 subjects). Accordingly, the one-way ANOVA or Kruskal-Wallis test was used to compare the differences between the scores. The significance of this test has been determined at the alpha level of $p<0.05$, given that this is a small selected group of athletes. Univariate analysis of variance (ANOVA) was used for analyzing differences between age groups. The effect size was estimated by calculating the Eta-squared difference coefficient (η2), using the following criteria: a negligible effect to 0.01, a little effect from 0.01 to 0.06, a medium effect from 0.06 to 0.14, and large effect over 0.14 [11].

RESULTS

No significant differences were found between three groups in maximal strength of thigh muscles for both legs in 60°/s of concentric contraction. The variable *maximal strength of knee extensor of right leg* (KER) was closest to statistical significance ($p = 0.055$), but still was above normative. Results for maximal strength of thigh muscles for both legs in 180°/s of concentric contraction, show statistical significant differences ($p = 0.017$), with large effect size (0.31%) showed up in variable *maximal strength of knee extensor of left leg*

Table 2. Differences in mean values of maximal strength of thigh muscles for both legs in concentric contraction mode (60º/s and 180º/s) between seniors, juniors and cadets.

Variable	Seniors (n = 8)	Juniors (n =9)	Cadets (n = 8)	F	p	η^2
	mean ±(SD)	mean ±(SD)	mean ±(SD)			
KER60 º/s con	239.88 ±41.35[b,c]	238.11 ±59.2[c]	178.00 ±62.19	3.316	0.055	0.232
KEL60 º/s con	242.50 ±41.41[b,c]	241.33 ±55.4[c]	186.50 ±57.81	3.059	0.067	0.218
KFR60 º/s con	152.38 ±30.96	155.78 ±62.76	120.25 ±34.80	1.487	0.248	0.119
KFL60 º/s con	161.88 ±40.12	164.00 ±54.94	126.50 ±31.06	1.895	0.174	0.147
KER180 º/s con	154.63 ±30.78	156.56 ±48.84[c]	116.75 ±33.99	2.684	0.091	0.196
KEL180 º/s con	158.00 ±24.63[c]	159.00 ±38.00[cc]	114.00 ±34.12	4.957	0.017	0.311
KFR180 º/s con	118.00 ±25.49	113.33 ±43.17	89.00 ±6.61	2.016	0.157	0.155
KFL180 º/s con	118.38 ±30.37	122.67 ±33.74	94.38 ±18.32	2.353	0.119	0.176

Abbreviations: **SD** standard deviation; **F** values of F test; **p** statistical significance; η2 effect size difference, **KER** knee extensor of right leg; **KEL** knee extensor of left leg; **KFR** knee flexor of right leg; **KFL** knee flexor of left leg; **con** concentric contraction; **a** statistically significantly higher than seniors at significance level p<0.05, **b** statistically significantly higher than juniors at significance level p<0.05, **c** statistically significantly higher than cadets at significance level p<0.05; **cc** statistically significantly higher than cadets at significance level p<0.01.

(KEL). Analyzing the result with LSD Post Hoc test differences showed up between juniors and cadets at a significant level of p<0.05 in variable KER in the aforementioned angular velocity. Additional to that, statistically significant differences obtained in variable KEL between seniors and cadets at a significance level of p<0.05 and between juniors and cadets at a significance level of p<0.01 (Table 2).

Table 3 shows results for maximal strength of thigh muscles at 180°/s, with no statistically significant difference.

There were no statistically significant differences between testing groups for the unilateral conventional ratio (H/Q_{conv}) of the thigh muscles for both legs at 60°/s performed at concentric contraction mode. As regards to second angular velocity (180°/s) for the same ratio, results show that there were no statistically significant differences between those groups for both legs. The value which has a group of cadets for left leg is the nearest to the statistical significance (p = 0.29). Results of H/Q_{conv} ratio at 60°/s of eccentric contraction show that there were no statistically significant differences between tested groups for both legs. Although there were no statistically significant differences, juniors had the biggest value (68.1%), following a group of cadets (67.9%) and seniors (61.7%), which presents almost the benchmark of normal values. As for the same ratio but at 180°/s angular velocity, it can be said that there were also no statistically significant differences for either the right or left leg of tested groups and the values were within normal limits (Table 4).

The analysis of differences for the unilateral functional ratio of thigh muscles (H/Q_{func}) and results for the right leg indicate that there are no statistically significant differences in this variable. The results are the same for the left leg (Table 5).

When considering the ratio of flexors of the dominant and non-dominant leg, it is possible to determine that there was a statistically significant difference between tested groups (p = 0.028). Thus, the highest values and above referent (<10%) had a group of seniors (11.2%), and right behind them were cadets and juniors (7.79%; 4.58%, respectively), which are below values that indicate a certain degree of risk of injury (10-15%) (Table 6).

Table 3. Differences in values of maximal strength of thigh muscles at 60º/s and 180º/s eccentric contraction between seniors, juniors and cadets.

Variable	Seniors (n = 8)	Juniors (n =9)	Cadets (n = 8)	F	p	η²
	mean ±(SD)	mean ±(SD)	mean ±(SD)			
KER60 º/s ecc	276.75 ±64.20	280.67 ±103.53	225.25 ±58.45	1.245	0.307	0.102
KEL60 º/s ecc	278.50 ±57.54	283.89 ±99.03	235.25 ±83.48	0.855	0.439	0.072
KFR60 º/s ecc	172.88 ±34.48	187.11 ±93.30	150.38 ±22.30	0.779	0.471	0.066
KFL60 º/s ecc	170.88 ±39.79	195.11 ±90.38	155.13 ±45.93	0.836	0.447	0.071
KER180 º/s ecc	263.75 ±70.72	275.89 ±94.50	213.25 ±60.08	1.524	0.240	0.122
KEL180 º/s ecc	282.25 ±57.31	273.22 ±104.46	231.50 ±87.13	0.797	0.463	0.068
KFR180 º/s ecc	169.50 ±37.83	195.33 ±91.60	142.13 ±17.14	1.666	0.212	0.132
KFL180 º/s ecc	178.75 ±41.59	203.33 ±82.18	144.63 ±40.30	2.079	0.149	0.159

Abbreviations: **ecc** eccentric contraction

Table 4. Differences in values of unilateral conventional ratio (%) for both legs at 60º/s and 180º/s concentric and eccentric contraction between groups.

Variable Leg mean ±(SD)		Seniors (n = 8)	Juniors (n =9)	Cadets (n = 8)	F	p
		mean ±(SD)	mean ±(SD)	mean ±(SD)		
Con 60º/s KF/KE	R	63.77 ±9.2	65.7 ±20.6	69.3 ±11.1	0.291	0.751
	L	66.4 ±10.5	68.0 ±15.9	69.3 ±9.3	0.111	0.895
Con 180º/s KF/KE	R	77.1 ±14.0	72.7 ±18.5	78.5 ±12.6	0.331	0.722
	L	74.3 ±12.4	77.6 ±15.0	85.6 ±15.5	1.286	0.296
Ecc 60º/s KF/KE	R	63.5 ±10.4	65.5 ±10.6	68.3 ±8.3	0.470	0.631
	L	61.7 ±9.7	68.1 ±11.4	67.9 ±10.9	0.932	0.409
Ecc 180º/s KF/KE	R	65.8 ±12.6	69.1 ±10.5	69.3 ±11.5	0.238	0.790
	L	63.8 ±12.9	74.8 ±12.5	66.2 ±14.0	1.675	0.210

Abbreviations: **KF/KE** ratio knee flexor/extensor; **R** right; **L** left.

DISCUSSION

We found no differences between groups for the assessment of muscle strength, although there was an evident trend of increasing muscle strength from cadet to senior age category. Therefore, the hypothesis turned out to be false.

Dynamic asymmetry represents the differences in muscle strength between opposite sides of the human body. One of the segments of dynamic asymmetry is the asymmetry in the strength of the individual extremity, known as unilateral asymmetry, in which strength of agonist and antagonist muscles are in relation. The balance between agonist and antagonist muscles is crucial for the stabilization of joint structure during dynamic muscle contractions [12]. In addition, a very important segment of dynamic asymmetry is a bilateral asymmetry, which indicates an imbalance in muscle strength of opposite sides

Table 5. Differences in values of unilateral functional ratio (%) for both legs at 60º/ between groups.

Variable		Seniors (n = 8)	Juniors (n =9)	Cadets (n = 8)	F	p
Ecc/Con 60º/s	Leg	mean ±(SD)	mean ±(SD)	mean ±(SD)		
KFecc/KEcon	R	72.4 ±11.7	77.9 ±24.8	90.5 ±24.1	1.536	0.237
	L	71.2 ±15.8	81.1 ±27.6	83.9 ±9.9	0.917	0.415

Table 6. Differences in values of bilateral ratio (%) of thigh muscles of the dominant and non-dominant leg at 60º/s of concentric contraction between groups.

Variable	Seniors (n = 8)	Juniors (n =9)	Cadets (n = 8)	F	p
Con 60º/s	mean ±(SD)	mean ±(SD)	mean ±(SD)		
KEdom/KEnondom	4.33 ±2.68	4.59 ±2.75	7.16 ±8.7	0.670	0.522
KFdom/KFnondom	11.2 ±5.9	4.58 ±3.25	7.79 ±4.68	4.235	0.028

Abbreviations: **KEdom/KEnondom** ratio knee extensor of dominant leg/knee extensor of non-dominant leg; **KFdom/KFnondom** ratio knee flexor of dominant leg/knee flexor of non-dominant leg.

of the human body. Bilateral imbalances between opposite sides of the human body can be caused by several factors, such as hand dominance, leg dominance, previous injury and specific motor requirements in sports [13, 14]. Concerning all of the mentioned, after analyzing differences in maximal muscle strength between three groups of subjects, it was valuable to estimate unilateral and bilateral ratios between groups and have information about statically significant differences and productivity of asymmetry during growing up in all three categories. Thus, in this study were estimated unilateral conventional ratio at both contraction modes, unilateral functional and bilateral ratio between knee extensors and flexors.

In Table 4. are presented the results of unilateral conventional ratio (H/Q_{conv}) estimated at 60°/s of concentric contraction and regarding evident is that there were no statistically significant differences between groups such as values are within a normal range (>60%) [15]. Therefore, it is important to mention that the highest value of this ratio had cadets for both legs with identical values (69.3%). Behind them are juniors and with the most considerable asymmetry of those three groups were seniors, but as mentioned, within a normal range. Concerning aforementioned, it can be said that asymmetry increases in line with age categories.

Now, after all being said about maximal muscle strength and just mentioned ratio between subjects in this study, it could be concluded that strength is increasing as age category increases, but symmetry between agonist and antagonist of thigh muscles are decreasing as age category increases.

As increase in angular velocity was notable, it was considered that asymmetry increased as well [16]. Thus, several studies proved that if gravity influence annulled during testing will not significantly change the level of asymmetry [17-19]. However, some researches ascertained that the normal ratio is in a range of 0.60 to 0.80, and if testing angular velocity the range is 60 to 240 [15, 20].

Regarding that, for an estimate, a unilateral conventional ratio at 180°/s kept the same normal limit as for the slower angular velocity (60%). Thus, statistically significant differences between tested groups in the variable unilateral conventional ratio (H/Q_{conv}) do not exist even in the case of increasing angular velocity. Whatever, it is possible to observe the higher values of symmetry relative to values estimated at the slower angular velocity. The highest values of H/Q_{conv} ratio of the right leg had a group of cadets (78.5%), right behind them was a group of seniors (77.1%), but the lowest values of this ratio had a group of juniors (72.7%). Values of the same ration, but for the left leg were also the highest in a group of cadets (85.6%), right behind them were a group of juniors (77.6%), and the lowest values had a group of seniors (74.3%).

Additionaly, this study estimated H/Q_{conv} ratio for both legs at 60°/s and 180°/s of eccentric contraction between mentioned groups of subjects. Thus, in the right leg ratio, there were no statistically significant differences between subjects at 60°/s ecc, but values were within the normal range of this ratio. As in previously presented contraction mode, a group of cadets had the highest values of this ratio (68.3%), than a group of juniors (65.5%), and the lowest values had a group of seniors (63.5%). As for the right leg, values of the left were in the normal range with no statistically significant differences. The highest values were in a group of juniors (68.1%), following a group of cadets (67.9%), and the lowest values had seniors (61.7%). In the same ratio, but at a higher angular velocity, no statistically significant differences were observed for both legs between the tested groups. Recorded values for the right leg were higher than those indicating the risk of injury. Cadets and juniors had almost the same values (69.3%; 69.1%, respectively), but seniors had lower values (65.8%). Estimated values for the left leg were an above-set limit of the ratio (60%), but with a difference that, in this case, juniors had the highest values in this variable (74.8%), after them cadets (66.2%) and seniors (63.8%).

The estimation of isokinetic eccentric antagonist muscle strength relative to the agonist muscle strength perform at concentric mode may give a reliable value ratio in describing the potential of the antagonist muscle group. According to that, the mentioned ratio presents a useful method in showing a risk of injury relative to the conventional H/Q_{conv} ratio [21]. The functional ratio known as "dynamic control ratio" for the first time was used by Dvir et al. [22]. Since then, H/Q functional ratio is used more often to impress the eccentric-concentric ratio. Unilateral functional ratio (H_{ecc}/Q_{con}) indicate knee joint muscle stabilization at preforming specific actions, even for flexion or extension in the mentioned joint [20].

Regarding that, subjects included in this research were exposed to estimation of unilateral functional ratio. Results showed that there were no statistically significant differences for both legs and values presented an above limit suggested in this research as the risk of injury (60%). Cadets, in this case, showed extremely high values of H/Q_{func} ratio of the right leg (90.5%), juniors and seniors demonstrated lower values than cadets (77.9%; 72.4%, respectively), but still in the normal range. Therefore, cadets have shown the most significant symmetry value of left leg (83.9%), while juniors and seniors demonstrated lower values than cadets (81.1%; 71.2%, respectively), but again within the normal range.

A bilateral ratio of a dominant and non-dominant leg at 60°/s in concentric contraction mode was calculated. Eliot [23] set a limit of 10-15% as the low-level risk of injury, but the limit of 20% set as a high-level risk of injury [24]. Thus, there was no statistically significant difference for the extensor muscle of lower extremities of subjects included in this study for the mentioned variable. In addition, the lower values of this ratio were in a group of seniors (4.33%), greater values were in a group of juniors (4.59%), and the highest values, but still in the normal range, were in a group of cadets (7.16%). In the same ratio but for the flexors of both legs statistically significant difference with significance level of p = 0.02 was observed. It was noted that the highest values are in a group of seniors (11.2%) and those values were in a category of risk of injury (10-15%). The subjects from a group of cadets had values below 10%, accurately 7.79%, and the lower values were in a group of juniors (4.58%), which were almost identical to those noted for extensor muscle of lower extremities.

It can be noted in Table 1. that for all participants, the bodyweight was almost equal, it can further be suggested that the cadet age category subjects had less muscle mass compared to other subjects. This proposal is based on the observed values of maximal muscle strength in which the youngest respondents had the lowest scores of the mentioned variable. This proposal was based on research conducted by Drid et al. [25] in which they presented the results of seniors in the half-heavyweight category who demonstrated higher scores in maximal thigh muscle strength compared to other participants.

Thus, in the mentioned study, national and international level judokas in half-heavyweight category were tested and the best results of maximal strength of left knee extensor muscles were noted for international level judokas (308.06Nm) at 60°/s with average values of body weight 100.70kg. Concerning this information, in this study, the best values at 60°/s performed subjects, which belong to a group of seniors (239.88Nm), but noticeably lower relative to respondents we compared with. It is obvious that the higher mass in professional sport, especially in judo, indicates higher muscle mass, which allows better production of muscle force. In the study conducted by Radjo et al. [26] paradox was noted, but it matches to proposals mentioned above. Thus, in the mentioned study, judokas from the middle category had an average body mass of 75.27kg, but for all subjects in this study, mean bodyweight was approximately 82kg. It is evident that they had lower body mass values, but higher numerical values of maximal knee extensor strength at 60°/s in concentric contraction mode. In a study carried out by Radjo et al. [26] subjects' values for the right extensor were (254.9Nm); left extensor (266Nm). To be able to discuss this topic more accurately, the same subjects included in this study should undergo a body composition assessment and determine whether this is one of the possible reasons why cadet age subjects produce less muscle force than older subjects, even if they are approximate in body weight values.

Thus, Drid et al. [27] in their research obtained values of bilateral ratio at a subsample of seniors, indicating the difference between knee extensor muscles of the right and left leg were 0.15%, whereas respondents in this study had values 4.33%. The values of knee flexor muscles of the right and left leg, from the mentioned study, were 8%, and respondents from this study had values above the allowed limit of 10% (11.2%). In research conducted by Drid et al. [27] extremely low H/Q ratio values of right and left leg in a group of senior judokas was observed. Thus, noted values were 40.54% for the right and 40.84% for the left leg at 60°/s in concentric contraction mode, but in our study for a group of seniors and for the same variable values were 67.77% for the right and 66.4% for the left leg. Observing the results, it is evident that there was no enough muscle force in knee flexor muscles. The participants in the mentioned study had values of knee flexor of right leg 109.20Nm and left leg 110.07Nm, while in this study, seniors had values of knee flexor of right leg 152.8Nm and left leg 161.88Nm.

Thus, it would be useful observe the relation between judo and other sports and compare the results between subjects from this study and those from a team sport, for example football players examined by Radjo et al. [26]. In the mentioned study statistically significant differences were found in strength of thigh muscles between judokas and football players, but if we compare values of maximal strength with our study sample, which had almost equal values of muscle mass and body mass index, it may be concluded that judokas have higher numerical values of maximal strength at 60°/s at concentric contraction than football players. The greater difference was evident in values of knee flexor muscles (judokas: right 155.78Nm, left 164Nm; football players: right 128.34Nm, left 128.48Nm), than in values of knee extensor muscles, but still, in that variable judokas also had higher numerical values compared to football players.

Regarding that success in judo highly dependents on maximal strength of lower extremities, greater values are expected to appear among judokas than in football players, because their success is less dependent on maximal strength of lower extremities compared to judokas in their sport [26]. As an explanation of those results, it can be said that the difference in the level of strength may appear due to performance of specific throwing techniques in judo, like *uchi-mata*, *harai-goshi*, *osoto-gari*, *and ouchi-gari* [28, 29]. Nevertheless, the smaller ratio was obvious at H/Q_{conv} 60°/s in football players related to the ratio of our study participants. Thus, football players demonstrated values of 54.59% for the right leg and 56.46% for the left leg, but respondents who belonged to a group of juniors presented values of 65.7% for right and 68% for the left leg.

It can be said that the limitation of this study is a small sample size, and a recommendation for future research, besides a larger group of participants could be an assessment of a female judokas' thigh muscle strength. The next research can be longitudinal, which means that it will be useful to supervise the ontogenetical development of each participant from the cadet to the senior age category in specific time intervals, and acquire reliable insight of differences between all subjects.

CONCLUSIONS

Although no differences were confirmed in each variable for the assessment of muscle strength, there was an evident trend of increasing muscle strength from cadet to senior age category. In many cases of assessed angular velocities and types of muscle contraction, the symmetry of thigh muscles decreased as the age category increased. Thus, all people who are leading someone's training process should be aware of the importance of adapting the training process to current possibilities of athletes and ensure the parallel development of muscles of both lower extremities. It is important to have balanced development of an agonistic and antagonistic group of muscles of both lower extremities.

Judo is a sport in which physical or even technical ambidexterity is very important, which is necessary for performing many techniques during training or fighting in a judo competition. The best judo athletes tend to master the technique on both sides of the body and use them concerning the situation that occurred on the tatami at the moment, rather than in the relationship of which hand or leg is dominant. As confirmed in many studies, it is evident that estimating maximal torque can be useful for judokas of different age categories. Additionally, asymmetry can be detected, which has to be monitored and adequately treated.

Thanks to isokinetic muscle strength (torque) tests, it is possible to have a current condition of athlete's muscle groups, and an imbalance (ratio) between muscle groups. However, the main cause of injuries among athletes is the imbalance mentioned above. If there is an imbalance, the muscles will produce a different level of force during the movement, leading to damage the weaker muscles involved in the movement protocol. The crucial isokinetic role is in the process of recovalence of athletes. Therefore, if we want to estimate the condition of athlete after injury or after treatment, to investigate whether the muscle functionality is at the level it was before the injury and when will the athlete be ready to return to usual activities. Moreover, the role of isokinetic is to estimate the quality of a particular experimental treatment conducted in a longitudinal study, for example, when the goal is to evaluate the efficiency and influence of specific training programs on muscle strength improvement in particular sport. Based on the results obtained in this study, it can be concluded that judo does not lead to functional asymmetry of the thigh muscles of athletes who belong to different age categories.

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