ORGINAL SCIENTIFIC PAPER

Dejan Cokorilo[1]
[1] Faculty of sport and physical education, Novi Sad
UDK: 796.817.26
DOI: 10.7251/SIZ0217013C

DIFFERENCES IN MANIFESTATION OF PEAK TORQUE OF THIGH MUSCULATURE AT DIFFERENT ANGULAR VELOCITIES IN KARATE ATHLETES

Abstract

The main goal of this research was to determine differences in manifestation of peak torque of agonist and antagonist muscles of the thigh, at different angular velocities in karate athletes of different age groups, as well as to determine unilateral (hamstring/quadriceps) and bilateral relationships (left/right leg) based on these values. Potential muscle imbalance around the knee area and between the left and right leg is determined via unilateral and bilateral relationships. Several studies showed that the reduced strength relationship between the hamstring and the quadriceps muscle results in an increased rate and incidence of the lower leg injuries, such as rupture of anterior cruciate ligament (ACL), overuse syndrome, hamstring strains and tears. The testing was performed on an isokinetic dynamometer, which consisted the evaluation of peak torque of the quadriceps and hamstring muscles at velocities of 60°/s and 180°/s, for both concentric and eccentric muscle actions. The sample size consisted of 28 karate athletes, separated into tri age groups: cadet, junior and senior. The results of this research showed that for both concentric and eccentric muscle actions statistically significant differences (p≤0,05) between variables of maximal torque development of knee flexors and knee extensor muscles at different angular velocities within all age groups are present. At the velocity of 180°/s values of peak torque were smaller. As regards to the unilateral relationship, it was determined that statistically significant differences are present at different speeds across all age groups. Greater values were obtained at velocities of 180°/s. No significant differences were noticed between bilateral relationships at different velocities within all age groups. The values of unilateral relationship among this age group ranged from 50% to 80%, which according to the commonly accepted criteria doesn't sort them in a group of athletes with increased injury risk. On the other hand, the values of bilateral relationship among some age groups surpassed the limit of 10% which was taken as a reference point. Therefore, it was recommended to these athletes to undertake certain precautionary measures in order to correct this difference.

Key words: *karate athletes; isokinetic; peak torque; bilateral relationship; unilateral relationship*;

INTRODUCTION

Karate or karatedo (jap. Empty hand, or more precisely the way of the empty hand) is a martial art which originated in Japan. In a literal translation „kara" means empty, „te" means hand or fist, thus an empty hand, or how to defend, or to fight „without using weapons" (Chaabene et al., 2012). As a sport discipline karate demands a high level of technical skills and proficiency, precise movement control in both static and dynamic conditions, along with the capability of executing techniques (blocks, hits, strikes, sweeps, undertakes, false actions, tricks etc.) in the shortest amount of time (Wilk et al., 1983; Sorensen et al., 1996; Zehr et al., 1997; Mori et al., 2002). In order to efficiently and successfully participate in this martial art, an athlete must possess highly developed aerobic and anaerobic capacities, as well as a high level of explosive strength, reaction speed and a satisfactory strength level. Nowadays, karate is one of the most massively participated individual sports which consists of two competition disciplines: forms (katas) and sport battle (kumite) (Koropanovski et al., 2011).

Manifestation of peak torque of the upper thigh musculature in karate athletes was measured via the isokinetic dynamometer. Isokinetic represent a method of engaging muscles in an active motion during which constant speed is chosen, while the resistance is automatically adjusted. As opposed to isometric exercises, in which the speed and resistance remain unchanged, and isotonic exercises, in which the velocity varies, and the resistance remains constant, in isokinetic exercises movement is performed under constant velocity (dynamic speed, 1-300°/s) with adjustable resistance. Isokinetic method is used in both diagnostic (evaluation) and rehabilitation purposes. Isokinetic devices provide conditions for athletes to develop maximal force in full range of motion (ROM) whilst at the same time adjusting and accommodating resistance according to pain sensations or fatigue occurrence. Therefore, the occurrence of overloading the muscle or joint structures is avoided (Drid et al., 2009). Isokinetic testing devices are used for evaluating the current conditions of the locomotion system, by quantitatively testing the strength levels of selected muscle groups under different movement velocities. During the testing process of extremities, slower velocities are most commonly used for measuring the maximal strength capabilities, and on the other hand greater velocities are used (with greater number of repetitions) for determining muscle endurance capabilities.

It is possible to obtain the following parameters when using isokinetic testing method: strength capabilities of certain selected muscle groups, strength relationship between agonists and antagonists, bilateral comparison of the same muscle groups, the amount of total work, muscle endurance expressed via the fatigue index, range of motion for the tested joint etc.

Testing on an isokinetic dynamometer included both the flexor and extensor muscles of the knee joint at velocities of 60°/s and 180°/s, in both concentric and eccentric muscle regimes. One of the basic parameters which was used in this research paper was the peak torque. Peak torque (Nm) represents maximal value of rotational force developed during measured movement at certain angular velocity (Jaric, 2002). Based on this parameter differences between karate athletes at different angular velocities were determined, so that potential muscle imbalance around the knee joint could be determined. Muscle imbalance around the knee joint has been previously addresses in several studies which have shown that a reduced strength relationship between knee flexors and extensors results in increased incidence of lower limb injuries, such as ACL ruptures, overuse syndrome, hamstring strains and ruptures, etc. (Knapik et al., 1991; Aagaard et al., 1998). This is determined via the unilateral relationship. Data obtained from the isokinetic dynamometer present a very valuable piece of information for both the coach and the athlete, because it ensures precise planning of the training process, as well as preventing a great number of injuries at the same time.

Unilateral relationship, i.e. relationship between flexor and extensor muscles of the knee joint is considered a relatively good indicator of normal – physiological strength balance of antagonist muscles of the knee joint, but it greatly depends on the velocities at which isokinetic testing is performed. For lower testing velocities (0º/s – 60º/s) it amounts to 50%-60% depending on the participants and the testing device used. Unilateral relationships (agonist/antagonist) of upper thigh musculature are most commonly termed in the literature as "H/Q ratio". Relationship between agonists and antagonists may point to weakness of certain muscles group. "Conventional" relationship is the most commonly described relationship in the literature and it is calculated by dividing values of peak torque of concentric hamstring contraction by the value of peak torque of the concentric quadriceps contraction (H/Q_{CONV}). However it is believed that the "functional" relationship (H/Q_{FUNC}) is more relevant. In order to calculate the functional relationship, relationship of the values of peak torque of eccentric hamstring contraction need to be divided by concentric quadriceps muscle peak torque. That way the relative capability of the hamstring muscle to function in an eccentric contraction and therefore function as knee stabilizer is estimated, which is a situation that occurs very frequently across a wide spectrum of sport activities (Ayala et al., 2012). Most authors use 50% and 80% as reference values for conventional relationship between knee flexors and extensors (Andrade et al., 2012). According to Ayala et al. functional relationship between hamstring and quadriceps muscles which is less than 0.6, increases the chance of suffering from a hamstring injury seventeen fold. Functional relationship from 0.7 to 1 is accepted as sufficient for maintaining dynamic stability and integrity. 1 to 1 (1:1) relationship has been accepted as a reference value.

As for the bilateral relationship, one of the studies defined musculoskeletal abnormalities as bilateral imbalance of strength of the quadriceps muscle and hamstring muscle that is greater than 10%

(Rahnama et al., 2005). On the other hand Knapik et al. have defined the bilateral relationships between hamstring and quadriceps muscles as all values greater than 15%.

Skaton-Silva et al., (2012) in their research of estimating muscle efficiency of dominant and non-dominant extremities obtained results that the imbalance between agonists and antagonists (for knee and elbow joints) is less than 10%, therefore the group of authors concluded that daily karate practice doesn't lead to bilateral asymmetry which may results in increased injury incidence of neither the lower limbs nor the upper limbs. Probst et al., (2007) have researched flexibility and strength levels of the lower limbs (muscle balance of agonist and antagonists) and knee stability during the execution of specific leg karate techniques, with assumption that additional overload of the leg musculature will result in negative outcomes during the performance of karate specific techniques, stances, and movements, as well as in an increased risk of knee injury. The authors concluded that karate training process resulted in significant improvements in strength levels of the quadriceps muscle and to in a decreased time to the onset of muscle contraction without concomitant and accompanying risk of knee injury. The authors also found that certain aspects of karate training process, such as the frontal direct kick (jap. Mae-Geri), can be implemented as part of other sports, especially in those sports where a high level of quadriceps strength is required with a concomitant short time until the onset of muscular activity. The results of these research studies benefit the well-known fact that all four extremities are included within karate training process. The results of flexibility tests between the control group and the karate group, which evaluated flexion, extension of the knee joint, hip joint and ankle joint, as well as their rotational capabilities, showed that the flexibility presents a very important component of many sports, and to karate sport as well (due to great amplitudes of Jodan kicks). However, the most surprising fact is that within the same research study, the results obtained for the flexibility levels of the lower limbs, and especially of the hamstring muscles, of the karate group were worse compared to the same results of the control group.

The problem of research presents an analysis of differences in manifestation of peak torque of the upper lower limb musculature at different angular velocities in karate athletes. The object of research was the manifestation of peak torque of the upper thigh musculature in karate athletes. The main goal research was to determine differences in manifestation of peak torque of the agonist and antagonist muscles of the upper thigh musculature, at different angular velocities in karate athletes of different age, and based on these results to calculate unilateral (hamstring/quadriceps) and bilateral relationships (left/right leg). On the foundations of the main goal, partial goals have also been devised:

1. To determine the unilateral relationship differences (hamstring/quadriceps), at different angular velocities in the manifestation of peak torque of the upper thigh musculature in karate athletes of different age.

2. To determine the bilateral relationship differences (left/right leg) at different angular velocities in the manifestation of peak torque of the upper thigh musculature in karate athletes of different age.

METHOD

The sample size consisted of n=28 karate athletes, of cadet, junior and senior age. They were divided into three groups: 9 senior karate athletes (24,1 ± 3,72 years); 9 junior karate athletes (17,6 ± 0,84 years); 10 cadet karate athletes (15,85 ± 0,69 years); All participants were competitive athletes, winners of international and state level championships. All tests were carried out within the ethical rules and guidelines and each participant has been presented with a clear and thorough explanation of the testing procedure, potential dangers and benefits as well as expected outcomes of the testing process.

For testing isokinetic strength levels of the hamstring and quadriceps musculature a HUMAN NORM isokinetic dynamometer was used. The device was recalibrated before each testing procedure. The device recorded the following values: peak torque, peak torque expressed as percentage of the total body mass, maximal work and total work expressed as percentage of total body mass. The same procedure was carried out for both left and right legs (Madsem et al., 1996: Gleeson et al., 1996). The range of motion (ROM) of the tested lower leg limb was 90 degrees. The same person carried out the instruction process before testing and during the testing process.

The following isokinetic parameters have been used in this research study:

- Peak torque of concentric muscular contraction of knee extensors of the right leg (CE-R);
- Peak torque of concentric muscular contraction of knee extensors of the left leg (CE-L);
- Peak torque of concentric muscular contraction of knee flexors of the right leg (CF-R);
- Peak torque of concentric muscular contraction of knee flexors of the left leg (CF-L);
- Peak torque of eccentric muscular contraction of knee flexors of the right leg (EF-R);
- Peak torque of eccentric muscular contraction of knee flexors of the left leg (EF-L);
- Bilateral relationship of extensors left and right legs (CE-L/CE-R);
- Bilateral relationship of flexors left and right legs (CF-L/CF-R);
- Conventional relationship between flexors and extensors of the right leg (H/QCONV-R)
- Conventional relationship between flexors and extensors of the left leg (H/QCONV-L)
- Functional relationship between flexors and extensors of the right leg (H/QFUNC-R)
- Functional relationship between flexors and extensors of the left leg (H/QFUNC-L).

In order to test and measure the strength levels of knee flexors and extensors, after a standardized warm up, the participants sat on an isokinetic dynamometer. In order to get familiarized with the testing protocol each participant performed up to three trials, which should have been 50%, 70% and 90% of their maximal effort. The ROM has been set to 90°. Standardized protocol was used: each leg was tested four times (maximal effort) at angular velocities of 60°/s and 180°/s (extension and flexion) (Drid et al., 2009). In order to eliminate any negative side effects of fatigue the participant were given adequate rest time between sets (>2 min.). The testing device recorded the following variables during the testing procedure: peak torque, peak torque expressed as percentage of body mass, maximal work output and total work expressed as percentage of body mass. The same procedure was carried out for both left and right legs (Madsen et al., 1996; Gleeson et al., 1996).

For data analysis and data processing IBM Statistical package for Social Science (SPSS) [version 20.0] was used. Univariate analysis of variance (ANOVA) was used to determine whether statistically significant differences exist in manifestation of peak torque at different angular velocities in karate athletes of different age. Paired-Samples T test was used to determine differences in manifestation of peak torque in karate athletes performed at different angular velocities. The level of statistical significance has been set at $p \leq 0,05$.

RESULTS

Results of peak torque of upper thigh musculature at angular velocity of 60°/s for karate athletes of different age groups are shown in Table 1. Based on the results obtained through the Kolmogorov-Smirnov test it was concluded that there are not statistically significant deviations from a normal distribution, which in further analysis of data allow the use of parametric techniques. Based on the results in Table 1. it can be concluded that within the first six variables of peak torque there is a statistically significant difference between karate athletes of different age groups ($p \leq 0,05$). The differences between age groups were calculated via the "LSD Post hoc" method. There is a statistically significant difference within the first six variables among karate senior athletes and karate cadet athletes, in favor for seniors. As far as the relationship between seniors and juniors a statistically significant difference exists in variable of peak torque for concentric muscular contraction of left upper thigh extensor muscles (CE-L) as well as in the variable of peak torque for a concentric contraction of right upper thigh flexor muscles (CF-R). Seniors obtained better average results. In comparison between cadets and juniors a statistically significant difference exists within the first six variables and it goes favor of juniors.

Among the variables that refer to bilateral, unilateral and functional relationship no statistically significant difference has been observed between groups, except for bilateral relationship variable of left leg flexor muscles (CF-L/CF-R) between cadets and juniors. Cadets possess a greater asymmetry level.

Table 1. Univariate analysis of variance between variables among different karate athlete's age groups, at angular velocity of 60°/s.

Variables		Cadets	Juniors	Seniors	F	P
		AS±SD	AS±SD	AS±SD		
CE-R		147,80±37,16	188,78±30,57*aa	212,78±34,53*aa	8,757	0,001
CE-L		137,90±34,48	183,00±37,58*aa	215,78±35,59*aa *bb	11,333	0,000
CF-R	(Nm)	98,60±26,04	126,67±9,34*aa	145,67±22,65*aa *bb	12,258	0,000
CF-L		89,70±25,34	125,33±13,96*aa	143,44±34,27*aa	10,691	0,000
EF-R		109,60±25,62	150,78±33,38*aa	165,67±49,23*aa	5,917	0,008
EF-L		103,90±23,48	156,11±25,56*aa	175,11±52,82*aa	10,038	0,001
CE-L/CE-F		10,08±7,92	10,73±9,25	7,33±6,63	0,461	0,636
CF-L/CF-R		13,15±9,84*bb	5,81±5,52	11,20±6,50	2,311	0,120
H/QCONV-R	(%)	66,93±8,31	68,68±12,68	68,85±7,00	0,118	0,889
H/QCONV-L		65,18±8,48	70,13±10,90	66,59±12,02	0,552	0,583
H/QFUNC-R		76,63±17,61	81,00±18,48	77,21±17,99	0,160	0,853
H/QFUNC-L		78,10±17,22	86,88±13,95	79,88±16,76	0,771	0,473

Legend: *aa – statistically significant difference ($p \leq 0,05$) compared to cadets; *bb – statistically significant difference ($p \leq 0,05$) compared to juniors; *cc – statistically significant difference ($p \leq 0,05$) compared to seniors.

Results of peak torque of upper thigh musculature at angular velocity of 180°/s for karate athletes of different age groups are shown in Table 2. Based on the results obtained through the Kolmogorov-Smirnov test it was concluded that there are no statistically significant deviations from a normal distribution, which in further analysis of data allow the use of parametric techniques. Based on the results in Table 2. it can be seen that out of six variables that refer to manifestation of peak torque, only in variable of peak torque in eccentric contraction of the right upper thigh musculature (EF-R) a statistically significant difference among groups is not present. There is a statistically significant difference within the first six variables among karate senior athletes and karate cadet athletes, in favor for seniors. Between cadets and juniors a statistically significant difference is present in variables od peak torque of extensor muscles in concentric contraction of both legs (CE-R, CE-L), peak torque of flexors in a concentric contraction of both legs (CF-R, CF-R) and in peak torque of flexors muscles in an eccentric contraction of the left leg (EF-L). The difference goes in favor of juniors. There are no statistically significant differences between juniors and cadets in the variable of peak torque of flexors muscles in eccentric contraction of the right leg (EF-R). There are no statistically significant differences between juniors and cadets in the first six variables.

There are no statistically significant differences in variables of bilateral, unilateral and functional relationships across all groups.

Table 2. Univariate analysis of variance between variables among different karate athlete's age groups, at angular velocity of 180°/s.

Variables		Cadets	Juniors	Seniors	F	P
		AS±SD	AS±SD	AS±SD		
CE-R		98,30 ±22,70	118,67±21,89*aa	137,11±20,270*aa	7,609	0,003
CE-L		94,10± 22,69	122,78±16,12*aa	133,89±23,640*aa	9,038	0,001
CF-R	(Nm)	75,60±16,12	90,78±10,94*aa	102,33±16,06*aa	7,982	0,002
CF-L		73,20±15,85	94,89±11,37*aa	102,44±23,30*aa	7,237	0,003
EF-R		119,30±23,77	144,00±32,77	159,22±59,54*aa	2,306	1,210
EF-L		114,50±31,01	165,11±37,05*aa	176,11±64,28*aa	4,930	0,016
CE-R/CE-L	(%)	9,13±5,65	7,23±5,63	7,82±5,97	0,274	0,763
CF-R/CF-L		9,94±6,52	4,81±6,10	9,48±7,73	1,599	0,222

H/QCONV-R	77,44±6,28	78,40±15,16	74,87±8,21	0,274	0,762
H/QCONV-L	78,91±10,20	78,30±12,11	76,64±11,57	0,101	0,904
H/QFUNC-R	123,83±21,68	122,95±27,48	116,16±40,90	0,172	0,843
H/QFUNC-L	123,72±23,50	135,27±27,11	131,02±45,59	0,297	0,746

Legend: ^{*aa} – statistically significant difference ($p \leq 0,05$) compared to cadets; ^{*bb} – statistically significant difference ($p \leq 0,05$) compared to juniors; ^{*cc} – statistically significant difference ($p \leq 0,05$) compared to seniors.

Differences between variables at angular velocities of 60°/s and 180°/s among cadets, junior and seniors is depicted separately in Tables (3,4,5). The same trend of statistical significance appears across all three tables and across all the age groups. Based on p values it can be seen that among the first six variables of peak torque manifestation a statistically significant difference is present among the first four variables, during peak torque of flexors and extensors in concentric contraction of both legs (CE-R, CE-L, CF-R, CF-L). Greater differences are obtained at angular velocity of 60°/s. There are no statistically significant differences among variables of peak torque manifestation of flexor muscles in eccentric contraction (EF-R, EF-L).

Table 3. Significance of differences between velocities of 60°/s and 180°/s in cadets

Variables		$AS_1 \pm SD_1$	$AS_2 \pm SD_2$	t	P
CE-R	(Nm)	147,80±37,16	98,30 ±22,70	9,142	**0.000**
CE-L		137,90±34,48	94,10± 22,69	9,073	**0,000**
CF-R		98,60±26,04	75,60±16,12	4,993	**0,001**
CF-L		89,70±25,34	73,20±15,85	4,337	**0,002**
EF-R		109,60±25,62	119,30±23,77	-1.851	0,097
EF-L		103,90±23,48	114,50±31,01	-1,636	0,136
CE-R/CE-L	(%)	10,08±7,92	9,13±5,65	0,346	0,737
CF-R/CF-L		13,15±9,84	9,94±6,52	0,829	0,429
H/QCONV-R		66,93±8,31	77,44±6,28	-8,241	**0,000**
H/QCONV-L		65,18±8,48	78,91±10,20	-5,697	**0,000**
H/QFUNC-R		76,63±17,61	123,83±21,68	-11,472	**0,000**
H/QFUNC-L		78,10±17,22	123,72±23,50	-7,616	**0,000**

Table 4. Significance of differences between velocities of 60°/s and 180°/s in juniors

Variables		$AS_1 \pm SD_1$	$AS_2 \pm SD_2$	t	p
CE-R	(Nm)	188,78±30,57	118,67±21,89	10,479	**0,000**
CE-L		183,00±37,58	122,78±16,12	6,104	**0,000**
CF-R		126,67±9,34	90,78±10,94	9,694	**0,000**
CF-L		125,33±13,96	94,89±11,37	7,934	**0,000**
EF-R		150,78±33,38	144,00±32,77	0,547	0,599
EF-L		156,11±25,56	165,11±37,05	-1,715	0,125
CE-D/CE-L	(%)	10,73±9,25	7,23±5,63	1,214	0,259
CF-D/CF-L		5,81±5,52	4,81±6,10	0,360	0,728
H/QCONV-R		68,68±12,68	78,40±15,16	-3,145	**0,014**
H/QCONV-L		70,13±10,90	78,30±12,11	-2,750	**0,025**
H/QFUNC-R		81,00±18,48	122,95±27,48	-3,802	**0,005**
H/QFUNC-L		86,88±13,95	135,27±27,11	-5,876	**0,000**

As far as percent values are concerned, there are no statistically significant differences in variables of bilateral relationship of flexors and extensors of both legs (CE-L/CE-R, CF-L/CF-R). However a statistically significant difference is present for variables of unilateral (H/QCONV-R, HQCONV/L) and functional relationship of both legs (H/QFUNC-R, H/QFUNC-L). Greater percent values are obtained at angular velocity of 180°/s.

Table 5. Significance of differences between velocities of 60°/s and 180°/s in seniors

Variables		$AS_1 \pm SD_1$	$AS_2 \pm SD_2$	t	P
CE-R	(Nm)	212,78±34,53	137,11±20,270	13,079	**0,000**
CE-L		215,78±35,59	133,89±23,640	14,417	**0,000**
CF-R		145,67±22,65	102,33±16,06	8,955	**0,000**
CF-L		143,44±34,27	102,44±23,30	8,398	**0,000**
EF-R		165,67±49,23	159,22±59,54	0,479	0,645
EF-L		175,11±52,82	176,11±64,28	-0,061	0,953
CE-R/CE-L	(%)	7,33±6,63	7,82±5,97	0,191	0,854
CF-R/CF-L		11,20±6,50	9,48±7,73	0,556	0,593
H/QCONV-R		68,85±7,00	74,87±8,21	-2,331	**0,048**
H/QCONV-L		66,59±12,02	76,64±11,57	-4,662	**0,002**
H/QFUNC-R		77,21±17,99	116,16±40,90	-3,339	**0,010**
H/QFUNC-L		79,88±16,76	131,02±45,59	-3,610	**0,007**

DISCUSSION

In the past years testing on an isokinetic dynamometer has become the most prevalent and dominant method of evaluating muscular imbalances between agonists and antagonists as well as between different legs. Data obtained in this manner presents a remarkably relevant and useful information for both athletes and coaches, because it provides precise planning of the training process, and it also contributes to a decreased rate of sport injuries, which present the biggest danger of today's sport. Isokinetic testing should be carried out multiple times throughout the year in different phases of the training cycle. This way, based on obtained results, training process can be geared towards specifically aimed strength improvements and strengthening of weak areas (better success rate in certain sport).

Based on the results obtained in this study, it can be concluded that statistically significant differences in manifestation of peak torque in karate athletes of different ages at angular velocity of 60°/s and 180°/s are present. The biggest differences are between senior and cadet age groups, which was expected due to the big age difference, and therefore the value of peak torque manifestation in all six variables, at both angular velocities is statistically greater in favor of seniors. A similar situation is present between juniors and cadets where in all six variables at angular velocity of 60°/s the value of peak torque manifestation is statistically greater in juniors, while at angular velocity of 180°/s this is the case in four out of six variables. Reason for such discrepancy may lie in the reason that cadets haven't reached full maturity and a sensitive period for development of maximal strength is still ahead of them, which according to Guzhalowski occurs between ages 16 and 18. Between seniors and juniors, statistically significant differences are present in smaller number of variables, which tells us that their results are pretty similar.

For all six variables that are connected to peak torque manifestation across all age groups a statistically significant differences is present for both flexors and extensors at different angular velocities. Peak torque values at smaller velocities (60°/s) are greater, while on the other hand at greater velocities (180°/s) values of peak torque are smaller. This rule of thumb is as well-known as the Hill's curve. This is corroborated with findings from Daneshjoo et al. (2013) and Kofotils et al. (2007).

Bilateral relationship has been defined in one of the studies as imbalance between two legs that is greater than 10 (Rahnama et al., 2005). Of course, same muscle groups are compared (extensors to extensors, flexors with flexors). Estimation of bilateral strength asymmetry in muscles of the lower limb is of great value and importance, due to its adequate use for injury prevention and due to the performance manifested in competitions. In this research paper bilateral asymmetry values obtained at angular velocities of 60°/s usually surpass 10%, which has been taken as a reference value. On the other hand, bilateral asymmetry values at extensor and flexor muscles obtained at angular velocities of 180°/s are usually below 10%. This velocity is closer to velocities experienced in competition, and is therefore more relevant compared to velocity of 60°/s. Of course a precise percent line cannot be drawn, and therefore certain precautions should be undertaken in order to correct this imbalance. For imbalance correction Drid et al., (2009) recommend proprioception training modality.

Unilateral relationship between agonists and antagonists is used for examining functional capabilities of knee stability and muscle balance between hamstrings and quadriceps across different movements (Aagaard et al., 1998). If hamstring muscle is too weak, an increased possibility of injury of the ACL is present, because they have a synergistic function in stabilizing the knee joint and keeping its structural and functional integrity. Two different relationships should be distinguished, and these are conventional and functional relationships.

The most described relationship within the literature is definitely the "conventional" relationship, which is calculated by dividing value of peak concentric hamstring torque with the value of peak concentric quadriceps torque (H/QCONV). For reference values of conventional relationship between hamstring and quadriceps muscles most authors take values of 50% to 80%. (Andrade et al., 2012). In this research, values for conventional relationship at velocities of 60°/s are 67,66%±9,8%, while for velocity of 180°/s they are 7,46%±10,53%. These values are well within normal range, meaning that this groups of karate athletes, according to this parameter doesn't have an increased likelihood of injury occurrence. These results have also been obtained by Probst et al., (2007).

When conventional relationship is compared between different angular velocities, statistically significant differences are present across all age groups. Values of conventional relationship are greater at velocities of 180°/s than at 60°/s. These results match the results obtained by Hewett et al. (2008). They believe that this occurs because as the velocity of motion increases during seated, open-chain isokinetic activity, the forward momentum of the tibia increases to a point where increased hamstrings recruitment is required to limit both extension rotation and anterior translation of the joint. Therefore, as angular velocity increases men tend to increase peak torque levels of hamstring muscles, in order to stabilize the joint and guard the ACL. The interesting fact is that this doesn't happen in women and the potential reasons for this, authors believe are differences in stature and development between men and women. Therefore, as speed of movement increases women are to a far greater degree exposed to injuries of this sort.

However, it is believed that "functional" relationship (H/QFUNC) is of much greater importance. In order to calculate functional relationship, the relationship of peak torque values of eccentric muscular contraction of the hamstring muscles is divided by concentric values of peak torque of the quadriceps muscle. This way, relative capability of the hamstring muscle to function in eccentric regime is estimated, and also in this way it stabilizes the knee joint, which is a very frequently occurring situation in many sport related activities. If the reference values of the functional relationship between hamstring and quadriceps muscle fall below 60%, the risk of an injury occurrence increases seventeen fold. Functional relationship between 70% and 100% has been accepted as adequate for dynamic stability. 1:1 relationship has been accepted as reference value. (Ayala et al., 2012). In this research the functional relationship values at velocity of 60°/s was 9,86%±31,05%, which puts this group of karate athletes in a population with sufficient dynamic stability. At velocities of 180°/s results are far greater, and are as follows: 125, 43%±31,05% and clearly show that even at greater velocities karate athletes do not have an increased risk of injury which may occur due muscular imbalances. This type of values are obtained across all age groups. CCertain authors suggest a screening process of both conventional and functional relationships of strength levels during the off-season in healthy athletes in order to identify athletes who are in greater risk of suffering from an injury of the lower limbs during the training process and competition (Croisier, 2004).

CONCLUSION

The first analysis of differences has determined that statistically significant differences are present in the manifestation of maximal torque across all age groups of karate athletes at different angular velocities. Peak torque values are greater at lower angular velocities, while these values are lower at higher angular velocities. This fact is known as the Hills law.

The second analysis of differences has shown a presence of statistically significant differences in unilateral relationship at different angular velocities across all age groups of karate athletes. This was confirmed for both conventional and functional relationships. At both velocities results are within the range of reference values from 50% to 80% for conventional relationship. Results for functional relationship are within reference ranges as well.

Third analyses has determined that there are no statistical differences in bilateral relationship at different angular velocities in any of the examined age groups. As for the results, they surpass the limit of 10% in certain age groups, which we took as a reference value, and therefore we recommend that certain measures should be undertaken in order to correct this.

Finally conclusion of this research is that karate athletes do not have any significant unilateral asymmetries, and therefore do not have an increased risk of suffering from sport injuries such as ACL rupture, hamstring strains and tears, nor from the overuse syndrome. On the other hand, certain values of bilateral relationship which surpass 10% in certain age groups are calling for caution. These differences should be carefully treated, and Drid et al., (2009) recommend proprioceptive training as the best solution.

REFERENCES

1. Aagard, P., Simonsen, E.B. Magnusen, S.P. Larsson, P.T.B., Dyhre-Poulsen, P. (1998). A new concept for isokinetic hamstrings-quadriceps muscle strength ratio. *American Journal of Sports Medicine, 26*, 231-237.
2. Andrade, M.S., De Lira, C.A., Koffes, F.C., et al. (2012). Isokinetic hamstrings-toquadriceps peak torque ratio: the influence of sport modality, gender, and angular velocity. *Journal of Sports Sciences, 30*, 547-553.
3. Ayala, F., De Ste Croix, M., Sainz de Baranda, P., Santonja, F. (2012). Absolute Reliability of Hamstring to Quadriceps Strength Imbalance Ratios Calculated Using Peak Torque, Joint Angle-Specific Torque and Joint ROM-Specific Torque Values. *International Journal of Sports Medicine*, 33(11), 909-916.
4. Chaabene, H., Hachana, Y., Franchini, E., Mkaouer, B., Chamari, K. (2012). Physical and physiological profile of elite karate athletes. *Journal of Sports Medicine, 42*(10), 829-843.
5. Croisier, J., L. (2004). Factors associated with recurrent hamstring injuries . *Sports Medicine* 34, 681 – 695
6. Daneshjoo, A., Rahnama, N., Mokhtar Abdul, H., Yusof, A. (2013). Bilateral and Unilateral Asymmetries of Isokinetic Strength and Flexibility in Male Young Professional Soccer Players. *Journal of Human Kinetics*, 36, 45.
7. Drid, P., Drapsin, M., Trivic, T., Lukač, D., Obadov, S., Milosevic, Z. (2009). Asymmetry of muscle strength in elite athletes. *Biomedical Human Kinetics, 1*(1), 3-5.
8. Gleeson, N.P., Mercer, T.H. (1996). The utility of isokinetic dynamometry in the assessment of human muscle function. *Sports Medicine*, 21(1), 18-34.
9. Hewett, E., T., Myer, D., G., Zazulak, T., B. (2008). Hamstrings to quadriceps peak torque ratios diverge between sexes with increasing isokinetic angular velocity. *Sci Med Sport, 11(5), 452–459*
10. Jaric, S., Radosavljevic – Jaric, S., Johansson, H. (2002). Muscle force and muscle torque in humans require different methods when adjusting for differences in body size. *Journal of Applied Physiology*, 87, 304-307.
11. Knapik, J. J., Bauman, C.L, Jones, B. H., Harris, J. M., Vaughan, L. (1991). Preseason strength and flexibility imbalances associated with athletic injuries in female collegiate athletes. *American Journal Sports Medicine*, 19, 76–81
12. Kofotolis, N. D., Kellis, E. (2007). Cross-training effects of a proprioceptive neuromuscular facilitation exercise program on knee musculature. *Physicaly Therapy Sport*, 2007; 8: 109-116
13. Koropanovski, N., Berjan, B., Boţić, P., Pazin, N., Sanader, A., Jarić, S. (2011). Anthropometric and Physical Performance Profiles of Elite Karate Kumite and Kata Competitors. *Journal of Human Kinetics*, 30, 107-114
14. Madsen, O.R. (1996). Torque, total work, power, torque acceleration energy and acceleration time assessed on a dynamometer: reliability of knee and elbow extensor and flexor strength measurements. *European Journal Applied Physiology*, 74, 206-210.
15. Mori, S., Ohtani, Y., Imanaka, K. (2002). Reaction times and anticipatory skills of karate athletes. *Human Movement Science, 21*(2), 213-230.

16. Probst, M.M., Fletcher, R., Seelig, D.S. (2007). A comparison of lower-body flexibility, strength, and knee stability between karate athletes and active controls. *Journal Strength and Conditioning Research*, 21(2), 451-455
17. Rahnama, N., Lees, A., Bambaecichi, E. (2005). A comparison of muscle strength and flexibility between the preferred and non-preferred leg in English soccer players. *Ergonomics*, 48(11-14), 1568-1575.
18. Scattone-Silva, R., Lessi, G.C., Lobato, D.F.M., Serrão, F.V. (2012). Acceleration time, peak torque and time to peak torque in elite karate athletes. *Science & Sports*, *27*(4), e31-e37.
19. Sorensen, H., Zacho, M., Simonsen, E. B., Dyhre-Poulsen, P., Klausen, K. (1996). Dynamics of the martial arts high front kick. *Journal of Sports Sciences, 14*(6), 483-495.
Wilk, S.R., McNair, R.E., Feld, M.E. (1983). The physics of karate. *American Journal of Physics*, *51*, 783-790.
20. Zehr, E.P., Sale, D.G., Dowling, J.J. (1997). Ballistic movement performance in karate athletes. *Medicine and Science in Sports and Exercise, 29*(10), 1366-1373.

Received: October 18, 2017
Revision received: December 24, 2017
Accepted: December 28, 2017

Correspondence:
Dejan Cokorilo
Faculty of sport and physical education, Novi Sad
e-mail:cokorilon@gmail.com