Muscular strength of knee extensors and flexors and bilateral and ipsilateral ratio in elite male kickboxers

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A Study Design
B Data Collection
C Statistical Analysis
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E Funds Collection

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ABSTRACT

Background & Study Aim: Kickboxing is combat sport where the form of combat are strikes, performed by hands and legs. The aim of this study was verification of the hypothesized that the non-preferred leg of elite male kickboxers would have lower knee extensor and flexor strength and there will be a higher incidence of bilateral and unilateral strength deficit.

Materials and Methods: The study involved elite kickboxing athletes (n = 17, age 23.6 ±7.1 years, body height 183.3 ±5.5 cm and body weight 80.1 ±11.8 kg). The participants' concentric muscle contractions were tested on the isokinetic dynamometer (Cybex NORM ®, Humac, CA, USA) at angular speeds of 60, 180 and 300°·s^{-1}. The following variables were evaluated: maximum peak muscle torque of knee extensors (PTE) and flexors (PTF) in the preferred (PL) and non-preferred leg (NL), bilateral ratio between the exerted strength of knee extensors (Q:Q) and flexors (H:H) and unilateral ratio of muscle torque for both PL and NL (H:Q_{PL} and H:Q_{NL}, respectively).

Results: The results indicated a significant effect of angular velocity (λ = 0.27, $F_{4,190}$ = 44.01, p<0.01, η^2 = 0.48) and laterality (λ = 0.93, $F_{2,95}$ = 3.36, p < 0.05, η^2 = 0.07) on peak torque in male kickboxers. The comparison of PTE revealed an insignificant difference between both limbs (p>0.05). On the contrary, in PTF, kickboxers produced significantly greater muscular strength in the preferred limb at velocities of 60° and 180°·s^{-1} (p<0.05). The effect of angular velocity on the bilateral ratio (Q:Q ratio, H:H ratio) in kickboxers was not significant (λ = 0.98, $F_{2,31}$ = 0.23, p>0.05, η^2 = 0.42). We revealed a significant difference in the size of the bilateral ratio between knee extensors (Q:Q ratio) and flexors (H:H ratio) ($F_{1,32}$ = 5.55, p < 0.05, η^2 = 0.15). A significantly higher bilateral deficit was found in knee flexors at angular velocities of 180° and 300°·s^{-1} (p<0.05). A significantly higher H:Q ratio (p<0.05) was observed in favour of the preferred limb at lower angular velocities (60° or 180°·s^{-1}, respectively). The results revealed strength asymmetries in favour of PTF when almost 60% of athletes achieved a critical value at higher velocities. The ipsilateral ratio (H:Q) was significantly lower in the non-preferred limb, which indicates a lower preparedness of the non-preferred limb.

Conclusions: The research presents PTEs and PTFs in the preferred and non-preferred limb at different angular velocities. These data may serve comparative purposes for other researchers, as well as a base (criterion) of assessment for elite professional kickboxers or for comparison with other martial arts, respectively. In terms of practice, the results may be beneficial for athletes, coaches, physiotherapists, doctors and other clinical staff.

Keywords: combat sports • isokinetic strength • strength asymmetries • maladaptation • youth athletes

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Kickboxing – combat sport where the form of combat are strikes, performed by hands and legs.

Isokinetics – exercises with an accommodating resistance and fixed speed.

Concentric muscle action – development of muscle tension while the origin and insertion of the muscle approach each other, often referred to as positive work.

Torque – a force that produces or tends to produce a rotation about a point or axis, usually measured in units of Newton-meters (N· m).

Deficit – a measured deficiency in a muscle's performance as compared to the bilateral or contra-lateral side, to normative data.

Ratio – the relationship in quantity, amount, or size between two or more things, usually used to evaluate the relationship between the agonist and antagonist muscles or between concentric and eccentric muscle action.

One rep max – *noun* full form of **1RM** [39].

1RM – *noun* the maximum weight that a person can lift for a single rep of any given exercise. Full form **one rep max** [39].

INTRODUCTION

Kickboxing is a mixture of martial arts, which involves "two competitors directing full-force strikes with the hands, elbows, knees, shins and feet at each other" [1]. The goal is to use strength, sport-specific skills and stamina to physically overcome an opponent. Kickboxing is also characterized by full contact between fighters who punch and especially kick during the competition, which requires intensive muscular activity [2].

Optimal performance in semi-contact and full contact kickboxing is dependent on the appropriate timing of a kickboxer's optimal level of technical, tactical, psychological and physical characteristics and their symbiosis. Literature suggests that optimal kickboxing performance depends not only on high levels of aerobic power and anaerobic power [3, 4] but also on high levels of static, maximum and dynamic strength of the lower and upper limbs, exceptional coordination abilities of the upper and lower limbs in terms of punches and kicks [5], and a high level of stability and a fast reaction to various stimuli [6].

Assessment of muscular strength provides information regarding a given muscle group [7, 8]. The objective assessment of muscular strength can note the risk of potential injuries [9, 10].

Strength imbalances have been found to be one of the strongest injury predictors in competitive sports [11, 12]. Asymmetrical strength across the lower extremities can be defined as the inability to produce a force of contraction that is equal across the quadriceps and hamstring of both the right and left sides [13]. In kickboxing, the athletes are forced to switch between high demanding skills which require strength, power, coordination and agility, with these qualities being symmetrically distributed to the lower extremities for maximal body balance and skill efficiency. Long-termed preferred and uncompensated load of one side of the body (punching, kicking with preferred limb) may lead to asymmetry and dominance of one limb, what can be a result of pre-existing limb preference (handedness, footedness). It has been documented that strength asymmetry across the body can be linked to increased prevalence of injury [14, 15] and impaired performance in athletes [15, 16].

Although asymmetrical strength has been linked to a variety of pathological conditions, relatively little research is currently being conducted to identify these deficits in elite kickboxers. Isokinetic dynamometry is a method used to determine the functional pattern of strength and muscle balance mainly through the 'peak torque' and 'agonist/antagonist relative balance' isokinetic variables [17, 18] and enables implementation of isokinetic strength training exercises [19]. Knapik et al. [20] state that the athletes with muscle strength imbalances higher than 15% in a bilateral comparison of extremities had 2.6-times higher frequency of injuries when compared to athletes who had a difference lower than 15%. Ipsilateral (H:Q ratio) reflects the percentage proportion of peak torque of agonist and antagonist muscle groups of the same limb. H:Q is an indicator of functional ability of muscle groups around the knee joint as a performance criterion. This ratio is difficult to generalize; however some studies present its magnitude in the range of 50% to 80% depending on knee angle and angular velocity [21].

Muscular strength in kickboxers, quadriceps and hamstring strength and their strength ratio in athletes of various forms of combat sports have been the focus of a number of studies [3, 22-24]. Authors of several studies have tested muscular strength using field tests. For example, Slimani et al. [25] observed the effects of cognitive training strategies on muscular force in healthy competitors in combat sports (taekwondo, kickboxing and karate), while muscular strength was identified using the countermovement jump, medicine ball throw, and one repetition maximum (1RM) strength (bench press and half squat test). Ouergui et al. [4] examined the effects of five weeks of kickboxing training on physical fitness and muscular strength was tested using field tests (upper body: bench press test, medicine ball test; lower body: squat jump and countermovement jump test).

Some studies have presented the selected variables of isokinetic strength of the lower limbs in kickboxers, but there are also certain limits. In the study by Machado et al. [23], the authors used a one-velocity protocol ($60°\cdot s^{-1}$); however, there was a low number of participants (n = 5) and the athletes' performance level was not stated. Similarly, Szafranski et al. [26] used a one-velocity protocol ($240°\cdot s^{-1}$). Zabukovec et al. [3] used a two-velocity protocol (60 and $180°\cdot s^{-1}$) in their study, but the performance at high angular velocity was missing, there was a low number of participants (n = 4), they did not test knee flexors and they tested only one limb. The key specific activities in kickboxing (punching, kicking, blocking, jumping, turning, etc.) are performed at high velocities. However, Machado et al. [23] and Pedzich et al. [27] noted the lack of literature regarding the muscle torque of martial arts athletes.

The aim of this study was verification of hypothesized that the non-preferred leg of elite male kickboxers would have lower knee extensor and flexor strength and there will be a higher incidence of bilateral and unilateral strength deficit.

MATERIAL AND METHODS

Subjects

Elite Czech kickboxers (n = 17, age 23.6 ± 7.1 years, body height 183.3 ± 5.5 cm and body mass 80.1 ± 11.8 kg) took part in the present study. Elite kickboxers were members of the national team, and in recent years, they have achieved significant domestic (medallists in national competitions) and international success (World champion in WKA, WTKA, WKF, WKU association, European champion in the WAKO association and medallists in international competitions). The participants' specialization was light-contact, semi-contact and full-contact disciplines. The average training experience of the kickboxers was 8.2 ±4.9 years and they had 5 to 6 training sessions per week, each lasting 1.5 hours. The measurement was carried out within a competition period at a national camp.

All subjects performing tests on isokinetic strength dynamometry had not undergone any surgery on the knee joint, and in the two days before testing, they did not undergo any exhausting physical load. All test subjects were notified of the content and implementation of testing procedures and endorsed it with their signatures. The research was approved by the ethical committee of the Faculty of Physical Education and Sport, Charles University in Prague (Czech Republic). Measurements were carried out in accordance with the ethical standards of the Declaration of Helsinki and ethical standards in sport and exercise science research [28].

Anthropometric measurement

Before testing muscular strength, participants took part in the basic measurement of anthropometric indicators. Body height was measured using a digital stadiometer (SECA 242, Hamburg, Germany) and body weight using a digital scale (SECA 769, Hamburg, Germany).

Assessment of strength indicators

The muscular strength of the lower limbs was assessed using a Cybex Humac Norm isokinetic dynamometer (Cybex NORM ®, Humac, CA, USA). It is a hydraulically driven and microcomputer-controlled device operating in a continuous passive motion, isometric, isotonic and isokinetic concentric and eccentric modes. The following variables were evaluated during concentric contraction at three different angular velocities (60°, 180° and 300°$\cdot$s^{-1}): peak muscle torque of knee extensors (PTE) and flexors (PTF) in the preferred (PL) and non-preferred leg (NL), bilateral ratio between the exerted strength of knee extensors (Q:Q) and flexors (H:H) and unilateral ratio of muscle torque for both PL and NL (H:Q_{PL} and H:$Q_{NL,}$ respectively). The lower extremities were evaluated in a random order. Testing was carried out in the morning between 9:00 to 11:00 am. Limb dominance was defined by determining which leg each participant preferred to use to kick (kicking leg). The tested subject sat on the seat of the dynamometer, with an 85° torso inclination. The range of motion was 90° (maximum extension was marked and set as "anatomic zero "0°"). The participant's trunk and thigh of the tested limb were fixed by means of the dynamometer's fixing straps (thorax, pelvis and tested thigh) so that movement was confined to a single joint movement only (knee extension – flexion). Torque was gravity corrected and dynamometer calibration was performed in accordance with the manufacturer's instructions. Before measurement, all tested subjects completed a short warm-up (12 minutes bicycle ergometer cycling 80 to 90 W / 80 to 90 rpm, followed by two sets of half squats with 10 repetitions and finally two sets of forward lunges with 10 repetitions). Following five submaximal warm-up repetitions, the athletes performed 5 repetitions with maximum effort. The rest interval between the trials and testing attempts was 60 seconds. Visual feedback and verbal stimulation were given during the testing.

Statistical analysis

For statistical processing of the research data, we used descriptive statistics. The measure of location was expressed using the arithmetic mean and the measure of variability was expressed using standard deviation. To assess the significance of independent variables' effects (angular velocity, limb preference, muscle group) on dependent variables (peak torque, bilateral and ipsilateral ratio), multivariate analysis of variance and mixed model repeated measures ANOVA (between and within subjects effects) were used. We used the Wilk's lambda (λ) to test whether there were differences between the means of identified groups of subjects (independent variables, factors) on a dependent variables. To evaluate the equality of error variances, *Levene's* test was used. To compare the observed indicators between the preferred and non-preferred leg, we used a paired *t*-test for comparison of means of two dependent samples. Data normality was set using the Shapiro-Wilk test. Moreover, the effect size between preferred and non-preferred legs was assessed using *Cohen's* "*d*" coefficient of effect size [29]. The probability of type I error (alpha) was set at 0.05 in all statistical analyses. Statistical analysis was carried out using IBM® SPSS® v21 (Statistical Package for Social Sciences, Inc., Chicago, IL, 2012).

RESULTS

The results showed a significant effect of independent factors (angular velocity: $\lambda = 0.27$, $F_{4,190} = 44.01$, $p<0.01$, $\eta^2 = 0.48$; laterality: $\lambda = 0.93$, $F_{2,95} = 3.36$, $p<0.05$, $\eta^2 = 0.07$) on peak torque in kickboxers. The effect of the interaction between angular velocity* laterality was not significant ($\lambda = 0.98$, $F_{4,190} = 0.44$, $p>0.05$, $\eta^2 = 0.01$). As velocity increased, muscular strength significantly decreased (Figure 1, 2, Table 1, 2).

Paired comparison of the measured values did not reveal any significant changes in the muscular strength of knee extensors at the monitored contraction velocities (Table 1). On the contrary, the athletes produced significantly greater muscular strength in knee flexors on the preferred limb at the velocities of 60° and 180°·s^{-1} (Table 2).

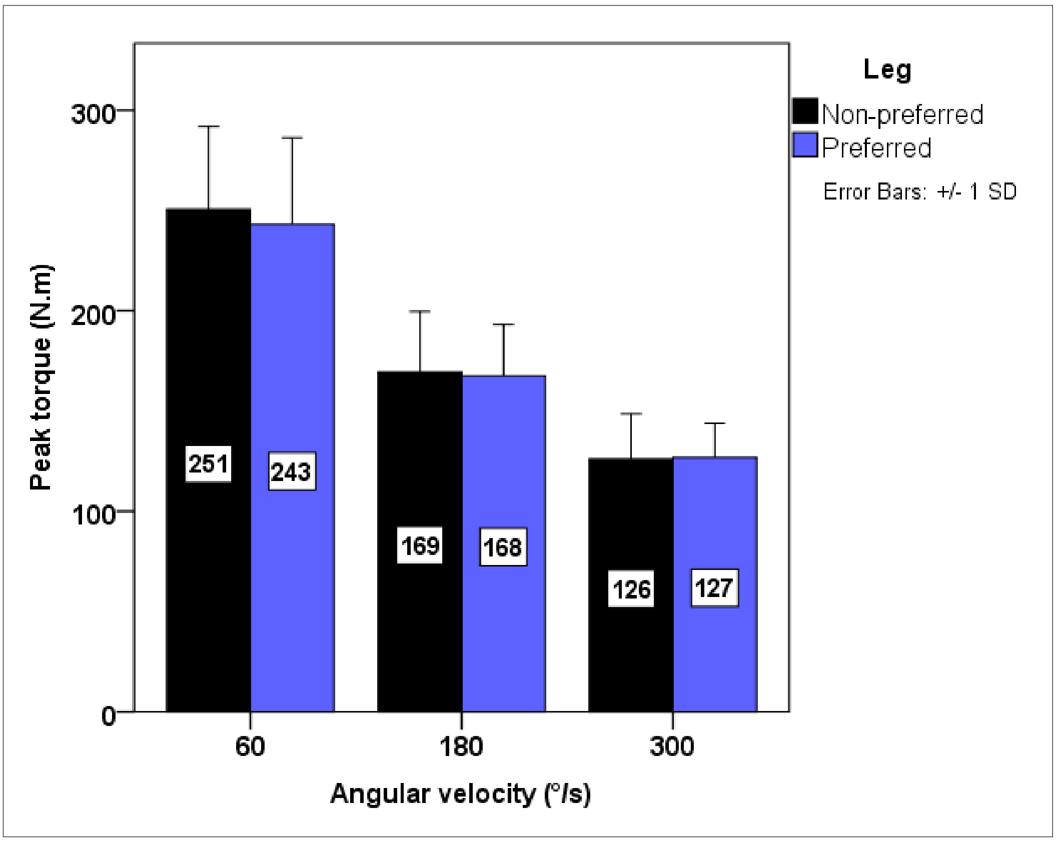

Figure 1. Comparisons of peak muscle torques of knee extensors at different angular velocities.

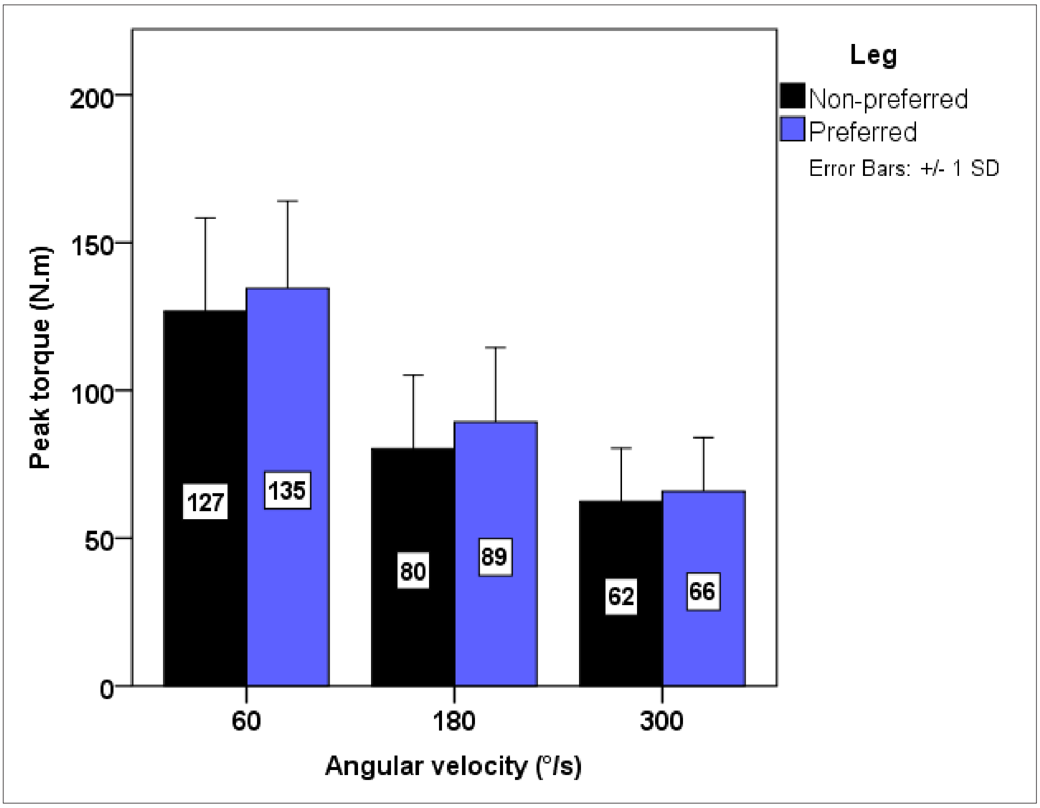

Figure 2. Comparisons of peak muscle torques of knee flexors at different angular velocities.

Table 1. Peak muscle torque of knee extensors (N · m) in the preferred and non-preferred lower extremities.

Velocity (°·s⁻¹)	Preferred extremity mean (SD)	Non-preferred extremity mean (SD)	t	p	d	
60	243.12 (43.18)	250.52 (41.31)	–0.92	N.S.	0.18	small
180	167.59 (25.12)	169.41 (30.23)	–0.47	N.S.	0.07	small
300	126.82 (17.11)	126.00 (22.61)	0.3	N.S.	0.04	small
F	213.68	464.28				
p	p<0.01	p<0.01				
Eta	0.930	0.967				

Legend: **N.S.** nonsignificant difference, **d** Cohen's coefficient of effect size.

The analysis did not show any significant effect of angular velocity on the bilateral ratio (Q:Q ratio, H:H ratio) in kickboxers ($\lambda = 0.98$, $F_{2,31} = 0.23$, $p>0.05$, $\eta^2 = 0.42$). However, it revealed a significant difference in the size of the bilateral ratio between knee extensors (Q:Q ratio) and flexors (H:H ratio) ($F_{1,32} = 5.55$, $p<0.05$, $\eta^2 = 0.15$) (Figure 3). A significantly higher bilateral deficit was detected in knee flexors at the velocities of 180° and 300°·s^{-1} (Table 3).

Mixed-model ANOVA showed a significant effect of angular speed on the size of the H:Q ratio regardless of limb preference ($\lambda = 0.98$, $F_{2,31} = 3.74$, $p < 0.05$, $\eta^2 = 0.19$), which means that with increasing movement velocity, H:Q significantly decreases. However, the analysis of the effect of contraction velocity in the preferred or non-preferred limb, respectively, indicated that this effect was not significant (Table 4). A higher H:Q ratio was found in favour of the preferred

Table 2. Peak muscle torque of knee flexors (N· m) in the preferred and non-preferred lower extremities.

Velocity ($°\cdot s^{-1}$)	Preferred extremity mean (SD)	Non-preferred extremity mean(SD)	t	p	d	
60	134.53 (29.57)	126.82 (31.56)	2.52	p<0.05	0.25	small
180	89.29 (25.20)	80.24 (24.96)	3.87	p<0.01	0.36	small
300	65.88 (18.22)	62.47 (17.95)	1.63	N.S.	0.19	small
F	330.63	219.32				
p	p<0.01	p<0.01				
Eta	0.954	0.932				

Legend: **N.S**. nonsignificant difference, **d** Cohen's coefficient of effect size.

Table 3. Bilateral ratio between peak muscle torque of knee extensors (Q:Q) and flexors (H:H).

Velocity ($°\cdot s^{-1}$)	Q:Q ratio mean(SD)	H:H ratio mean(SD)	t	p	d	
60	8.53 (6.05)	9.58 (6.00)	–0.44	N.S.	0.17	small
180	5.71 (5.19)	13.24 (11.09)	–2.64	*p*<0.05	0.87	high
300	5.65 (4.59)	11.35(9.16)	–2.16	*p*<0.05	0.79	high
F	2.87	1.3				
p	p>0.05	p>0.05				
Eta	0.15	0.08				

Legend: **N.S**. nonsignificant difference, **d** Cohen's coefficient of effect size.

Table 4. Ipsilateral ratio between peak muscle torque of knee flexors and extensors in the preferred and non-preferred lower extremities (H:Q).

Velocity ($°\cdot s^{-1}$)	Preferred extremity mean (SD)	Non-preferred extremity mean(SD)	t	p	d	
60	**54.71** (8.72)	**50.41** (7.80)	2.3	p<0.05	0.52	medium
180	**52.65** (9.98)	**47.82** (7.77)	3.93	p<0.01	0.54	medium
300	51.82 (10.94)	49.29 (9.59)	1.35	N.S.	0.25	small
F	3.17	2.15				
p	p>0.05	p>0.05				
Eta	0.17	0.12				

Legend: **N.S.** nonsignificant difference, **d** Cohen's coefficient of effect size.

limb at lower angular velocities (60° or 180°·s^{-1}, respectively).

DISCUSSION

The research showed a significant decrease of muscular strength of knee extensors and flexors depending on angular velocity. The difference between forces produced at low velocity (60°·s^{-1}) and high velocity (300°·s^{-1}) in knee extensors on the preferred leg amounted to 49.8%, and on the non-preferred leg, it was 47.7%. Similar results were found in professional soccer players, where the authors detected a decrease caused by velocity (60° vs. 300°·s^{-1}) by 46.9% [30].

The difference in knee flexors was higher, namely 51.1% (both limbs). Maly et al. [31] reported a lower difference between the muscle strength of knee flexors at the highest and lowest velocity (36.4% in the preferred leg and 34.9% in the non-preferred leg) in youth soccer players. A primary determinant of a hard and effective strike is muscular strength produced at a high contraction velocity and the optimal neuromuscular coordination of the movement. A powerful strike demanding strong and fast muscular contraction to produce a maximum speed to the distal extremity during the time of contact with the opponent. From sport practice point of view is very important note, that each strike should be performed with maximal force generation in the least amount of time, and the rest periods between sets should be adequate enough to ensure that kickboxer sufficiently recovers for the next set.

Generally, it is known that muscular strength production decreases with increasing contraction velocity. At higher speeds of muscular contraction, the time required for the connection of actin and myosin filaments (Huxley's model) shortens, so the duration of the contact phase is reduced in the overall cycle. Cross-bridges must be re-released shortly after their connection without sufficient time to produce power, so the share of combined bridges in the muscle declines and the produced strength is lower [8].

Knee extensor strength at the velocity of 60°·s^{-1} was higher (preferred leg 243.12 ±43.18 N · m, non-preferred leg = 250.52 ±41.31 N· m) in comparison to the study by Zabukovec et al. [3] who found a value of 220 N · m in elite professional kickboxers (n = 4). A much lower strength of knee extensors in kickboxers (right limb = 148.49 ±32.74 N· m, left limb = 146.02 ±31.67 N · m) was published by Machado et al. [23]. However, the authors state that average time of training experience was 2 ±1 year. Based on the results, we can conclude that elite kickboxers achieved higher muscular strength of knee extensors by up to 42% in comparison to beginners. The results of knee extensor strength at a higher velocity (180°·s^{-1}) (PTE_{PL}: 167.59 ±25.12 N · m, PTE_{NL}: 169.41 ±30.23 N· m) were similar to the results from the study by Zabukovec et al. [3] (168 N· m). The comparison of our results with elite kickboxers at the highest angular velocity (300°·s^{-1}) was not possible due to the lack of literature. Szafranski et al. [26] examined experienced kickboxers (training experience = 10.4 ±4.9 years), and at the velocity of 240°·s^{-1}, they presented a high level of knee extensor strength (PTE_{PL} = 157.17 N · m, PTE_{NL} = 156.99 N · m).

Knee flexor strength (PTF_{PL}: 134.53±29.57 N · m, PTF_{NL}: 126.82 ± 31.56 N· m) at the lowest angular velocity was higher in comparison to less experienced kickboxers' performance (PTF_{PL}: 71.76 ± 13.03 N· m, PTF_{NL}: 68.94 ±14.93 N· m) according to Machado et al. [23]. Maximum peak muscle torque is a reliable indicator of muscle activity both in the intact (healthy, undamaged) knee and after injury. Identified outputs of peak muscle torque of particular muscle groups near the knee joint determine the measure of integrity and stability of the joint.

The main factor (limb preference) did not show any significant effect on the level of muscular strength during isokinetic contraction. While the level of extensor strength did not vary with regard to limb preference (Table 1), in the case of knee flexors, we detected significantly higher muscular strength in favour of the preferred limb (Table 2) at the velocities of 60° and 180°·s^{-1}, however the differences from the clinical significance point of view are small (effect size) On the other hand we need to account also possible biological and technical errors of assessment. However, Impellizzeri et al. [32] reported high intraclass correlation values (0.90-0.98) with low range of standard error of measurement (4.3% to 7.7%) for peak torque and average work within the three separately (96 hours between sessions) at three different angular velocities (60°, 120° and 180°·s^{-1}). Machado et al. [23] reported insignificant differences in the muscular strength of knee extensors and flexors in relation to limb preference at velocity of 60°· s^{-1}. However, the limit of the study was a low number of participants (n = 5) and a short duration of training experience (2 ±1 year). Differences in knee flexor strength could have been caused by the unequal specific training load of athletes, the unilateral specific load as a result of long-term maladaptation processes and the uncompensated physical load of athletes.

The bilateral ratio (Q:Q, H:H ratio) did not significantly change in relation to angular velocity (Table 3). However, the comparison of the bilateral ratio between knee extensors (Q:Q ratio) and flexors (HH ratio) revealed a significantly higher bilateral deficit in knee flexors at higher contraction velocities (180°, 300°·s^{-1}). Bilateral deficit in knee extensors (Q:Q ratio) was 5.65% to 8.53%, and in knee flexors (H:H), it was 9.58% to 13.24%. The key specific activities in kickboxing (high power muscular activity, kicking, punching) are performed especially at high velocity. From an inter-individual point of view, 10 kickboxers (58.8%) reached the ratio of H:H ≥10% at a velocity of 180° or 300°·s^{-1}, respectively.

Right-to-left force differences of more than 15% may indicate some type of injury or may increase the risk of injury [33]. Fousekis et al. [34] suggest that long-term training in soccer causes strength asymmetries of different characters and degrees.

The proper implementation of specific techniques, e.g., overhead kicks, requires an optimal range of joint mobility. Muscle imbalances and shortened muscles can limit the range of joint mobility, making it a limiting factor for the proper implementation of kickboxing techniques (kick, punch). A cause of muscle imbalance can be unilateral physical load, overloading in the kickboxer's base stance, a combination of acyclic movements in irregular intervals and the lack of regular compensation exercises in training sessions. Limb preference in kickboxing may lead to strength asymmetries, mainly in knee flexors, which may result in large changes in the myodynamic characteristics of the muscles. These strength asymmetries may influence the athlete's optimal performance (technique), and they also may be a potential risk for injury.

The speed of muscle contraction did not have any significant effect on the ipsilateral ratio (H:Q) in any limb (Table 4). At all tested velocities, we detected a lower H:Q ratio in the non-preferred limb (47.82% to 50.41%) than in the preferred one (51.82% to 54.71%). Machado et al. [23] presented lower values for both limbs (H:Q_{PL} = 48 ±2.5%, H:Q_{NL}: 47 ±1.8%) at a velocity of 60°·s^{-1} in comparison to our study (H:Q_{PL} = 54.71 ±8.72%, H:Q_{NL}: 50.41 ±7.80%). It is difficult to generalize this ratio, but some studies indicate its size in the range of 50% to 80% depending on angular velocity [21, 35]. Hoffman et al. [36] state that a normal H:Q ratio is 6:10.

Another study by Aagaard et al. [37] reported that a H:Q ratio lower than 60% assessed at lower velocities may increase susceptibility to injury for an athlete. In our study, we found that 12 athletes (71%) achieved H:Q <60%, and even in 7 athletes (58%) H:Q was <50% in at least one of the tested limbs. Maintenance of the H/Q ratio throughout the competition is crucial for physical performance or effective mobility in the fight area. Hewett et al. [38] stated that "If the hamstring peak torque decreased, the quadriceps activation should also be decreased, since a net external flexor moment is needed to flex the knee joint. Thus, the decrease in hamstring strength limits the potential of muscular co-contraction for protecting knee joint ligaments".

Some limitations of the study need to be noted. Although the isokinetic strength assessment revealed the higher occurrence of strength asymmetries in knee flexors, and lower ipsilateral ratio in the non-preferred limb, we should take into account the fact that all measurements were done in concentric contraction. Therefore, future research should be considered also eccentric muscle contraction. Another potential limitation of this study is the small number of athletes with wide range of age, but on the other hand all of them are highly skilled and were member of Czech national team. It means, that our results are valid only for comparable group of athletes.

CONCLUSIONS

The study presents the muscular strength of knee extensors and flexors in the preferred and non-preferred limb at three angular velocities. These data may serve comparative purposes for other researchers, as a base (criterion) of assessment of elite professional kickboxers or for comparison with other martial arts. The results revealed strength asymmetries in favour of knee flexors, when almost 60% of athletes achieved a critical value at higher velocities. The ipsilateral ratio (H:Q) was significantly lower in the non-preferred limb, which indicates a lower preparedness of the non-preferred limb. Strength imbalances may affect motor performance, potentially leading to stronger limbs in human motor movement, and they may negatively influence musculoskeletal function from a health prevention point of view. In terms of practice, the results may be beneficial for athletes, coaches, physiotherapists, doctors and other clinical staff in elite fighters. Early identification of muscle imbalances and their compensation using verified intervention procedures should be a part of strength conditioning intervention of elite kickboxers with the aim of early elimination of the detected maladaptive effects. This is very important from the perspective of future performance, health, overall well-being and health care expenses as a consequent of post – injury rehabilitation. Functional intervention regimes should be started as soon as possible and tailored to the individual.

REFERENCES

1. Buse J. Kickboxing. In: Kordi R, Maffulli N, Wroble R et al., editors. Combat Sports Medicine. London: Springer-Verlag; 2009: 331-350
2. Salci Y. The metabolic demands and ability to sustain work outputs during kickboxing competitions. Int J Perform Anal Sport 2015; 15: 39-52
3. Zabukovec R, Tiidus PM. Physiological and anthropometric profile of elite kickboxers. J Strength Cond Res 1995; 9: 240-242
4. Ouergui I, Hssin N, Haddad M et al. Time-motion analysis of elite male kickboxing competition. J Strength Cond Res 2014; 28: 3537-3543
5. Nikolaidis PT, Fragkiadakis G, Papadopoulos CE et al. Differences in force-velocity characteristics of upper and lower limbs of male kickboxers. Balt J Health Phys Act 2011; 3: 147-153
6. Cetin MC, Tasgin O, Arslan F. The relationship between reaction time and decision-making in elite kickboxing athletes. World Appl Sci J 2011; 12: 1826-1831
7. Lehnert M, Xaverova Z, De Ste Croix M. Changes in Muscle Strength in U19 Soccer Players During an Annual Training Cycle. J Hum Kinet 2014; 42: 175-185
8. Maly T, Zahalka F, Mala L et al. The bilateral strength and power asymmetries in untrained boys. Open Med 2015; 10: 224-232
9. Boguszewska K, Boguszewski D, Busko K. Special Judo Fitness Test and biomechanics measurements as a way to control of physical fitness in young judoists. Arch Budo 2010; 6: 205-209
10. Diaz-Lara FJ, Garcia JMG, Monteiro LF et al. Body composition, isometric hand grip and explosive strength leg - similarities and differences between novices and experts in an international competition of Brazilian jiu jitsu. Arch Budo 2014; 10: 211-217
11. Croisier JL, Ganteaume S, Binet J et al. Strength imbalances and prevention of hamstring injury in professional soccer players – A prospective study. Am J Sports Med 2008; 36: 1469-1475
12. Yeung SS, Suen AMY, Yeung EW. A prospective cohort study of hamstring injuries in competitive sprinters: preseason muscle imbalance as a possible risk factor. Br J Sports Med 2009; 43: 589-594
13. Keeley DW, Plummer HA, Oliver GD. Predicting asymmetrical lower extremity strength deficits in college-aged men and women using common horizontal and vertical power field tests: a possible screening mechanism. J Strength Cond Res 2011; 25: 1632-1637
14. McCall A, Carling C, Nedelec M et al. Risk factors, testing and preventative strategies for non-contact injuries in professional football: current perceptions and practices of 44 teams from various premier leagues. Br J Sports Med 2014; 48: 1352-1357
15. Lehnert M, De Ste Croix M, Zaatar A et al. Muscular and neuromuscular control following soccer-specific exercise in youth male footballers: Changes in injury risk mechanisms. Scand J Med Sci Sports 2016 [Epub ahead of print]
16. Maly T, Zahalka F, Mala L. Unilateral and ipsilateral strength asymmetries in elite youth soccer players with respect to muscle group and limb dominance. Int J Morphol 2016; 34: 1339-1344
17. Terreri ASAP, Greve JMD, Amatuzzi MM. Avaliação isocinética no joelho do atleta. Rev Bras Med Esporte 2001; 7: 170-174
18. Young WB, James R, Montgomery I. Is muscle power related to running speed with changes of direction? J Sports Med Phys Fitness 2002; 42: 282-288
19. Drid P, Ostojic SM, Vujkov S et al. Physiological adaptations of a specific muscle-imbalance reduction training programme in the elite female judokas. Arch Budo 2011; 7: 61-64
20. Knapik JJ, Bauman CL, Jones BH et al. Preseason strength and flexibility imbalances associated with athletic injuries in female collegiate athletes. Am J Sports Med 1991; 19: 76-81
21. Kong PW, Burns S. Bilateral difference in hamstrings to quadriceps ratio in healthy males and females. Phys Ther Sport 2010; 11: 12-17
22. O'Donovan O, Cheung J, Catley M et al. An investigation of leg and trunk strength and reaction times of hard-style martial arts practitioners. J Sports Sci Med 2006; 5: 5-12
23. Machado SM, de Souza RA, Simao AP et al. Comparative study of isokinetic variables of the knee in taekwondo and kickboxing athletes. Fit Perf J 2009; 8: 407-411
24. Fong SSM, Tsang WWN, Ng GYF. Lower limb joint sense, muscle strength and postural stability in adolescent Taekwondo practitioners. Int Sportmed J 2013; 14: 44-52
25. Slimani M, Cheour F. Effects of cognitive training strategies on muscular force and psychological skills in healthy striking combat sports practitioners. Sport Sci Health 2016; 12: 141-149
26. Szafranski K, Boguszewski D. Comparison of maximum muscle torque values of extensors and flexors of the knee joint in kickboxing and taekwondo athletes. JCSMA 2015; 2: 59-62
27. Pedzich W, Mastalerz A, Sadowski J. Estimation of muscle torque in various combat sports. Acta Bioeng Biomech 2012; 14: 107-112
28. Harriss DJ, Atkinson G. Update – Ethical Standards in Sport and Exercise Science Research. Int J Sports Med 2011; 32: 819-821
29. Cohen J. Statistics a power primer. Psychol Bull 1992; 112: 115-159
30. Maly T, Zahalka F, Mala L. Differences between isokinetic strength characteristic of more and less successful professional soccer teams. JPES 2011; 11: 306-312
31. Maly T, Zahalka F, Mala L. Isokinetic strength, ipsilateral and bilateral ratio of peak muscle torque in knee flexors and extensors in elite

young soccer players. Acta Kinesiol 2010; 4: 14-23

32. Impellizzeri FM, Bizzini M, Rampinini E et al. Reliability of isokinetic strength imbalance ratios measured using the Cybex NORM dynamometer. Clin Physiol Funct Imaging 2008; 28: 113-119

33. Newton RU, Kraemer WJ. Power. In: Ackland TR, Elliot BC, Bloomfield J, editors. Applied anatomy and biomechanics in sport. Champaign (IL): Human Kinetics; 2009: 155-175

34. Fousekis K, Tsepis E, Vagenas G. Lower limb strength in professional soccer players: profile, asymmetry, and training age. J Sports Sci Med 2010; 9: 364-373

35. Rosene JM, Fogarty TD, Mahaffey BL. Isokinetic Hamstrings: Quadriceps Ratios in Intercollegiate Athletes. J Athl Train 2001; 36: 378-383

36. Hoffman JR, Maresh CM, Armstrong LE. Isokinetic and dynamic constant resistance strength testing: Implication for sport. Phys Ther Practice 1992; 2: 42-53

37. Aagaard P, Simonsen EB, Magnusson SP et al. A new concept for isokinetic hamstring: Quadriceps muscle strength ratio. Am J Sports Med 1998; 26: 231-237

38. Hewett TE, Myer GD, Zazulak BT. Hamstrings to quadriceps peak torque ratios diverge between sexes with increasing isokinetic angular velocity. J Sci Med Sport 2008; 11: 452-459

39. Dictionary of Sport and Exercise Science. Over 5,000 Terms Clearly Defined. London: A & B Black; 2006

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