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An isokinetic profile in senior female and male karate athletes national team level

Aleksandar Kotrljanovic[1ACD], Dragan Atanasov[2BE], Dragoljub Veljovic[1AD], Patrik Drid[1ABDE]

[1] Faculty of Sport and Physical Education, University of Novi Sad, Novi Sad, Serbia
[2] Faculty of Sport, University Union – Nikola Tesla, Belgrade, Serbia

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Abstract

Background & Study Aim: Using isokinetic testing in order to detect antagonist/agonist strength ratios we can get reliable and reproducible measurements which can be used for injury prevention. Knowledge of these phenomena is essential in order to detect possible differences and similarities, as well as compare results between genders of karate athletes. The aim of this study is isokinetic profile in elite female and male karate athletes.

Material & Methods: The testing group was comprised of 9 male and 9 female karate athletes and they were all members of National karate team of Serbia. Each participant completed the testing in single session (~1.5 h), and each group completed the testing over the course of 3 days, with testing occurring at the same time of the day. We investigated conventional concentric strength ratios and contralateral differences for both shoulders and knees at both 60°/s and 180°/s testing speeds. For the results analysis, the Statistical Package for Social Science (SPSS), version 20.0 was used.

Results: Significant differences were observed in knee and shoulder strength between female and male karate athletes. Both female and male karate athletes showed recommended results for conventional concentric H:Q strength ratio, as well as in contralateral concentric H and Q strength ratio. Also, both athletes showed higher conventional concentric ER:IR strength ratio than recommended.

Conclusions: There was a number of individuals with imbalances greater than recommended, but karate group as a whole was at a low risk of musculoskeletal injury and it can be concluded that karate stimulate body symmetrically during training over the years.

Keywords: cross-sectional studies • knee injuries • martial arts • muscle strength • physical fitness • shoulder • torque

Corresponding Author: Aleksandar Kotrljanovic, Faculty of Sport and Physical Education, University of Novi Sad, Njegoseva 46; Indjija; Serbia; e-mail: kotrljanovic@gmail.com

Conventional concentric strength ratio – represents concentric antagonist to concentric agonist strength ratio.

Contralateral asymmetry – represents asymmetry of the opposite sides of the body.

Position – *noun* **1**.the place where a player is standing or playing **2.** the way in which a person's body is arranged [64].

Posture *noun* the position in which a body is arranged, or the way a person usually holds his or her body when standing [64].

Kumite – is a semi-contact karate competitive concurrence, where two athletes perform various kicking, punching and blocking techniques towards each other with maximum control in order to gain points and win the match. Destruction is fictive.

Isokinetic training *noun* weight training in which the muscle contracts at a constant speed, requiring specialised equipment [65].

Muscle strength – essential and basic physical capacity in combat sports by which the body moving status is modified [65].

Injury *noun* damage or a wound caused to a person's body [64].

Injury mechanism *noun* the way in which a casualty sustained his or her injury, e.g. in a fall or collision, which may help with diagnosis and treatment decisions [64].

Martial arts – *plural noun* any of various systems of combat and self-defence, e.g. judo or karate, developed especially in Japan and Korea and now usually practised as a sport [64].

Martial Arts – are systems of fight practices (practiced in many reasons: self-defence, competition, self-improvement, physical health and fitness, mental and physical development) [66].

Technique – *noun* a way of performing an action [64].

Technique – specific procedures to move one's body to perform the task that needs to be accomplished [67].

Sports technique – a method of performing a motor task specified in the rules of a given sports discipline that depends on particular athletes' somatic, motor and psychic properties [68, p. 153].

Introduction

Karate is currently considered one of the most widely practiced system of Japanese martial arts in the world [1] and it is divided into *kata* and *kumite*. *Kata* has a conventional structure were athletes perform predetermined series of movements and techniques in known order against imaginary opponents, whereas *kumite* has dynamic structured and involves overcoming competitor with a use of various movements, defensive and offensive techniques [2]. Beside that these two karate specializations has different structure, in the study of Vujkov et al. [3] they did not found significant differences in body composition and individual cardio-metabolic and thermal responses to simulated competition (specific effort) in elite male *kata* and *kumite* athletes. Karate requires both aerobic and anaerobic capabilities [4, 5] but beside that, multi-choice reaction time, explosive power and strength are also important skills for performance of karate [6]. According to the rules imposed by the World Karate Federation, athlete's main goal is to score by touching the opponent; hence high-intensity actions in punching and kicking techniques are required prior to a response from the opponent [7]. Also, karate athletes spend a great deal of time training in positions (posture) that could place significant amount of stress on joints such as the hips, ankles and especially the knees [8, 9]. Thus, a better understanding of the muscle performance of these athletes may be of great usefulness in injury rehabilitation and prevention centres.

The isokinetic testing can provide valuable information in combat sports regarding strength of certain muscle groups and its imbalance detection [10]. The hamstrings-to-quadriceps (H:Q) peak torque ratio has received a lot of attention regarding its use to quantify muscular imbalance as well as in rehabilitation and physical conditioning [11]. The H:Q strength ratio is critical in providing muscular stability in the knee and in preventing anterior cruciate ligament (ACL) injuries [12-16]. Contraction force of the quadriceps muscle during knee extension produces substantial anterior directed shear of the tibia relative to the femur at extended joint angles [17, 18] and this shear can be counteracted not only by the ACL but also by hamstring co-activation [19]. Thus, low muscle strength of the hamstrings relative to quadriceps has been proposed to increase the risk of noncontact knee joint injuries [12, 20, 21] and some studies also showed that asymmetries between dominant and non-dominant limbs can also be related to an increased risk of injury in athletes [22, 23]. Also, numerous studies have investigated the muscular balance of shoulder rotator cuff muscles in an attempt to identify imbalances that may be associated with shoulder injuries [24-27]. Of all the muscle groups of the shoulder, evaluation of the shoulder external rotators (ER) and internal rotators (IR) is most informative because those muscle groups are responsible for dynamic stabilization of the glenohumeral joint [28]. One of the possible mechanisms, leading to shoulder injury, may be a strength imbalance between those muscles [29], which is easily assessed using isokinetic strength testing.

The traditional method compares the maximal concentric strength of the hamstrings and quadriceps muscles and is referred to as the conventional concentric H:Q strength ratio [12]. To assess the muscular imbalance of the shoulder rotator muscles, numerous studies also used the conventional concentric ER:IR strength ratio, which is calculated as the ratio of the strength of the ER to that of the IR in concentric action [24-27]. It is well known that elite athletes may develop significant muscular asymmetries in response to daily high demand sports training, as well as that specificity of the sport gestures may lead to muscle imbalances that could predispose these athletes to injuries [30-32], but muscle symmetry of the lower extremities (due to specific techniques) and possibility of ankle, hip, and knee injury was scarcely investigated in karate [9, 33].

The basic premise of our research is the need to determine: peak torques during concentric knee extension (Qcon) and flexion (Hcon) in both legs, as well as during concentric internal (IRcon) and external (ERcon) rotations in both shoulders, at both 60°/s and 180°/s angular velocities. Knowledge of these phenomena is essential in order to detect possible differences and similarities, as well as compare results between genders of karate athletes.

Thus, the aim of the present study is isokinetic profile in elite female and male karate athletes. We hypothesized: (1) that sport adaptations related to the daily practice of this martial art would produce muscle imbalances that could predispose these athletes to higher risk of musculoskeletal injury; (2) Secondly, we expected that we will have statistical significant differences between female and male karate athletes in results of peak muscle torques.

Material and methods

Participants

Eighteen karate athletes (9 males and 9 females), members of national team of Serbia, volunteered to

participate in this study (Table 1). All participants were healthy, with no limitations to participate in the study and were currently under the supervision of their coaching staff. The study conformed to the standards set by the Declaration of Helsinki and all used procedures were approved by the University of Novi Sad ethics committee.

Table 1. Participant characteristics (mean and standard deviation).

Variable	Male (n=9)	Female (n=9)
age (years)	24.1 ±3.72	21.25 ±2.76
height (cm)	183.10 ±5.70	167.63 ±4.17
mass (kg)	78.19 ±9.73	63.05 ±3.56

Design

This cross-sectional analysis is comprised of knee and shoulder isokinetic testing. Each participant completed the testing in single session (~1.5 h), and each group completed the testing over the course of 3 days, with testing occurring at the same time of day. Testing for all athletes took place during their respective off-season after a rest day (~24 h) and before training on that day.

Procedures

After a standardized warm-up, all participants were positioned at Humac Norm dynamometer (Lumex, Ronkonkoma, NY, USA) to assess concentric isokinetic hamstrings (H) and quadriceps (Q) strength on each leg. Familiarization consisted of 3 repetitions at an individually perceived 50%, 70%, and 90% of maximum exertion at each position (posture) [34]. Prior to each testing gravity compensation was performed using Humac software and the ROM was set to 90°. Standardized testing protocol was used, with each leg tested 4 times at 60°/s and 180°/s angular velocities (extensions and flexions) [10, 35]. Participants were given appropriate rest between trials (>2 min) to prevent the effects of fatigue.

Peak values of thigh muscles torques were recorded during knee extension and knee flexion: right and left quadriceps (Q-R and Q-L, respectively), and right and left hamstrings (H-R and H-L, respectively). Following data collection, conventional concentric H:Q strength ratio and contralateral asymmetries were calculated. To calculate the conventional H:Q strength ratio, a participants concentric hamstring peak torque was divided by the concentric quadriceps peak torque, while contralateral asymmetry was defined as difference between opposite sides of the body expressed in percentage.

After leg testing, muscular strength of the IR and ER shoulders rotators have been determined. The testing apparatus was set up and participants positioned in the seated position and stabilized uniformly as described in the Humac Norm owner's manual for IR and ER, with 45° of shoulder abduction in the scapular plane [36, 37] inducing the least constraint for the rotator cuff and thus prevents pain 38, 39]. The humerus was aligned with the rotational axis of the dynamometer. The elbow was supported in 90° flexion, and the forearm and wrist were in neutral pronation/supination. Auto adhesive straps were placed horizontally across the chest and pelvis to stabilize the trunk to the seat. Participants were tested through a 70° range of motion, composed of 30° for internal rotation and 40° for external rotation, from a reference position of the forearm horizontal at 0°.

Statistical analysis

For the results analysis, the Statistical Package for Social Science (SPSS), version 20.0 was used. Shapiro-Wilk Test indicated that the present data were suitable for nonparametric analysis. Therefore, in the present research, we used descriptive statistics (mean and standard deviation) and, in order to determine a significant statistical differences between groups, we used Mann Whitney test.

Results

We found statistical significant differences ($p \leq 0.01$) between male and female karate athletes in peak torques in both legs and shoulders, during both 60°/s and 180°/s testing speeds. Male karate athletes produced greater results in all above mentioned indicators (Table 2).

No statistical significant differences ($p \leq 0.05$) between male and female karate athletes in results of conventional concentric H:Q and ER:IR strength ratios during both 60°/s and 180°/s testing speeds. Both male and female karate athletes had recommended conventional concentric H:Q strength ratio (71.75 ±7.83 and 73.64 ±6.08, respectively), and higher results than recommended for conventional concentric ER:IR strength ratio (78.92 ±8.49 and 91.14 ±18.51, respectively). Also, results showed no statistical significant differences ($p \leq 0.05$) between male and female karate athletes in contralateral H and Q and contralateral ER and IR strength ratios during both 60°/s and 180°/s

Table 2. Male and Female karate athletes values (mean and standard deviation) at two angular velocities.

Indicator 60°/s		Male (n = 9)		Female (n = 9)	
		180°/s	60°/s	180°/s	
Avg. PT Q (Nm)	R	**212.78** ±34.54**	**137.11** ± 20.27**	135.22 ±32.92	87.67 ±20.16
	L	**215.78** ±35.60**	**133.89** ±23.64**	137.44 ±27.13	88.89 ±14.31
Avg. PT H (Nm)	R	**145.67** ±22.65**	**102.33** ±16.06**	88.67 ±20.51	66.78 ±10.85
	L	**143.44** ±34.27**	**102.44** ±23.31**	97.89 ±21.09	70.00 ±12.94
Avg. PT IR (Nm)	R	**44.11** ±8.42**	**37.33** ±8.25**	25.44 ±5.43	20.33 ±4.09
	L	**44.00** ±10.48**	**37.56** ±9.33**	21.78 ±3.31	18.56 ±3.81
Avg. PT ER (Nm)	R	**34.67** ±5.83**	**28.33** ±3.84**	19.67 ±2.74	20.11 ±9.93
	L	**34.78** ± 6.59**	**28.56** ±4.61**	20.22 ±3.31	16.22 ±3.15
H:Q (%)	R	68.89 ±6.81	74.89 ±8.10	66.56 ±9.44	78.11 ±11.91
	L	66.56 ±12.14	76.67 ±11.44	71.22 ±4.68	78.67 ±6.54
ER:IR (%)	R	80.11 ±14.39	77.11 ±8.67	79.67 ±13.79	101.33 ±50.33
	L	80.11 ±7.24	78.33 ±14.27	93.89 ±14.68	89.67 ±19.82
Q-R:Q-L (%)		7.33 ±6.67	7.78 ±5.95	7.11 ±11.14	8.11 ±10.01
H-R:H-L (%)		11.22 ±6.534	9.44 ±7.88	10.67 ±9.35	10.33 ±5.75
IR-R:IR-L (%)		13.89 ±7.817	16.22 ±11.78	13.56 ±12.98	11.67 ±13.57
ER-R:ER-L (%)		8.78 ±6.65	11.67 ±6.40	8.44 ±7.45	14.33 ±15.40

Avg. average; **PT** peak torque; **R** right side; **L** left side; **Q** quadriceps; **H** hamstrings; **IR** internal rotation; **ER** external rotation; **H:Q** conventional concentric hamstrings to quadriceps strength ratio; **ER:IR** conventional concentric external to internal rotation strength ratio; **Q-R:Q-L** contralateral quadriceps strength ratio; **H-R:H-L** contralateral hamstrings strength ratio; **IR-R:IR**-L contralateral internal rotation strength ratio; **ER-R:ER-L** contralateral external rotation strength ratio. ****** Statistical significance of ≤0.01 compared to females.

testing speeds. Both male and female karate athletes showed recommended contralateral asymmetry for both Q and H at both 60°/s and 180°/s testing speeds, while contralateral asymmetry of ER and IR strength showed that only male karate athletes had higher result in IR strength ratio (15.06 ±9.40) than recommended, while others results was acceptable (Table 3).

Discussion

Our study showed that male karate athletes produced statistical significant greater results (p≤0.01) in Q and H, as well as in ER and IR muscle torques during both 60°/s and 180°/s angular velocities compare to female. Results from our study are in agreement with the ones from Probst et al. [9] where they also showed significant gender differences in Q and H peak torques at both 60°/s and 180°/s, with men karate athletes demonstrating greater values (p≤ 0.05).

The typical H:Q strength ratio of a healthy knee ranges from 50% to 80% and it is commonly accepted that H:Q strength ratio of 60% or higher is desirable in rehabilitation [40-42]. When examining H:Q strength ratio in men and women, several previous studies [43-46] reported greater H:Q strength ratio in men than in women and suggest that men activate their hamstring muscles more effectively than women.

In study of Hewett et al. [47] isokinetic dynamometer measurements show that male athletes demonstrate significantly greater H peak torque values with increasing maturity, while peak H torque remains stable with increasing maturational stage in female athletes, so they conclude that these neuromuscular imbalances may increase the risk of injury in pubertal and post pubertal female athletes. Also, according to Hewett, et al. [21] sex differences in H:Q strength ratio are particularly pronounced at higher movement speeds, similar to those seen in various sport

Table 3. Male and female karate athletes values (mean and standard deviation) for both legs and shoulders at both angular velocities – no statistical significant differences (p≤0.05) between results.

+Indicator	Male (n = 9)	Female (n = 9)
$H:Q_{60}$	67.72 ±7.83	68.89 ±5.95
$H:Q_{180}$	75.78 ±8.79	78.39 ±7.19
$H:Q_{60+180}$	71.75 ±7.83	73.64 ±6.08
$ER:IR_{60}$	80.11 ±9.66	86.78 ±10.28
$ER:IR_{180}$	77.72 ±8.93	95.50 ±31.14
$ER:IR_{60+180}$	78.92 ±8.49	91.14 ±18.51
$Q\text{-}R:Q\text{-}L_{60+180}$	7.56 ±4.97	7.61 ±10.51
$H\text{-}R:H\text{-}L_{60+180}$	10.33 ±5.40	10.50 ±6.37
$IR\text{-}R:IR\text{-}L_{60+180}$	15.06 ±9.40	12.61 ±11.89
$ER\text{-}R:ER\text{-}L_{60+180}$	10.22 ±5.40	11.39 ±10.71

$H:Q_{60}$ conventional concentric hamstrings to quadriceps strength ratio for both legs at 60°/s angular velocity; **$H:Q_{180}$** conventional concentric hamstrings to quadriceps strength ratio for both legs at 180°/s angular velocity; **$H:Q_{60+180}$** conventional concentric hamstrings to quadriceps strength ratio for both legs at both 60°/s and 180°/s angular velocities; **$ER:IR_{60}$** conventional concentric external to internal rotation strength ratio for both shoulders at 60°/s angular velocity; **$ER:IR_{180}$** conventional concentric external to internal rotation strength ratio for both shoulders at 180°/s angular velocity; **$ER:IR_{60+180}$** conventional concentric external to internal rotation strength ratio for both shoulders at both 60°/s and 180°/s angular velocities; **$Q\text{-}R:Q\text{-}L_{60+180}$** contralateral concentric quadriceps strength ratio at both 60°/s and 180°/s angular velocities; **$H\text{-}R:H\text{-}L_{60+180}$** contralateral concentric hamstrings strength ratio at both 60°/s and 180°/s angular velocities; **$IR\text{-}R:IR\text{-}L_{60+180}$** contralateral concentric internal rotation strength ratio at both 60°/s and 180°/s angular velocities; **$ER\text{-}R:ER\text{-}L_{60+180}$** contralateral concentric external rotation strength ratio at both 60°/s and 180°/s angular velocities.

activities, and it has been suggested that these differences in the H:Q strength ratio play an important role in the two-to-eight times higher likelihood of ACL injuries observed in women [14, 45, 48]. However, results in present study showed that there is no statistical significant differences (p≤0.05) between male and female karate athletes in conventional concentric H:Q strength ratio during both testing speeds, as well as that both male and female karate athletes had recommended conventional concentric H:Q strength ratio (71.75 ±7.83 and 73.64 ±6.08, respectively).

Our results are in agreement with the results from Probst et al. [9] where karate group also demonstrated acceptable H:Q strength ratio (62%), but in direct contrast with the results of Scattone-Silva et al. [33] where karate athletes presented H:Q strength ratios smaller than recommended, suggesting that they might be at increased risk of injury. It should be noted that athletes from study of Probst et al. [9] had smaller time of karate practice (belts ranged from green to black), however, in our study all karate athletes were with black belt and with long experience in this martial art, but still with recommended results for asymmetry and with lower risk of knee injury.

Having evaluated the results of our study we found that there is no statistical significant differences (p≤0.05) between male and female karate athletes in contralateral H and Q and contralateral ER and IR strength ratios during both 60°/s and 180°/s testing speeds. Although there were a number of individuals with contralateral Q and H strength differences greater than 15%, as a group, male karate athletes had results for Q (7.56 ±4.97) and H (10.33 ±5.40), while female had results for Q (7.61 ±10.51) and H (10.50 ±6.37), which means that both male and female athletes were not at increased risk for musculoskeletal injury [22, 23, 49]. Results from our study are also in agreement with previous research of Probst et al. [9] and Scattone-Silva et al. [33] where karate athletes also did not appear to be at increased risk of injury because contralateral Q and H strength differences were lower than 10%. These results indicates that karate training during years does not produce contralateral asymmetries in the lower limbs that could be related to an increased risk of injury.

As we mentioned before, numerous studies have investigated the muscular balance of shoulder rotator cuff muscles in an attempt to identify imbalances that may be associated with shoulder injuries [24-27]. Previous study [50] have recommended developing

a conventional concentric ER:IR strength ratio of 2:3-3:4 (0.66-0.75) to prevent shoulder injuries, as well as increasing the ER:IR ratio to 76%. Furthermore, results below 15% in contralateral ER and IR strength is generally recommended for lower risk of shoulder injury [51, 52]. Male and female karate athletes in our study showed higher results (78.92 ±8.49 and 91.14 ±18.51, respectively) than recommended for conventional concentric ER:IR strength ratio, while results of contralateral asymmetry of ER and IR strength ratio showed that only male karate athletes had higher IR strength ratio (15.06 ±9.40) than recommended, while contralateral ER strength ratio of male, as well as both contralateral ER and IR strength ratios of female was below 15% which means that they have low risk for shoulder injury. It is important to note that there are inherent difficulties in study comparisons related to the shoulder rotator muscles, due to differences in test equipment, upper limb position during the isokinetic strength test, and the angular speed at which the isokinetic strength test is performed.

This study had several limitations that should be addressed. Firstly, the number of karate athletes was somewhat small, but we wanted all subjects be elite and in senior population, so we can have comprehensive conclusions about influence of this martial art to muscle adaptations after many years of training. Secondly, in our study we used conventional concentric isokinetic measurements for both knees and shoulders which seems to have some limitations. For example, during knee joint movements the co-activation of H and Q muscle takes place through opposing contraction modes [53, 54] and consequently, the functional H_{ecc}:Q_{con} strength ratio is often preferred, because it represents the ratio of eccentric hamstrings and concentric quadriceps strength [12, 54]. Furthermore, studies have shown that during a side cutting maneuver where most noncontact ACL injuries are observed [55], neuromuscular activation of the hamstrings are only 30–50% of maximum activation [56, 57] supporting that contractile hamstring rate of force development (RFD) rather than maximal strength is an important parameter for the potential of muscle stabilization at the knee joint. Also, for shoulder measurements, functional ER_{ecc}:IR_{con} strength ratio is more appropriate than conventional concentric ER_{con}:IR_{con} strength ratio because it takes into account the eccentric action of the antagonist muscles, which contribute to dynamic glenohumeral joint stability [40, 58-63]. These are potential limitations and suggestions for further research recognized by the authors, however, we showed interesting findings in karate athletes with respect to training adaptations after many years of karate training.

Conclusions

Both male and female karate athletes showed that they have recommended conventional concentric H:Q strength ratio, as well as recommended contralateral asymmetry for both Q and H at both 60°/s and 180°/s testing speeds. Also, both athletes produced higher results than recommended for conventional concentric ER:IR strength ratio, while results in contralateral asymmetry of ER and IR strength showed that only male karate athletes had higher result in IR strength ratio (15.06 ±9.40) than recommended, while others results was in recommended range. Therefore, the initial hypothesis that karate athletes may be at increased risk of knee and shoulder injury as a result of certain training adaptations must be rejected, while on the other hand, second hypothesis should be accepted, because results in our study showed statistical significant differences between male in female athletes in peak torques in both legs and shoulders at both testing speeds.

Highlights

- The isokinetic testing can provide valuable information in combat sports in order to detect possible differences and asymmetries between muscle groups which may be very important for decreasing risk of musculoskeletal injury.
- Although karate group as a whole was at a low risk of musculoskeletal injury, there was a number of individuals with imbalances greater than recommended which means that in training process we should pay attention to every athlete individual.
- Diagnostics and isokinetic testing should be an integral part of every training process because just in that way we can be sure that we will decrease the number of injuries and improve sports performance.

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Competing interests

The authors declare that they have no competing interests.

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