Lower-body strength, power and flexibility in karateka: implications for musculoskeletal health

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

Ina Shaw [1ABCD], **Damien Schwartzel** [2ABC], **Lourens Millard** [1CD], **Gerrit Jan Breukelman** [1CD], **Brandon Stuwart Shaw** [1ABCD]

[1] Department of Human Movement Science, University of Zululand, Kwazulu-Natal, Republic of South Africa

[2] Department of Sport, Rehabilitation and Dental Sciences, Tshwane University of Technology, Pretoria, Republic of South Africa

Received: 14 February 2020; **Accepted:** 16 March 2020; **Published online:** 30 March 2020

AoBID: 13322

Abstract

Background and study aim: Karate training has a long history of improving general health and wellbeing, however, little or no research has been undertaken to determine the effect of karate training on muscular fitness, lower-body strength, power and flexibility. The aim of this study was to enhance the knowledge about lower-body strength, power and flexibility of karate athletes of different levels of training and not trainees.

Material and Methods: The study assessed lower-body isokinetic quadriceps and hamstring strength and power, and hip and knee flexibility in a group of elite karate athletes (group 1; n = 18), active karate athletes (group 2; n = 18) and active controls not participating in karate (group 3; n = 18).

Results: Physically active individuals not participating in karate have significantly ($p \leq 0.05$) increased hip flexion, hip extensor and hip rotation, but not hip abduction flexibility when compared to elite karateka. The elite karateka were found to have superior strength in their quadriceps at 60 and 180°.sec^{-1} and hamstrings at 60°.sec^{-1}. The elite karateka were also found to have significantly higher quadriceps peak torque values at 60°.sec^{-1} than the active non-karateka. For power, elite karate athletes were found to have a lower time to peak torque at 60°.sec^{-1} for their quadriceps when compared to active karate athletes.

Conclusions: The karateka display greater lower-body strength and power that their active counterparts and that the strength benefit is increasingly dependent on the level of karate experience. However, the non-karate athletes displayed improved lower-body flexibility when compared to the karateka, irrespective of level of training. This implies a possible need to supplement karate training with a flexibility-specific training program to more comprehensively improve muscular fitness.

Key words: kata • martial arts • muscular fitness

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

Ethical approval: The study was approved by the local Ethics Committee

Provenance & peer review: Not commissioned; externally peer-reviewed

Source of support: Departmental sources

Author's address: Lourens Millard, Department of Human Movement Science, University of Zululand, Private Bag X1001, KwaDlangezwa, 3886, Kwazulu-Natal, Republic of South Africa; e-mail: millardl@unizulu.ac.za

Strength – *noun* the fact of being strong [24].

Power – *noun* **1.** physical force or strength **2.** the ability, strength, and capacity to do something [24].

Flexibility – *noun* **1.** the amount or extent to which something can be bent **2.** the extent to which something can change or respond to a variety of conditions or situations [24].

Performance – *noun* the level at which a player or athlete is carrying out their activity, either in relation to others or in relation to personal goals or standards [24].

Physical activity – *noun* exercise and general movement that a person carries out as part of their day [24].

Kata (form) – is executed as a specified series of a variety of moves, with stepping and turning, while attempting to maintain perfect form. Kata displays a transition and flow from one posture and movement to another, teaching the karateka proper form and position, and encouraging them to visualize different scenarios for the use of each motion and technique in imaginary bout. There are various forms of kata developed through different karate styles.

MET – the metabolic equivalent of task is the objective measure of the ratio of the rate at which a person expends energy, relative to the mass of that person, while performing some specific physical activity compared to a reference, set by convention at 3.5 mL of oxygen per kilogram per minute, which is roughly equivalent to the energy expended when sitting quietly.

INTRODUCTION

According to the UN, the number of people older than 60 years will increase to 22% of the total population by 2050 [1]. However, as individuals age, they are more likely to develop disabilities and physical limitations that affect their ability to maintain independence, quality of life and physiological functional capacity [2, 3]. Essential physical fitness components necessary to negate these age-related effects on independence, quality of life and physiological functional capacity are muscular strength, power and flexibility [2].

Problematically, the muscular system undergoes a 40% loss of muscle mass and 30% decrease in strength by age 70 [4] and it is even more disconcerting that this age-related decline in muscular fitness affects the lower-body more that the upper-body [5]. Previous research has demonstrated that strength specifically appears to increase into the third decade of life, then plateaus through the fifth and/or sixth decade, followed by a rapid decliner [5]. The increased lower-body muscular fitness deterioration that occurs with aging (and inactivity) affects independence, quality of life and physiological functional capacity since the lower-body acts as a base during locomotion and is essential when performing in daily activities of living.

Due to the increasing longevity and increasing incidence of physical inactivity globally resulting in an associated decline in muscular fitness, effective approaches are required to assist the inactive and the elderly to maintain a healthy and active life. One such intervention that may prove useful in negating declines in muscular fitness (i.e. strength, power and flexibility) may be the use of martial arts. The sport of martial arts is made up of many different styles, including boxing, judo and karate. Specifically, karate training in general has a long history of improving general health and wellbeing. Karate as a form of physical activity has been demonstrated to be vigorous activity since it utilizes more than 6.0 METs or more than 7 kcal. × min^{-1} [6]. Previous research has demonstrated that karate is effective at increasing cardiorespiratory fitness and musculoskeletal fitness (i.e. strength, balance and power) [7]. Karate may achieve these health benefits since karate, as a sport, involves basic techniques, kata and sparring which in turn, are made up of punching, kicking, blocking and striking either from a stationary position or during various body movements or stances [8]. However, little or no research has been undertaken to determine the effect of karate training on muscular fitness, and specifically, lower-body strength, power and flexibility.

The aim of this study was to enhance the knowledge about lower-body strength, power and flexibility of karate athletes of different levels of training and not trainees.

MATERIAL AND METHODS

Participants

The present study took the guise of a cross-sectional study. A sample of 54 apparently healthy, adult (≥18 years) participants (n = 18 per group), of which 67% were male (n = 36) and 33% were female (n = 18), were recruited for participation in the present study. Group 1 consisted of elite International Shotokan Karate Federation (ISKF) World Cup squad members, Group 2 consisted of active karate athletes (with at least 2 years' experience) and active participants not participating in karate (with at least 2 years' exercising experience). All participants were free from any relative and absolute contraindications to exercise testing. Written informed consent was obtained from the participants after they were given a detailed verbal and written explanation of the study. Participation in the study was voluntary, and each of the participants could withdraw from the study at any time.

The study was conducted according to the Declaration of Helsinki.

Procedures

Flexibility of the lower-body was measured via a gravity-based goniometer (Leighton Flexometer, 3118 E Chaser Lane, Spokane, WA99223, USA). The flexometer consisted of a gravity needle and a strap that was placed around the tested limb/body area. As each tested limb/body area was being flexed and extended to maximum, the change in angle was measured and recorded [9].

Muscular strength and power testing of the lower-body followed the protocol as proposed by Shaw et al. [10] and took place following a 5-minute warm-up of light pedalling (heart rate <100 beats per minute) on a stationary cycle ergometer and 5 minutes of quadriceps and hamstring stretching. This was followed by positioning the participants on the isokinetic dynamometer. Stabilising straps were used to secure each subject and each subject's right knee was aligned with the dynamometer's axis of rotation using a line passing transversely through the femoral epicondyles of the dominant knee [11, 12]. The knee/hip adapter pad was then positioned three centimetre (3 cm) proximal to the medial malleolus. Participants were then asked to put their arms across their chest for the duration of the protocol in an attempt to fully isolate the muscle acting on the knee, and to eliminate any extraneous pelvic movement that might arise as a result of a subject using his/her arms to generate additional force [12]. Each subject's anatomical zero, range of motion and gravity effect torque was established according to the parameters of Cybex International. The Cybex Norm System's dynamometer was set at a damp setting of '2', to lessen torque overshoot resulting from participants trying to 'catch up' to the speed of the dynamometer. To be able to compare the results from each subject, standardisation was required as to the range of motion each subject was allowed. Each subject was limited to 100 degrees of range of motion, with the entire range of motion lying between 5° and 105° of knee flexion [10].

Participants then were familiarised with the equipment and warmed-up by performing one set of five progressive familiarisation repetitions of con-con contractions at 60 degrees per second (60°.sec^{-1}) [13]. The familiarisation repetitions consisted of two repetitions at 50% effort, two repetitions at 75% effort and one repetition at 100% effort [13]. The familiarisation repetitions attempted to prevent excessive discomfort in the test items to follow [14]. Upon completion of the familiarisation repetitions, participants immediately commenced with the test items. The trials consisted of five pairs of maximal (100% effort), intermittent, reciprocal, con-con contractions [15]. No verbal encouragement was given during all trials. In order to standardize visual feedback, the computer monitor was positioned one metre from each subject at chest level. Participants were instructed to carefully observe the monitor at all times. This procedure was followed for 180°.sec^{-1} subsequent to a 2-minute rest. Participants underwent testing at an indoor centre by the same researcher where the air temperature ranged from 22°C to 25°C.

Statistical analysis

All statistical procedures were carried out using the Statistical Package for Social Sciences (SPSS) for Windows version 20.0 (SPSS Inc., Chicago, IL, USA). Kruskal-Wallis was used to determine if any differences existed between the groups. Descriptive data is presented as means standard deviation (±). P-values ≤0.05 were considered statistically significant in the interpretation of the results.

RESULTS

Results indicate that physically active individuals not participating in karate have significantly ($p \le 0.05$) increased hip flexion (left: p = 0.001; right: p = 0.001), hip extensor (left: p = 0.001; right p = 0.001) and hip rotation (left: p = 0.016; right: p = 0.021), but not hip abduction (left: p = 0.001; right: p = 0.001) flexibility when compared to elite karateka (Table 1). This finding of a significantly decreased flexibility was also found in active karate athletes when compared to active participants not participating in karate. No significant differences were found in flexibility for the elite and active karateka. Knee flexion flexibility was found to be significantly higher in the elite karate group when compared to the active karate group (left: p = 0.032; right: p = 0.046).

Table 1. Cross-sectional comparison of lower-body flexibility and muscular strength across International Shotokan Karate Federation (ISKF) World Cup squad members, active karate athletes and active controls not participating in karate.

Variable	Elite karateka (n = 18)	Active karateka (n = 18)	Non-karateka (n = 18)
Age (years)	**25.67 ±11.55***	**36.5 ±10.21‡**	22.8 ±1.83
Body mass (kg)	**72.36 ±5.57***	**83.93 ±22.64‡**	68.2 ±7.18
Stature (cm)	175.92 ±6.38	176.67 ±8.91	170.83 ±10.46
	Flexibility		
Hip flexion: left (°)	**89.67 ±10.46†**	**85.33 ±13.43‡**	105.67 ±6.92
Hip flexion: right (°)	**94.33 ±13.95†**	**86.83 ±8.50‡**	102.17 ±12.73

Variable	Elite karateka (n = 18)	Active karateka (n = 18)	Non-karateka (n = 18)
Hip extension: left (°)	**47.67 ±10.42†**	**43.67 ±11.60‡**	56.5 ±23.76
Hip extension: right (°)	**45.50 ±18.48†**	**40.67 ±8.69‡**	67.5 ±8.17
Hip abduction/adduction: left (°)	80.00 ±13.58	84.50 ±7.58	91.00 ±7.92
Hip abduction/adduction: right (°)	81.33 ±13.49	82.67 ±6.25	89.50 ±8.78
Hip rotation: left (°)	65.00 ±19.86†	**67.67 ±10.56‡**	46.83 ±14.05
Hip rotation: right (°)	65.83 ±14.69†	**67.17 ±15.34‡**	47.17 ±12.42
Knee flexion/extension: left (°)	148.00 ±11.33*	**122.50 ±11.10‡**	154.17 ±14.89
Knee flexion/extension: right (°)	145.67 ±10.89*	**125.5 ±13.62‡**	158.83 ±9.28
	Muscular Strength		
Quad. peak torque 60°.sec^{-1}: left (Nm)	**169.83 ±50.31*†**	**152.33 ±45.93‡**	128.33 ±26.28
Quad. peak torque 60°.sec^{-1}: right (Nm)	**172.5 ±48.39*†**	**164.5 ±59.05‡**	133.67 ±32.25
Hamstring peak torque 60°.sec^{-1}: left (Nm)	**101.17 ±24.76†**	**102.00 ±19.92‡**	88.00 ±35.98
Hamstring peak torque 60°.sec^{-1}: right (Nm)	**103.50 ±22.40†**	**104.83 ±27.18‡**	87.83 ±30.94
Quad. peak torque 180°.sec^{-1}: left (Nm)	**73.67 ±20.72†**	**71.50 ±21.44‡**	60.5 ±18.01
Quad. peak torque 180°.sec^{-1}: right (Nm)	**74.67 ±21.05†**	**75.33 ±31.82‡**	60.33 ±24.60
Hamstring. peak torque 180°.sec^{-1}: left (Nm)	58.33 ±12.71	**63.00 ±21.09‡**	48.17 ±12.35
Hamstring. peak torque 180°.sec^{-1}: right (Nm)	59.83 ±13.24	**62.67 ±19.17‡**	49.50 ±12.05
	Muscular Power		
Quad. time to peak torque 60°.sec^{-1}: left (sec)	**0.64 ±0.15***	**0.74 ±0.10‡**	0.60 ±0.11
Quad. time to peak torque 60°.sec^{-1}: right (sec)	**0.68 ±0.15***	**0.74 ±0.90‡**	0.56 ±0.20
Hamstring time to peak torque 60°.sec^{-1}: left (sec)	**0.58 ±0.83†**	0.53 ±0.08	0.47 ±0.10
Hamstring time to peak torque 60°.sec^{-1}: Right (sec)	**0.60 ±0.08†**	**0.54 ±0.12‡**	0.45 ±0.94
Quad. time to peak torque 180°.sec^{-1}: left (sec)	0.62 ±0.04	0.63 ±0.08	0.65 ±0.48
Quad. time to peak torque 180°.sec^{-1}: right (sec)	0.65 ±0.49	0.62 ±0.60	0.61 ±0.04
Hamstring time to peak torque 180°.sec^{-1}: left (sec)	0.62 ±0.04	0.62 ±0.07	0.64 ±0.04
Hamstring time to peak torque 180°.sec^{-1}: right (sec)	0.63 ±0.39	0.62 ±0.63	0.60 ±0.30

Values are means standard deviation (±) kg: kilograms; cm: centimetres; °: degrees; Nm: Newton metres
* Indicates a significant ($p \le 0.05$) difference between Group 1 and Group 2
† Indicates a significant ($p \le 0.05$) difference between Group 1 and Group 3
‡ Indicates a significant ($p \le 0.05$) difference between Group 2 and Group 3

With regards to muscular strength, the elite karateka were found to have superior strength in their quadriceps at 60 (left: p = 0.001; right: p = 0.001) and 180°.sec^{-1} (left: p = 0.047; right: p = 0.046) and hamstrings at 60°.sec^{-1} (left: p = 0.020; right: p = 0.031) when compared to the active controls. The elite karateka were also found to have significantly higher quadriceps peak torque values at 60°.sec^{-1} when compared to the active karateka (left: p = 0.040; right: p = 0.048). In addition, the active karateka were found to have significantly increased lower-body strength on all measures when compared to the active controls. For muscular power, elite karate athletes were found to have a lower time to peak torque at 60°.sec^{-1} for their quadriceps when compared to active karate athletes (left: p = 0.039; right: p = 0.042). However, the elite karateka took more time to peak torque for their hamstrings at 60°.sec^{-1} than non-karate athletes (left: p = 0.030; right: p = 0.048). In turn, the active karate athletes demonstrated higher time to peak torque in their quadriceps (left: p = 0.018; right: p = 0.026) and left hamstring (p = 0.047) than active non-karate athletes (Table 1).

DISCUSSION

Recently, there has been an increase in popularity of martial arts, primarily due to the rise of mixed martial arts [16]. This study demonstrates that there is no difference in flexibility of the lower-body between elite and active karateka. However, the study made an interesting finding that physically active individuals not participating in karate have superior lower-body flexibility when compared to karateka, irrespective of level of karate training. The present study's findings contrast those found in previous longitudinal [17, 18] and cross-sectional studies [19]. Possible reasons for this finding may be due to the karateka in this sample having increased hypertrophy in their lower body when compared to the other sampled athletic population, although this was not measured by the present study. In addition, static flexibility measures such as those used in the present study may not prove appropriate to evaluate karate performance. The present study also focuses on one style (i.e. ISKF) and therefore caution should be exercised in extrapolating the findings to all styles of karate. Other forms of karate may display different flexibility levels due to different training patterns and differences in teaching philosophies, and this cross-sectional finding merits further investigation.

The study demonstrated that elite karateka have superior strength in their quadriceps at 60 and 180°.sec^{-1} and hamstrings at 60°.sec^{-1}. The elite karateka were also found to have higher quadriceps peak torque values at 60°.sec^{-1} than the active non-karateka. This confirms the previous research that has demonstrated increases in strength following a period of karate training [17] and other cross-sectional studies [19].

While the Wingate test has mainly been utilized to determine power, or changes thereof, following a period of longitudinal karate training [20], the present found conflicting results of the effect of karate when compared to generally active athletes. While several studies have demonstrated that karate training increases power longitudinally [18, 21], the present study found that elite karateka have more power in their quadriceps when compared to active karate athletes. However, these elite karateka had less power in their hamstrings than non-karate athletes. In turn, the active karate athletes demonstrated lower power in their quadriceps and left hamstring than active non-karate athletes. This finding is disconcerting in that a karateka's ability to accelerate their lower limbs rapidly to maximal force seems critical to athletic success in that sport. Again, since the present study focuses on one style (i.e. ISKF), caution should be exercised in extrapolating the findings to all styles of karate. In addition, it has previously been found that karate performance relies more on muscle power at low rather than high loads [22]. However, little or no research has been conducted cross-sectionally comparing power of matched karate athletes and other non-karate sports and additional research is warranted to confirm this finding.

CONCLUSIONS

An increasing incidence of physical inactivity and the increasing longevity of the global population have led to the development of disabilities and physical limitations that affects an individual's ability to maintain independence, quality of life and physiological functional capacity. As such, novel interventions are required to maintain independence, quality of life and physiological functional capacity. This may be achieved through the use of cost-effective physical activity interventions or sports such as martial arts. The findings of the present study confirm karate training's long history of improving general health and wellbeing [23], by demonstrating that karateka display greater lower-body strength and power than their active counterparts and that the strength benefit is increased dependant on the level of karate experience. Problematically, the non-karate athletes displayed improved lower-body flexibility when compared to the karateka, irrespective of level of training. This implies a possible need to supplement karate training with a flexibility-specific training program to more comprehensively improve muscular fitness.

ACKNOWLEDGEMENTS

The authors would like to thank the Department of Sport, Rehabilitation and Dental Sciences, Tshwane University of Technology, South Africa for the use of its isokinetic dynamometer and the International Physical Activity Projects (IPAP) for its assistance with the statistical analyses.

REFERENCES

1. United Nations. World Population Prospects: The 2004 Revision. New York: United Nations; 2005
2. Anton MM, Spirduso WW, Tanaka H. Age-related declines in anaerobic muscular performance: weightlifting and powerlifting. Med Sci Sports Exerc 2004; 36(1): 143-147
3. Milanović Z, Pantelić S, Trajković N et al. Age-related decrease in physical activity and functional fitness among elderly men and women. Clin Interv Aging 2013; 18: 549-556
4. Rogers MA, Evans WJ. Changes in skeletal muscle with aging: Effects of exercise training. Exerc Sport Sci Rev 1993; 21: 65-102
5. Bemben MG, Massey BH, Bemben DA et al. Isometric muscle force production as a function of age in healthy 20- to 74-yr-old men. Med Sci Sports Exerc 1991; 23: 1302-1310
6. United States of America Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Division of Nutrition and Physical Activity. Promoting physical activity: a guide for community action. Champaign: Human Kinetics; 1999
7. Doria C, Veicsteina A, Limonta E et al. Energetics of karate (kata and kumite techniques) in top-level athletes. Eur J Appl Physiol 2009; 107(5): 603-610
8. Yoshimura Y, Imamura H. Effects of basic karate exercises on maximal oxygen uptake in sedentary collegiate women. J Health Sci 2010; 56(6): 721-726
9. Fourie M, Gildenhuys GM, Shaw BS et al. Effects of a mat Pilates program on flexibility in elderly woman. Med Sport (Roma) 2013; 66(4): 545-553
10. Shaw I, Shaw BS, Cilliers JF et al. Influence of visual feedback on knee extensor isokinetic concentric and eccentric peak torque. Afr J Phys Activ Health Sci 2009; Suppl: 257-264
11. Magee DJ, Currier DP. Effect of number of repetitions on isokinetic knee strength. Physiother Can 1986; 38(6): 344-348
12. Perrin DH. Isokinetic Exercise and Assessment. Champaign: Human Kinetics; 1993
13. Ford WJ, Bailey SD, Babich K et al. Effects of hip position on gravity effect torque. Med Sci Sports Exerc 1994; 26(1): 230-234
14. Mawdsley RH, Croft BJ. The effects of submaximal contractions on an isokinetic test session. J Orthop Sports Phys Ther 1982; 4(2): 74-77
15. Dvir Z, David G. Suboptimal muscular performance: measuring isokonetic strength of knee extensors with new testing protocol. Arch Phys Med Rehabil 1996; 77(6): 578-581
16. Zetaruk MN, Violan MA, Zurukourski D et al. Injuries in martial arts: a comparison of five styles. Br J Sports Med 2005; 39(1): 29-33
17. Padulo J, Chamari K, Chaabène H et al. The effects of one-week training camp on motor skills in Karate kids. J Sports Med Phys Fitness 2014; 54(6): 715-724
18. Violen MA, Small EW, Zetaruk MN et al. The effect of karate training on flexibility, muscle strength and balance in 18 to 13-year old boys. Pediatr Exerc Sci 1997; 9: 55-64
19. Probst MM, Fletcher R, Seelig DS. A comparison of lower-body flexibility, strength, and knee stability between karate athletes and active controls. J Strength Cond Res 2007; 21(2): 451-455
20. Sbriccoli P, Bazzucchi I, Di Mario A et al. Assessment of maximal cardiorespiratory performance and muscle power in the Italian Olympic judoka. J Strength Cond Res 2007; 21(3): 738-744
21. Alesi M, Bianco A, Padulo J et al. Motor and cognitive development: the role of karate. Muscles Ligaments Tendons J 2014; 4(2): 114-120
22. Roschel H, Batista M, Monteiro R et al. Association between neuromuscular tests and kumite performance on the Brazilian karate national team. J Sports Sci Med 2009; 8(CSSI3): 20-24
23. Shariat A, Shaw BS, Kargarfard M et al. Kinanthropometric attributes of elite male judo, karate and taekwondo athletes. Rev Bras Med Esporte 2017; 23(4): 260-263
24. Dictionary of Sport and Exercise Science. Over 5,000 Terms Clearly Defined. London: A & B Black; 2006

Cite this article as: Shaw I, Schwartzel D, Millard L et al. Lower-body strength, power and flexibility in karateka: implications for musculoskeletal health. Arch Budo 2020; 16: 77-82