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Effects of plyometric training on lower and upper extremity power in karate practitioners

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Summary

Introduction. It has been suggested that the performance characteristics of competitive karate formats (intermittent high-intensity activity of brief duration with short recovery periods) involve a large anaerobic component. Hence, performance and effectiveness may be improved by enhancing anaerobic power and capacity. The aim of this study was to investigate the effects of an 8-week plyometric-based intervention in adolescent karate practitioners.

Material and methods. Nineteen male karate practitioners were divided into an experimental and control group. The control group performed traditional karate training (four sessions per week). Training in the experimental group was amended to include plyometric-based exercises targeting the lower and upper body but maintained the same training volume as the control group (four sessions per week). Pre- and post-intervention anaerobic performance was measured by calculating peak power (PP) and the time to reach PP (tPP) in a 10-s variation of the Wingate Anaerobic Test separately for the upper and lower extremities.

Results. PP and tPP magnitudes significantly increased in the experimental group and the between-group differences at post-intervention were also significant.

Conclusions. The introduction of plyometric exercises in a traditional karate training protocol can significantly increase upper- and lower-extremity anaerobic performance.

Introduction

Modern sport and fitness are guided by methodological advances in training modalities and protocols. Among many training formats that have been developed, plyometrics has been found to be particularly conducive to the enhancement of force and speed or what is commonly known as explosive power [1]. Plyometrics are exercises in which the targeted muscle groups perform repeated extensions and contractions at maximal force. This rapid shift from eccentric contraction to concentric contraction under significant load can lead to significant neuromuscular improvements as long as there is a fast transition between the muscle contractions [2]. The literature suggests that plyometric-based training is most effective when integrated and systematically executed (2–3 times per week) with other training measures as part of a comprehensive training regime [3]. For example, the effectiveness of merging plyometrics training with resistance training has been demonstrated by Rahimi and Behpur, with subjects showing enhanced anaerobic power and muscular strength compared with cohorts executing one training modality alone [4]. The enhanced training effects of integrating plyometric exercises with regular training were also demonstrated by Faigenbaum et al. via improved performance in fitness tests such as the long jump, medicine ball throw, or shuttle run [5]. A literature review (studies published between 2000–2014) on the effects of plyometric interventions in young soccer players also confirmed the benefits of including plyometrics in daily training [6]. Athletic performance improved in a large cross-section of measures including kicking distance, running speed, jumping ability, and overall agility.

Karate is a discipline that requires the comprehensive development of multiple motor skills to promote high neuromuscular coordination while amplifying the strength and speed of standard and atypical movements. Studies that have addressed the determinants of martial arts performance found a number of specific functional variables that are critical for success. Several works [7–9] analyzing various martial arts reported that this includes the maximum development of speed-based components such as reaction time, movement execution time, and movement frequency in highly variable and complex situations [10]. Research that compared the effects of plyometric training with traditional sprint training on other speed-based variables including stride length, stride frequency, or ground contact times found that plyometrics provided an enhanced training stimulus by improving sprint velocity in the 5–10 m interval [11]. However, both the plyometric and sprint training groups showed a similar magnitude of improvement in 20-m and 40-m sprint velocity. Hence, the powerful stimuli that plyometrics can provide in enhancing a wide range of performance variables particularly in the speed–force domain suggest its applicability in traditional karate training. Regarding the general effects of plyometrics, research has indicated that it is most effective in improving jump ability particularly jump height and running velocity when compared with a traditional training protocol [12].

A meta-analysis by de Villarreal et al. that included 56 studies analyzed the impact of various factors on the effects of plyometric interventions [13]. The most significant determining variables were training experience, the different types of plyometric-based exercises that were performed, and overall training volume. Additionally, males were more likely to obtain better power outcomes than females after completing a plyometric training program. Hence, training effects may be better observed if male subjects were to execute a large volume of highly varied plyometric exercises.

The influence of body build characteristics on training effects and thereby performance has also been reported, with variables such as body mass, body height, and lower extremity length can enhance power production and therefore generate greater ground reaction forces in jumping and running tasks [14]. Hence, research assessing the effectiveness of a given training intervention should consider the anthropometric differences present in a sample and select a sample with a similar anthropometric profile.

Currently, research in plyometrics is focused on optimizing training protocols to increase specific performance variables. Considering the anaerobic-dominant energy requirements of competitive karate formats (intermittent high-intensity activity of brief duration with short recovery periods), performance and effectiveness in karate may be improved by enhancing anaerobic power and capacity. Hence, the aim of this study was to investigate the effects of an 8-week plyometric-based intervention on upper and lower extremity peak anaerobic power in a sample of adolescent karate practitioners.

Material and methods

Nineteen male karate practitioners aged 15–19 years were recruited from local sports clubs. All had been regularly training prior to recruitment and were medically cleared to participate in intensive training. The sample was randomly divided into an experimental (E) and control (C) group. The intervention was conducted over a period of 8 weeks. Athletes in Group C (n = 9) attended three to four traditional karate sessions per week. Group E (n = 10) attended two karate sessions and two plyometrics sessions per week. Average session duration was 60–90 min. Both groups completed an equal number of training sessions.

The plyometrics session in Group E included eight upper and lower body exercises, performed in random order: Each exercise was performed until failure and repeated after 2–3 min of recovery to allow for phosphocreatine resynthesis [15]. Failure was treated as a significant degradation in task performance (power). Depending on the exercise, performance was assessed using a quantitative (i.e. reduction in jump height compared with previous repetitions) or qualitative (i.e. a loss of movement rhythm) measure. The total duration of each exercise was c.a. 10 min including the recovery periods (three sets total). Training load was progressively increased each week by increasing exercise repetitions or sets. After all exercise tasks were completed a cool-down was performed. The plyometrics session included the following exercises, performed in arbitrary order:

1. Push-ups over plate (one-handed to two-handed transition)
2. Vertical depth jumps
3. Burpees
4. Vertical depth jumps finished with a suri ashi sprint
5. Medicine ball step to chest pass
6. Power skipping over hurdles (at maximum frequency)
7. Resistance band lateral raises (at maximum frequency)
8. Alternate leg lateral jumps (at maximum frequency)

Lower and upper extremity power was assessed in laboratory conditions at the Exercise Laboratory at the University School of Physical Education in Wrocław, Poland. Pre- and post-test measures were collected immediately before and after the intervention. Lower extremity power was first assessed on a Monark Ergomedic 894E cycle ergometer and then upper extremity power on a Monark Ergomedic 891E arm ergometer. Workload was adjusted in line with the Wingate protocol in which 0.07 kg per 1 kg of the subject's body mass was used for lower extremity testing and 0.06 kg per 1 kg of body mass for upper extremity testing [16].

The test began with a 5 min low-resistance warm-up with increasing load on the Monark Ergomedic 894E. Afterwards, the participant performed a 10-s maximal cycling effort. A 30 min rest was provided before the participant performed a 10-s maximal effort on the arm crank ergometer. Motivation was provided to ensure maximal performance at the highest cadence. The duration of the effort was based on a pilot study in which it was found that power dropped significantly after 10 s. Anaerobic capacity was assessed by measuring peak power [W/kg] and time to peak power [s].

Statistical analysis of the data set was performed using the Statistica 10.0 software package (StatSoft, Poland). Basic descriptive statistics (means and standard deviations) were calculated for all variables. The non-parametric Mann-Whitney U test was used to identify any pre- and post-intervention differences. Statistical significance was set at $p < 0.05$.

Results

No significant between-group differences were observed for age, body height, and body mass. Statistical testing of the obtained peak power (PP) and time to peak power (tPP) me-

Table 1. Anthropometric characteristics of group E and C (x̄ and SD)

Group	Age [years]	Body height [cm]	Body mass [kg]
E $\bar{x}$	17.2	176.4	67.77
SD	0.92	7.65	10.6
C $\bar{x}$	16.44	174.1	63.85
SD	1.33	4.65	10.69

Table 2. Pre- and post-test lower extremity peak power (PP) and time to peak power (tPP) in Group E

Variable	Group E				Difference		
	Pre-test		Post-test		Absolute difference	Percent difference	*p*
	$\bar{x}$	*SD*	$\bar{x}$	*SD*			
PP [W/kg]	10.05	1.03	11.31	1.04	1.26	15.39	0.03*
tPP [s]	2.62	0.75	1.94	0.49	0.68	10.69	0.05*

* *p* ≤ 0.05, ** *p* ≤ 0.01

Table 3. Pre- and post-test lower extremity peak power (PP) and time to peak power (tPP) in Group C

Variable	Control group				Difference		
	Pre-test		Post-test		Absolute difference	Percent difference	*p*
	$\bar{x}$	*SD*	$\bar{x}$	*SD*			
PP [W/kg]	9.70	1.31	10.82	0.1	1.12	11.54	0.02*
tPP [s]	1.90	0.58	2.38	0.99	0.48	25.26	0.09

* *p* ≤ 0.05, ** *p* ≤ 0.01

Table 4. Pre- and post-test upper extremity peak power (PP) and time to peak power (tPP) in Group E

Variable	Group E				Difference		
	Pre-test		Post-test		Absolute difference	Percent difference	*p*
	$\bar{x}$	*SD*	$\bar{x}$	*SD*			
PP [W/kg]	7.21	0.96	8.32	0.84	1.11	15.39	0.03*
tPP [s]	2.28	0.41	2.05	0.42	0.23	10.69	0.03*

* *p* ≤ 0.05, ** *p* ≤ 0.01

Table 5. Pre- and post-test upper extremity peak power (PP) and time to peak power (tPP) in Group C

Variable	Control group				Difference		
	Pre-test		Post-test		Absolute difference	Percent difference	*p*
	$\bar{x}$	*SD*	$\bar{x}$	*SD*			
PP [W/kg]	7.76	1.27	8.71	1.77	0.95	12.24	0.1
tPP [s]	2.86	0.69	3.16	0.63	0.3	10.48	0.1

* *p* ≤ 0.05, ** *p* ≤ 0.01

asures revealed significant post-test improvements in both groups. Regarding lower extremity measures, PP and tPP increased by 15.39% and 10.69% in Group E, respectively ($p < 0.05$) (Tab. 2). In Group C, lower extremity PP significantly increased by 11.54% ($p < 0.05$) (Tab. 3). Lower extremity PP and tPP in Group E significantly increased by 15.39% and 10.69% upon completing the intervention ($p < 0.05$) (Tab. 4). No significant changes in tPP were observed in Group C (Tab. 5).

Discussion

It is difficult to assess the effectiveness of one comprehensive training framework versus another modality in disciplines that involve a large anaerobic component. Performance is the result of numerous physiological, biomechanical, and psychological factors. In martial arts such as karate, effective performance is further compounded by the complexity of the technical skills and moves that it involves. This requires training that not only induces beneficial biomechanical gains but refines the most opportune offensive and defensive techniques. One training strategy that can integrate a wide variety of sport-specific exercises while promoting anaerobic development is plyometrics. It is possible that it can provide more global benefits than traditional karate training.

In the assessment of anaerobic capacity, the literature cites anaerobic peak power and the time to its attainment as some of the most valid and reliable quantitative measures [17]. Studies that investigated the metabolic and physiological profile of combat athletes found that the development of maximal power in explosive bursts is an important predictor of performance especially in martial arts disciplines such as karate [18–21]. Anaerobic exercise testing revealed that male combat athletes share a similar level of average power (AP): wrestling ≈ 11.55 W/kg [22], taekwondo ≈ 10.1 W/kg [23], and ju-jitsu ≈ 11.4 W/kg [24]. Considering peak power output, one study reported a mean magnitude of 12.2 W/kg among judo athletes [25]. This finding is slightly larger than that found in the present sample of karate practitioners (lower and upper extremity PP = 8.32 and 11.31 W/kg, respectively). The relatively similar power outputs among martial arts athletes suggest the important role of explosive power and strength, alongside other fitness variables, in executing strong punches, kicks, and throws. Another variable that confirms strong anaerobic power output of the present sample was also the short tPP values, which in the plyometrics group was 1.94 s for the lower extremities and 1.80–3.16 s for the upper extremities. It is also worth noting that PP in the control group significantly improved but not tPP.

Studies that have assessed the effects of plyometrics in other disciplines have observed significant performance improvements in track and field jumping events, ski jumping, volleyball, and basketball and are credited to enhanced jumping ability [26–27]. Besides jumping ability, other studies have examined the biomechanical effects of an 8-week plyometric intervention to find significant increases in a wide range of speed–strength abilities [28].

Research on the physiology of plyometrics also analyzed the composition of muscle fibers in individual athletes and its influence on power production. Numerous studies confirmed the important role of muscle fiber composition, particularly the ratio of fast twitch to slow twitch muscle fibers, and training adaptations to exercise that involves the phosphagen (ATP-PCr) energy system [29–31]. This is due to the fact that plyometrics are based in a large part on the stretch-shortening cycle, inducing neuromuscular changes that promote faster and stronger responses to even minor and quick changes in muscle length. This results in greater power, speed, coordination, and muscle control [32] and other neuromuscular improvements particularly in trained adolescents [33]. Hence the significant performance gains that have been observed after 8-week plyometric interventions in the vertical jump, lateral jump, and depth jump [34,35].

Studies that involved the same training volume as in the present study (plyometrics twice a week for 8 weeks) have reported that this volume can significantly improve various performance measures [36]. It has also been suggested that just one plyometrics session per week is sufficient to induce beneficial training adaptations [37]. In addition to the training dose, it is important to also monitor training load via appropriate training strategies and training exercises. In the present study, the training load of the plyometric exercises was progressively increased each week by increasing the number of repetitions or sets. One interesting study focused on the effects of the training surface (in this case sand and grass) on various performance measures [38]. Future studies that investigate the effects of plyometrics training in karate practitioners should analyze differences in training surfaces (mat vs. hardwood), as this may responsible for a different training response via modified stretch-shortening cycle. Additional research is needed to further determine the most appropriate plyometric training protocols in young karate practitioners.

Conclusions

The introduction of plyometric exercises in a traditional karate training protocol resulted in a significant increase in upper- and lower-extremity anaerobic capacity as measured by anaerobic peak power and the time to its attainment. Such improvements may improve competitive performance and suggest the importance of including at least one weekly plyometrics session.

References

1. Bober T. , Rutkowska-Kucharska A., Pietraszewski B. Ćwiczenia plyometryczne. – charakterystyka biomechaniczna, wskaźniki, zastosowania. Sport Wyczynowy; 2007, nr 7-9/511-513.
2. Stiff MC. Biomechanical foundations of strenght and power training [in:]V.M. Zatsiorsky (ed.)Biomechanics in Sport.Oxford, Blacwell Publishing; 2000, pp.103
3. Markovic G. Does plyometric training improve vertical jump height A Metaanalytical. British journal of sports medicine 2007; 41 (6): 349-355.
4. Rahimi R, Behpur N. The effects of plyometric, weight and plyometric-weight training on anaerobic power and muscular strength. Physical Education and Sport 2005; Vol. 3, No 1, 81.
5. Faigenbaum AD, McFarland JE, Keiper FB. Effects of a Short-Term Plyometric and Resistance Training Program on Fitness Performance in Boys Age 12 to 15 Years. Journal of Sports Science and Medicine 2007; 06, 519 – 525.
6. Bedoya AA, Miltenberger MR, Lopez RM. Plyometric Training Effects on Athletic Performance in Youth Soccer Athletes: A Systematic Review, Strength Cond Res. 2015 Aug;29(8):2351-60. doi: 10.1519/JSC.
7. Choi HH. Encyklopedia of taekwon-do – 15 volumes ITF, Canada, 1983.
8. Lee KM. Taekwondo kyorugi – trening walki sportowej. Biblioteka trenera. COS, Warszawa, 1998.
9. Sozański H, Witczak T, Starzyński T. Podstawy treningu szybkości. Warszawa, 1999.
10. Bujak Z, Sadowski J, Litwiniuk A, Długołęcka B. Aids w świadomości osób trenujących sporty walki. Medycyna Sportowa 2006 ;1(6); Vol. 22, 35-39.
11. Rimmer E, Sleivert G. Effects of a Plyometrics Intervention Program on Sprint Performance. Journal of Strength and Conditioning Research 2000; 14(3), s. 295–301.

12. Kotzamanidis C. Effect of plyometric training on running performance and vertical jumping inprepubertal boys. Journal of Strength and Conditioning Research 2006; 20(2), s. 441-445.
13. Villarreal ES, Kellis E, Kraemer WJ, Izquierdo M. Determining variables of plyometric training for improving vertical jump height performance: a meta-analysis. J Strength Cond Res. 2009; 2: 495-506.
14. Mackala K. Mero A. A kinematics analysis of three best 100 m performance ever. Journal of Human Kinetics 2013; 36, 89-100.
15. Birch K.[red.]. Fizjologia sportu. Krótkie wykłady PWN SA, Warszawa, 2008.
16. Bar -Or O, Inbar O, Skinner JS. The Wingate Anaerobic Test. Human Kinetics, Champaign, 1996.
17. Bell W, Cobner DM. Effect of individual time to peak power output on the expression of peak power output in the 30-s Wingate anaerobic test. Int. J. Sports Med.2007, 28 (2), 135-139.
18. Kraemer WJ, Fry AC, Rubin MR. Physiological and performance responses to tournament wrestling. Med. Sci. Sports Exerc.2001; 33 (8), 1367-1378.
19. Cormie P, McGuigan MR, Newton RU. Developing maximal neuromuscular power: part 2 – training considerations for improving maximal power production. Sports Med.2011; 41(2), 125-146.
20. García-Pallarés J, López-Gullón JM, Muriel X, Díaz A, Izquierdo M. Physical fitness factors to predict male Olympic wrestling performance. Eur. J. Appl. Physiol. 2011; 111 (8), 1747-1758.
21. Walker TB, Lennemann LM, McGregor JN, Mauzy C, Zupan MF. Physiological and psychological characteristics of successful combat controller trainees. J. Spec. Oper. Med. 2011; 11 (1), 39-47.
22. Jaskólski A, Jaskólska J, Nieścieruk – Szafrańska B. Adach Z, Szupiluk M. Zależność spadku mocy w teście Wingate od wydolności tlenowej i beztlenowej .Wychowanie Fizyczne i Sport 1988; 1, s. 76-81.
23. Heller J, Peric T, Dlouhá R, Kohlíková E, Melichna J, Nováková H.: Physiological profiles of males and females Taekwon-do ITF black belts. J Sports Sci 1998; 16, s. 243-249.
24. Ambroży T., Klimek A., Pilch. Wydolność anaerobowa reprezentantów Polski w Ju- Jitsu. Medicina Sportiva Practica 2008; vol.8, s. 5-7.
25. Lech G, Tyka A, Pałka T, Krawczyk R. Wydolność fizyczna a przebieg walk i poziom sportowy zawodników Judo. Medicina Sportiva Practica 2007; Vol 8, nr 3: 81-85.
26. Virmavirta M., Komi PV. Measurement of take off forces in ski jumping. Scandinavian Journal of Medicine and Science in Sports 1993; 3(4), 229-236.
27. Chu DA. Jumping into Plyometrics, Champaing, IL. Leisure press.1991
28. Boraczyński T, Urniaż J. The effect of plyometric training on strength-speed abilities of basketball players. Research Yearbook; 2008 14(1):14-19.
29. Kaneko, M, Fuchimoto H, Toji H, Suei K. Training effect of different loads on the force-velocity relationship and mechanical power output in human muscle. Scand. J. Sports Sci.; 1983; 5:50-55.
30. Ronikier A. Fizjologia wysiłku w sporcie, fizjoterapii i rekreacji. Centralny Ośrodek Sportu, Warszawa, 2008.
31. Zatoń M, Jastrzębska A. Testy fizjologiczne w ocenie wydolności fizycznej. Warszawa, 2010.
32. Zając A, Wilk M, Poprzęcki S, Bacik B, Rzepka R, Mikołajec K, Nowak K. Współczesny trening siły mięśniowej. Katowice 2010; str. 265-266.
33. Attene G1, Iuliano E, Di Cagno A, Calcagno G, Moalla W, Aquino G, Padulo J. Improving neuromuscular performance in young basketball players: plyometric vs. technique training. J Sports Med Phys Fitness. 2015 Jan-Feb;55(1-2):1-8.
34. Potteiger JA, Lockwood RH, Haub MD, Dolezal BA, Almuzaini KS, Schroeder JM. Zebas CJ. Muscle power and fiber characteristics following 8 weeks of plyometric training. Journal of Strength and Conditioning Research 1999; 13(3), 275-279.
35. Chelly MS, Ghenem MA, Abid K, Hermassi S, Tabka Z, Shephard RJ. Effects of inseason short-term plyometric training program on leg power, jump- and sprint performance of soccer players. Journal of Strength and Conditioning Research 2010; 24(10), 2670-2676.
36. Chelly MS, Hermassi S, Aouadi R, Shephard RJ. Effects of 8-week in-season plyometric training on upper and lower limb performance of elite adolescent handball players. Journal of Strength & Conditioning Research 2014; Volume 28 - Issue 5 - p 1401–1410.
37. Rubley MD, Haase AC, Holcomb WR, Girouard TJ, Tandy RD.The effect of plyometric training on power and kicking distance in female adolescent soccer players. Journal of Strength & Conditioning Research: January 2011 - Volume 25 - Issue 1 - pp 129-134.
38. Impellizzeri FM., Rampinini E, Castagna C. Martino F, Fiorini S, Wisloff U. Effect of plyometric training on sand versus grass onmuscle soreness and jumping and sprinting ability in soccer players. Br. J Sports Med 2008; 42: s. 42–46.

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