Original articles

Aerobic and anaerobic power responses to the practice of taekwon-do

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Abstract

***Background*—Practising the martial art of taekwon-do (TKD) has been proposed to have beneficial effects on cardiovascular fitness as well as general physical ability. Furthermore, TKD masters and participants have promoted TKD as a total fitness programme. Research studies substantiating this, however, seem to be lacking, perhaps because TKD is recognised more as a method of self defence than a fitness programme.**

***Methods*—Nineteen TKD practitioners with an average age of 13.8 years and 10.4 months of TKD training experience were recruited to participate. Measurements included resting heart rate, aerobic power, anaerobic power, and anaerobic capacity.**

***Results*—Paired *t* test analysis showed no significant differences in either resting heart rate or aerobic power after training. However, significant differences were observed in anaerobic power and anaerobic capacity (p = 0.05). The increases in anaerobic power and anaerobic capacity were 28% and 61.5% respectively.**

***Conclusion*—The practice of TKD promotes anaerobic power and anaerobic capacity, but not aerobic power, in male adolescents.**

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Keywords: taekwon-do; poomses; V_{O_2}MAX; anaerobic power; anaerobic capacity

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Taekown-do (TKD), the Korean martial art, is characterised by fast, high, and spinning kicks. The name means "the art of kicking and punching". It is the most popular martial art in the world, studied in over 140 countries and practised by a million participants of all ages every day. According to Olson,[1] martial arts in general are some of the most recent additions to fitness classes practised in most major cities throughout the United States.

Only a few investigations have emphasised that TKD practice in general and TKD poomse (a series of movement sequences) in particular improve, among other things, cardiorespiratory endurance and general physical ability.[2 3] However, there is still little information on the acute cardiorespiratory responses to TKD practice, perhaps because TKD is thought of more as a method of self defence than a fitness programme.

Poomses are the essence of TKD and are relatively complex (25 different poomses) consisting of blocking, punching, and kicking techniques as well as twisting, leaping, turning, and jumping movements performed at high intensity and including a number of pauses. The purposes of the poomses are training in technical skills and overall improvement of physical ability and health; they are also performed at TKD championships and tournaments.

Research on TKD training has provided few data on which to base conclusions about the cardiorespiratory stress encountered by TKD practitioners. Telemetered heart rates of TKD practitioners performing poomses have been measured.[3] Results from this study suggest that TKD practice has the potential to raise heart rates sufficiently to increase cardiorespiratory fitness. Young[2] used two groups of men and compared the effects of TKD practice and an aerobic exercise programme on cardiorespiratory endurance, muscle endurance, and flexibility. No significant difference was found between the two groups with regard to cardiorespiratory or muscle endurance. In contrast, Thompson and Vinueza[4] reported that TKD practice had a minimal effect on cardiovascular fitness. Heller *et al*[5] likewise stated that cardiovascular endurance is not of prime importance for TKD practitioners. However, few studies have quantified other physiological effects of this type of exercise.[4 6] Similarly, little research has been directed to determining the anaerobic power of TKD practice, making it difficult to ascertain accurately the effect of TKD practice on aerobic and anaerobic responses. This investigation was therefore undertaken to examine the effect of TKD practice on aerobic and anaerobic power.

Methods

SUBJECTS

Nineteen male adolescents were recruited from one of the largest classical TKD clubs in the area of Marka, Amman, Jordan. The subjects were enrolled in an intermediate TKD class. Informed consent to take part in the investigation was obtained. Recruitment criteria were: (*a*) similar technical skill; (*b*) had practised TKD for about one year; (*c*) trained at least three times a week for one hour; (*d*) to eliminate any effect of sex, only male subjects

Table 1 Basic details of the 19 taekwon-do practitioners

Variable	Mean	SD
Age (years)	13.8	2.2
Body mass (kg)	52.4	3.6
Height (cm)	155.4	15.8
Body fat (%)	13.1	4.9
Training experience (months)	10.4	5.6

were selected. Table 1 gives the basic physical characteristics of the participants. Body fat was calculated as described by Lohman[7] and Lohman *et al*.[8]

EXPERIMENTAL PROCEDURES

TKD comprises various exercise sequences named poomses; a poomse is composed of several basic and advanced TKD techniques involving different stances, hand and foot techniques, and/or body movements in different directions. Different poomses vary in terms of style and technical content, ranging from repeated exercises of defence to attack movements of different rhythm, speed, power, and technical difficulty.

The typical TKD training session used in this investigation consisted of:

(*a*) 5–10 minute warm up period during which non-TKD activities (running, calisthenics, flexibility exercises, etc) were performed to prepare for the higher intensity activities;

(*b*) 15–20 minute period after the warm up in which TKD fundamentals (punches, blocks, kicks, twists, etc) were performed and repeated with a gradual increase in intensity;

(*c*) 7–10 minute period of progressively increasing intensity in which activities (poomses) were performed at high level intensity;

(*d*) 5–10 minute cool down period during which activities were performed to gradually reduce the heart rate to the levels reached at the end of the warm up period.

During the poomses training sessions, all subjects performed the same movements and techniques, which included different body stances and movements and different hand and leg techniques. The poomses simulate a fight (defence and attack) and are composed of displacements of the body, involving movements such as blocks, punches, kicks, twists, jumps, turns, or any combination, all of which are executed on a rectangular surface about 13.5 m^2 (3 × 4.5 m). These techniques and movements were performed as fast as possible, and resting heart rate was recorded using a Polar Vantage XL (Polar, Ventura, California, USA).

Each subject performed the poomses 15 times; the mean duration of the work interval was about 30 seconds followed by a one minute active rest interval between each poomse to maintain venous return. The training programme was performed three times a week for a total of eight weeks.

Table 2 Aerobic power (litres/min, ml/kg/min), resting heart rate, anaerobic power (W, W/kg), and anaerobic capacity (W, W/kg) of the subjects before and after taekwon-do practice

Variable	Before	After
VO_2MAX		
litres/min	1.9(0.2)	2.0(0.4)
ml/kg/min	36.3(9.2)	38.2(7.8)
Resting HR (beats/min)	80.0(6.0)	77.0(9.0)
Anaerobic power		
W	422 (87.6)	541.1(95.6)*
W/kg	8.1(1.2)	10.3(2.0)*
Anaerobic capacity		
W	235.6(70.2)	380.5(85.1)*
W/kg	4.5(0.6)	7.3(0.9)*

Values are mean (SD).
*p<0.05 compared with before (paired *t* test; *t* 18 = 2.1).
HR, Heart rate.

TEST PROCEDURES

Maximal aerobic power

Before testing, subjects were familiarised with the test procedures and equipment used. They then performed a graded continuous maximal exercise test on a cycle ergometer (model 814; Monark, Stockholm, Sweden). Subjects were allowed a three to four minute warm up period at zero load before the start of the test. The initial workload setting was 30 W and this was increased by about 12–18 W every two minutes as described by Adams.[9] Oxygen uptake (30 second sampling) and heart rate were measured continuously during the test using a computerised open circuit system running REP-200B software (Rayfield, Waitsfield, USA) and a conventional electrocardiogram monitoring system respectively.

Anaerobic power

Anaerobic power and capacity were determined using the Wingate Anaerobic Test (WnAT). A Monark cycle ergometer fitted with a photoelectric cell to count the number of revolutions of the pedals was used. Seat height was adjusted to suit the subject and toe clips were used to prevent the feet from slipping off the pedals. Subjects warmed up by pedalling for three minutes against a 2 kilopondmeter load. At the end of each minute, they were required to pedal as fast as possible against the actual relative resistance that they would be working against for a five second duration. During the three minute test period, the subjects were instructed to pedal as fast as possible from the beginning of the test and to try to maintain maximum pedalling speed throughout the 30 second period. At the beginning of the test, the subjects were instructed to pedal as fast as possible against unloaded resistance which was increased to a predetermined load within three seconds. The resistance applied was adjusted relative to body weight (0.075 × body weight in kg).[9] When this load was reached, the pedal revolutions were recorded mechanically for 30 seconds by a cycle monitor. Anaerobic power was calculated as the highest power output reached over a five second interval, and anaerobic capacity was calculated as the total work output during the 30 second test.[10]

STATISTICAL ANALYSIS

Descriptive statistics included means (SD). The paired *t* test was used to determine differences between two independent means. Statistical significance was set at p = 0.05.

Results

Table 2 gives data on cardiovascular function (Vo_2MAX, heart rate) before and after a TKD practice. The changes in V_{O_2}MAX were small, with absolute V_{O_2}MAX increasing from 1.9 (0.2) to 2.0 (0.4) litres/min and the relative value improving from 36.3 (9.2) to 38.2 (7.8) ml/kg/min. However, neither the absolute nor the relative values were significantly different. Also, no significant difference was found in resting heart rate after TKD practice (table 2).

Analysis by paired *t* test showed significant differences in anaerobic power and anaerobic capacity (table 2). The absolute anaerobic capacity increased by about 61.5% and that relative to body weight increased by about 62%.

Discussion

The lack of research into the effect of TKD practice on aerobic and anaerobic power prompted this investigation into the effects of TKD practice on cardiovascular function (V_{O_2}MAX, resting heart rate), anaerobic power, and anaerobic capacity. It was found that TKD practice and poomses training, involving adolescent male practitioners training for about 20 hours, had no significant effect on V_{O_2}MAX and resting heart rate. In contrast, a significant improvement was seen in anaerobic power and capacity. The absence of any improvement in cardiovascular function supports the conclusion that TKD practice and poomses training are inappropriate methods for developing and maintaining cardiovascular fitness.

The lack of improvement in V_{O_2}MAX and resting heart rate after TKD practice may be explained by the intensity of the TKD training protocol used in this study. It is possible that the poomses were not strenuous enough to elicit a cardiovascular effect. This may reflect the difficulty for TKD practitioners with only 10.4 months experience to sustain the required high intensity of the TKD poomses for a long period. It has been suggested that more experienced practitioners would perform their routines at a greater intensity.[11] In addition, the poomses selected in the present study were very basic ones which are learned by beginners. The purpose of these poomses was to improve combative prowess rather than cardiovascular fitness. The duration of the TKD practice and poomses training is also a contributing factor to the development of cardiovascular endurance. According to the American College of Sports Medicine guidelines for exercise testing and prescription,[12] the longer the duration (20 minutes minimum duration is recommended), the easier it is to increase cardiovascular endurance. On this basis, poomses performed for a total of nine minutes (15 × 30 seconds) as in this study would be too short to improve cardiovascular fitness.

The V_{O_2}MAX reported here was 38.2 ml/kg/min; other investigators have reported values of 53.8 ml/kg/min for Czech TKD black belt contestants,[5] 57 ml/kg/min for Spanish black belt players,[13] and 44 ml/kg/min for black belt practitioners.[4] Thus, our findings show a consistently low V_{O_2}MAX, which is probably representative of TKD practitioners. Therefore cardiovascular capacity does not appear to be of prime importance. Furthermore, studies of other martial arts such as karate, the Japanese equivalent of TKD, have reported low V_{O_2}MAX values in the practitioners. Francescato *et al*[14] reported a value of 36.8 ml/kg/min for karate (wodo style) participants. Shaw and Deutsch[11] showed that performing an intermittent 45 second karate kata had no significant effect on the aerobic power of the participants. These findings support the conclusion of the present study that TKD practice provides a minimal training stimulus for cardiovascular fitness.

The results of this study have implications about exercise prescription for fitness related improvement or skill and ability related improvement. If the goal of TKD is health related fitness, the workout should incorporate basic and easy to follow TKD skills such as punches and leg strikes. In contrast, complex combinations and numerous repetitions of high speed punches and kicks are more appropriate for improvement of skills.

This investigation provides unique data on the anaerobic power and capacity of 13 year old TKD practitioners. One of the major findings is that TKD can be used to improve anaerobic power and capacity. These findings are consistent with those of Francescato *et al*,[14] who showed that the anaerobic system is the main source of energy during karate. Heller *et al*[5] also suggested that TKD practitioners tended to show high anaerobic capability. Furthermore, Shin,[15] a seventh Dan black belt teacher, reported that the most effective TKD players are those who have both exceptional speed and strength.

Anaerobic power and capacity represent energy production from phosphagen and from combined phosphagen use and glycogenolysis respectively.[16] Francescato *et al*[14] showed that, during the practice of karate which is very intense, the major energy source is phosphagen (46–90%), the remainder coming from glycogenolysis (13%) or the lactic acid system and aerobic glycolysis (10–41%).

Support for the greater anaerobic fitness of TKD practitioners comes from the technique used by the subjects in this study. In contrast with karate practitioners, who use front kicks and arm movements, TKD practitioners use more complicated poomses consisting of kicks in different directions at maximum power and arm movements, such as blocking and punching with a rotated fist to add additional power to the punch. In this study, these routines were performed at high intensity and included an active pause for one minute. Hetzler *et al*[17] stated that TKD is a short poomse, but its proper execution requires the rapid and forceful movements of the large muscle group. These researchers also showed that blood lactate concentration increased from 1.51 to 3.23 mol/100 ml blood and found a decrease in blood pH from 7.39 to 7.34. Heller *et al*[5] similarly found the peak blood lactate concentration after 143 seconds of a TKD fight to be 11.4 mmol/l. It has been shown that this increase in blood lactate concentration and acidity are a reflection of the intensity and duration of the TKD performance.[18]

It has long been known that muscle becomes acidic during intense exercise because energy demands exceed oxidative capacity—that is, when the oxygen supply is limited, muscle must rely on anaerobic energy sources. This is supported by the results of Francescato *et al*[14] showing that the metabolic power of karate players is very high for short periods of kata (about 130 ml/kg/min for the 10 second kata) and decreases to about 68 ml/kg/min for the 80 second kata. Unfortunately, methodological difficulties prevented the invasive assessment of blood lactate concentration and blood pH responses to TKD training in the present study.

Anaerobic power reported in this investigation was 10.3 W/kg. Previous studies have reported values of 12.1 W/kg for Spanish TKD contestants[13] and 14.7 W/kg for the Czech TKD National Team.[5] Our lower results may be explained by differences in methods, training experience, and age. Nevertheless, these data indicate similar or even greater anaerobic power and capacity than found for other anaerobically trained athletes.[5] Consequently, TKD practice does appear to impose high demands on short term anaerobic performance ability. Thus, TKD practice may be an effective and specific method of anaerobic training for adolescent male practitioners.

A limitation of this study is the fact that the TKD practice protocols were not specific to cardiovascular fitness but included poomses designed to improve skill. In addition, care must be taken in extrapolating the findings to the whole population because only adolescent male subjects were studied.

In conclusion, it would appear that there was an improvement in anaerobic power and capacity with no concomitant improvement in V_{O_2}MAX and resting heart rate after an eight week TKD training programme. It is recommended that TKD trainers use the poomses and TKD training as a sport specific training method for improving and maintaining anaerobic power. Further controlled training investigations are needed to establish the precise effects of TKD workouts on acute cardiorespiratory responses.

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Take home massage
Assessment of cardiovascular endurance, anaerobic power, and anaerobic capacity in adolescent male TKD practitioners indicates that TKD practice and poomses training are inappropriate methods of improving and maintaining cardiovascular fitness. However, anaerobic power and capacity can be improved significantly. This suggests that TKD practice tends to rely more on anaerobic than aerobic metabolism.