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Physical, anthropometric and physiological profiles of experienced junior male and female South African Taekwondo athletes

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Abstract

The research was aimed at identifying the anthropometric, physical and physiological characteristics of junior Taekwondo athletes to achieve an international status. Data were collected from 25 males and 11 females aged 15.5 ±2.6 years. Measurements consisted of body composition (body fat percentage (%BF), sum of 6 skinfolds), flexibility (sit & reach, hip flexor (HF) and quadriceps flexibility (QF), lower extremity explosive power (vertical jump (Diff VJ) and vertical jump relative power (R Power), muscle endurance (sit-ups and push-ups), muscular strength (handgrip right and left), hexagonal agility (HEX) and agility T-test, aerobic power (20 m bleep test (20MST) converted to maximum oxygen uptake (VO_{2max}.). Data were analyzed using *t*-test for independent samples and Z-score statistics. Significant higher %BF and sum of skinfolds were recorded in junior female players. No differences in body mass, stature and BMI were found. Male athletes had higher ($p<0.001$) VO_{2max} (42.2±6.8 ml/kg/min) compared to females (31.7±6.5 ml/kg/min). Female athletes showed lower ($p<0.001$) results in push-ups (9.0±6.5 reps) compared to males (25.6±10.5 reps). Maximal grip strength (kg) of both hands was higher ($p<0.05$) in males. No differences in sit-ups, explosive leg power and agility were found between males and females. The analysis of individual Z-score for assessment of fitness variables has practical implications contributing to the trainability and performance of junior taekwondo athletes.

Keywords: Taekwondo athletes, physical, physiological, anthropometry.

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Introduction

Taekwondo (TKD) is a Korean martial art sport that originated 1500 years ago. This combat sport was used as a way of life, a strategy for self-defense, physical fitness and warfare being the aspect of concern at that point in time (Pons van Dijk, Huijt & Lodder, 2013). Today, over 140 countries practice Taekwondo globally out of which 120 nations are officially members of the World Taekwondo Federation (WTF) (Kazemi, Waalen, Morgan & White, 2006). Taekwondo was first introduced to the Olympics as a demonstration sport at the 1988 and 1992 Olympics in Seoul and Barcelona respectively. It was officially accepted as an Olympic combat sport in 2000 at the Sydney Olympics. TKD performances do not usually go beyond 2 minutes and its competitions consist of 3 rounds of 2 minutes each and 1 minute rest period. It is a contest in which opponents are directly and systematically confronting each other in a dynamic combat environment. In competitions participants wear protective equipment and devices. The basis of the sport allows the participant to use body kicks which are executed at high speed, quick and powerful kicks and punches on the torso, and sometimes kicking on the face (Kazemi et al., 2006). Emphasis lies on about 80% of the kicks which are allowed to the head and torso while no punches are permitted to the face. The purpose of TKD competition fighting is to overcome the opponent by accumulating greater points and the winner is the one who scores more points or knocks out the opponent.

Successful participants in combat sport like Karate, Judo, Boxing, and Taekwondo require high levels of technical, tactical, psychological, physical fitness and physiological characteristics (Chiodo et al., 2012). Taekwondo has unique technical actions and rules different from kick boxing and karate, although they share the same competitive level and have similar techniques such as kicks and punches.

TKD movements include blocks, punches, kicks, twisting, leaping, and jumping. It is a type of strength-power sport requiring high levels of anaerobic and aerobic capabilities characterized by explosive movements mainly by the lower limbs of the body, agility, flexibility, and muscular endurance are also critical for successful performance (Zar, Giliani, Ebrahim & Gorbani, 2008; Ball, Nolan & Wheelere, 2011; Campos, Bertuzzi, Dourado, Santos & Franchini, 2012).

It is clear that scientific information on such characteristics helps coaches to enhance athletes' performance, determine weaknesses and correct them by designing specific training programmes for improvement (Zar et al., 2008). High level physical fitness training programme has been designed to suit the specific demands of Taekwondo (Bridge, Jones, Hitchen & Sanchez, 2007). Specific Taekwondo conditioning prepares the contestants to effectively manage their

performance. The conditioning method requires improving both physiological demands of the competition and the physical competences of the participants (Yen Ke-tien, 2012). To date, there is no comprehensive study reporting on the physical and physiological profiles of young professional South African Taekwondo athletes. The purpose of this study was to investigate the anthropometric, physical, and physiological characteristics of junior South African Taekwondo athletes.

Methodology

Participants

Thirty six junior taekwondo athletes (24 males and 12 females) aged 15.5±2.6 years voluntarily participated in the study. The sample was made up of 6 male and 2 female internationally ranked fighters (African championships 1st to 3rd places), 4 Korean championship participants, 4 male world championship participants, 8 male and 4 female junior international medalists and 10 other internationally ranked athletes who had participated in the Korean Ambassador's Cup. The participants were members of the junior national South African Taekwondo team drawn from various provincial clubs. The inclusion criterion for participants in this study included minimum of two years of competitive Taekwondo experience, and an average competitive experience of three years. After securing ethical clearance and before participation, all athletes received verbal and written explanations of the procedures and potential risks. Participation was voluntary and athletes could decide not to participate. Having decided to participate, each athlete then signed an informed consent form. The study was conducted according to the Declaration of Helsinki and approved by the South African Taekwondo Federation (SATF).

The participants were asked to refrain from any food intake for two hours before the measurements and to avoid caffeine, alcohol and strenuous exercise for 48 hours before the tests.

Anthropometric measurements

Body mass of the individuals was measured in kilogram (kg) with participants in light clothes and bare footed using a digital scale (Kubota KA-10-150V, Japan). Stature was measured using a stadiometer (Lafayette, IN, USA) with the participants standing upright with their heads in the Frankfort plane. Body mass index (BMI) was calculated as weight divided by height squared (kg/m^2). Six skinfolds (triceps, biceps, subscapular, thigh, calf and suprailiac) were measured using the Holtain T/W Skinfold Caliper (Ross & Marfell-Jones, 1991).

Physical tests and physiological performance measurements

After sufficient warm-up and stretching the following tests were conducted:

1. Flexibility was measured in centimeters by the sit and reach(S&R) test using the La Fayette sit and reach box (Model 01285A, Lafayette, USA). The sit and reach test gauges the flexibility of the hamstrings and lower back muscles, with a reliability measure of 0.92 (Behm et al., 2006). Athletes were instructed to sit with their knees extended on the floor against the box. With hands on top of each other and palms facing down, the athletes pushed the ruler forward as far as possible without jerky movements. The score in centimeters was the most distant point reached by the edge of the ruler in contact with the finger tips.

2. Agility was tested using the hexagon test and the T-Test.
a) In the hexagon test, a hexagon 60cm on all sides and 120 degree internal angles was set up. At the start of the test, the athletes stood inside the hexagon and jumped out and in with both legs on all sides of the hexagon, completing three cycles. The test was finished after the third cycle and the time taken was measured in seconds using a stop watch (Katic, Blazevic, Krustolovic & Millic, 2005). The purpose of the test was to see how quickly the leg can move while changing directions.

b) The T-Test was used to determine the agility of body trunk without loss of balance. It included forward, lateral and backward running. A running course in the form of a capital letter T was marked on the floor. The vertical and horizontal arms of the T were both ten meters long. The vertical arm made a junction at the mid-point of the horizontal arm. To begin the test, a participant stood at the base of the vertical arm facing the horizontal arm. Upon auditory signal (whistle) the participant sprinted forward, towards the horizontal line. At the junction the athlete shuffled to the left without crossing legs and facing the direction of the run. Upon reaching the end of the horizontal line on the left the athlete shuffled laterally past the junction to the far end on the right. The athlete then shuffled laterally again towards the left for five meters to the junction of two lines. From the junction the athlete ran backward passing the starting point at the base of the vertical line. The participants repeated two timed trials and the faster time was recorded (Raven, Gettman, Pollock & Cooper, 1976; Getchell, 1985).

3. Muscular endurance was assessed by the one minute sit-up test (repetitions) and push-up test (repetitions).

a) The one minute sit-up test assessed the trunk and hip flexor muscular endurance. The athletes laid supine with the hips and knees in 90 degree of flexion with arms crossed over the chest. Correct sit-ups were ensured when the elbows touched the knees and the lower back touched the floor. The total number of sit-ups completed over a period of one minutes was counted (Sparling, 1997).
b) The one minute push-up test assessed the endurance of the arms and shoulder girdle i.e. upper body muscular endurance. From a straight arm front leaning rest

position, the performer was asked to lower the body until the chest touched the mat and then to push upwards to the straight arm support. The exercise was continued for as many repetitions as possible without rest. The score was the number of correct push-ups executed (Das & Chatterje, 2013).

4. Maximal strength of both right and left hands of the participant were assessed using a Takei hand grip dynamometer (Takei, Kikikogyo, Japan). The test was performed in a standing position, arms in 90º flexion alongside the body. The participant was asked to squeeze the dynamometer with maximum isometric effort for a 5 second period. Three trials were made with a resting period of about 10-20 seconds between the efforts to minimize the effects of muscle fatigue. The highest score was recorded according to American College of Sports Medicine (ACSM, 2000).

5. Explosive leg power was measured by the vertical jump test using the Swift yardstick device (Swift Yardstick, Swift Performance Equipment, Goonellabah, NSW, Australia). The athletes reached with their dominant arm as high as they could against the vane style apparatus to measure the initial reach height. Using a countermovement jump, the athletes jumped and reached as high as possible on the vane style apparatus. The difference (Diff VJ) between the highest point touched and the initial reach height was recorded as the score in centimeters. The ICC for test-retest reliability and TEM for the vertical jump is 0.96 and 3.3%, respectively (Gabbett, Kelly, Ralph & Driscol, 2009). The vertical jump anaerobic power was determined using Lewis nomogram (Sayer, Harackwwicz, Harman, Frykman & Rosenstein, 1999) and presented as relative power R in W/kg.

6. Aerobic power was measured using the multistage fitness test (MSFT).This test measured continuous running between two lines 20-meters apart in time to recorded beeps. The test is made up of 23 levels where each level lasts approximately one minute. Each level comprises a series of 20-meter shuttles where the starting speed is 8.5km/hr and increases by 0.5km/hr at each level. On the tape a single beep indicates the end of a shuttle and 3 beeps indicates the start of the next level. The athletes' score is the level and number of shuttles reached before he/she is unable to keep up with the CD recording. The score was converted to a predicted VO_{2max} equivalent value (Gabbett et al., 2009). The VO_{2max} obtained in a MSFT is highly correlated (r= 0.92) with VO_{2max} levels obtained using the direct oxygen consumption test (Ramsbottom, Brewer & Williams, 2009). The ICC for test-retest reliability and TEM for the multi-stage fitness test are reported as 0.90 and 3.1%, respectively (Leger, Mercier, Gadoury, & Lambert, 1988).

Statistical analysis

Statistical analyses were performed using IBM SPSS v. 20.0 (SPSS, Chicago, USA), Values from anthropometric, physical and physiological measurements and tests were expressed as mean ± SD. One-way analysis of variance (ANOVA), with a subsequent independent *t*-test was used to examine differences in physical and physiological characteristics among the Taekwondo athletes. The level of significance was set at $p \leq 0.05$.

In view of the relatively small sample size, the statistical power of the study was calculated using two statistical power calculators: Alpha error level criterion set at 0.05 or 5% confidence level and Beta criterion set at 0.80 or 80% confidence level (Zodplay, 2004). Z-criterion statistics (Marronna, Martony & Yohar, 2006) was applied for preparing computerised individual performance Z-score radar plots and used for comparison of the physical test results between athletes falling under the same category.

Results

Physical characteristics of the Taekwondo athletes are presented in Table 1. Male Taekwondo athletes tend to have slightly higher body mass and stature than females. No differences in BMI were noted. Statistically significantly higher body fat ($p<0.001$) and sum of skinfolds ($p<0.05$) were found in junior female athletes compared to males.

Table 1: Physical characteristics of the South African Taekwondo male and female athletes (mean ± SD)

Variable	Males (n=25)	Females (n=11)
Body mass (kg)	53.3±13.4	51.8±10.7
Stature (cm)	163.0±13.4	157.1±9.1
BMI (kg/m^2)	20.0±7.5	20.9±1.3
%BF	16.8±6.0	26.7±2.8*
SUM 6sf (mm)	67.5±49.2	119.7±35.0**

* $p< 0.001$ ** $p< 0.05$; %BF: body fat percentage; SUM 6sf (mm): sum of 6 skinfold in millimeters

Physical tests and physical performance profiles of the junior Taekwondo athletes are shown in Table 2. Male athletes have significantly higher maximal oxygen uptake ($p< 0.001$), maximum grip force of both hands ($p<0.05$) and higher ($p< 0.05$) upper body muscular endurance (push-ups). No significant differences were found in the following variables: BMI, body mass, stature, sit and reach, hip flexor flexibility, relative power, hexagon test, agility T-test and sit ups.

Table 2: Physical tests and physiological performance profiles of the South African Taekwondo male and female athletes (mean ± SD)

Variable	Males (n=25)	Female (n=11)
Sit & reach (cm)	40.1±7.9	42.6±6.4
Hip Flexor flexibility L(cm)	-11.2±7.9	-9.3±9.7
Hip Flexor flexibility R (cm)	10.7±8.1	7.6±9.7
Quadriceps flexibility L (cm)	59.8±9.4	59±10.3
Quadriceps flexibility R (cm)	59.7±12.1	62±9.5
Vertical jump height (cm)	49.0±14.0	41.5±7.3
Relative power R (W/kg)	15.1±2.8	14.0±1.2
Estimated Maximum oxygen uptake (ml/kg/min)	42.2±6.8	31.7±4.7 *
Hexagon test L (sec)	16.7±3.1	16.4±2.4
Hexagon test R (sec)	16.6±2.7	16.6±2.5
Agility T-test (sec)	12.6±1.2	14.2±1.4
Maximum grip force R(kg)	33.0±8.6	25.3±4.9 **
Maximum grip force L (kg)	32.9±8.7	24.6±5.2 **
Sit-ups (reps)	48.9±13.8	41.5±12.3
Push-ups (reps)	25.6±10.5	9.0±6.5 *

* p< 0.001 ** p< 0.05: cm: centimeters, R: right, L: left, W: Watts, sec: seconds, reps: repetitions, kg: kilograms

Z-criterion statistics was used to design Z-score radar plots based on six fitness components (agility, R-power, VO_{2max}, sit up, push up and sit and reach) that are relevant to success in taekwondo. These selected variables are very important in sustaining the athlete for the two minutes fight during the three rounds of play and are fundamental for the strategy and tactics in the fight.

The results of the Z-score individual radar plots (in %) of two TDK male athletes of the same category are presented in Table 3 and Figures 1 and 2.

Table: 3. Individual Z scores (in %) of two male Taekwondo athletes

		Agility (sec)	R Power	VO_{2max} (ml/kg/min)	Sit up (reps)	Push up (reps)	S&R (cm)
Z-score (in %)	M.P.	61.8	46	84	50	18.4	42.1
	N.D.	96.4	38.2	46	57.9	38.2	9.7

Analysis and practical implications of Z-score

Athlete M.P. (Figure 1) showed a better flexibility, slightly higher anaerobic power and greater aerobic power. Based on these results, the athlete is likely to perform better than the opponent. The athlete would be technically and tactically advised to utilize his skills earlier in the first round with accuracy when kicking during attacking more especially towards the face. That would be a simple way of earning more effective points. M.P. might be able to fight more rounds because of his higher aerobic power, but his training should be focused on improving muscular endurance and agility.

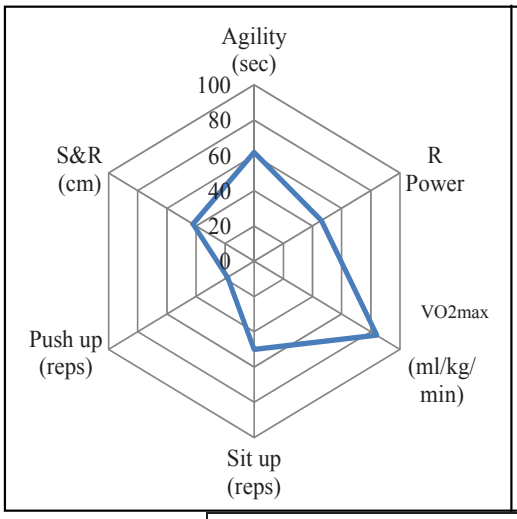

Figure 1: Z-score individual radar plots (in %) of male athlete M.P - 14yrs, 43.7 kg

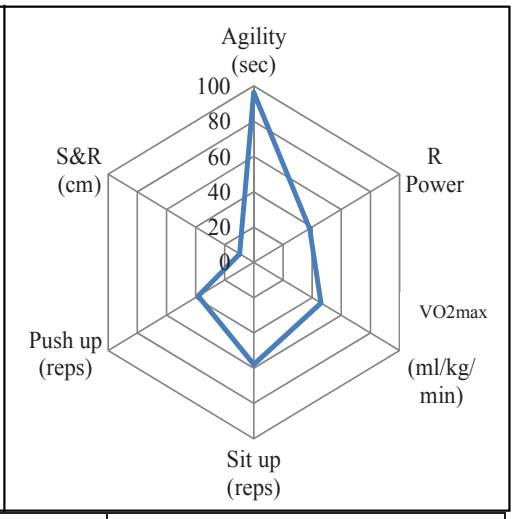

Figure 2: Z-score individual radar plots (in %) of male athlete N.D - 16yrs, 43.8 kg

Athlete N.D. (Figure 2) displayed greater level of agility and reasonable muscular endurance of the trunk and the upper body. He will be able to fight more than 3-min rounds and probably 3-5 times in the same day. Due to his high agility the athlete will stand a good chance to avoid all the powerful long kicks from his opponent by quickly changing the direction and attacking. The player needs to commit the first round to save energy, by thinking on how to create fast moves during the fight and escape attacks from his slow but flexible opponent. The coach needs to emphasize on technique and tactic on fast counterattacking movements with this player against the opponent. Athlete N.D. has to know how to avoid the most effective kicks from the opponent, by analyzing his strategy. The strategy is to play to survive until the last round because his muscular endurance would be an advantage for longer fight period.

The results of the Z-score individual radar plots (in %) of two female TDK athletes of the same category are presented in Table 4 and Figures 3 and 4.

Table 4: Individual Z-score (in%) of two Taekwondo female athletes.

		Agility (sec)	R Power	VO_{2max} (ml/kg/min)	Sit up (reps)	Push up (reps)	S&R (cm)
Z-score (in %)	C.J.	38.2	27.4	78.8	75.8	30.8	78.8
	S.C.	99.6	15.9	15.5	78.8	72.6	21.2

Analysis and practical implications of Z-score

Female athlete C.J. (Figure 3) showed a good trunk muscular endurance (assessed by sit-ups), flexibility, and greater aerobic power, but poor upper body

muscular endurance and low power performance. The athlete needs to set her favorable pace to accumulate more points in the game.

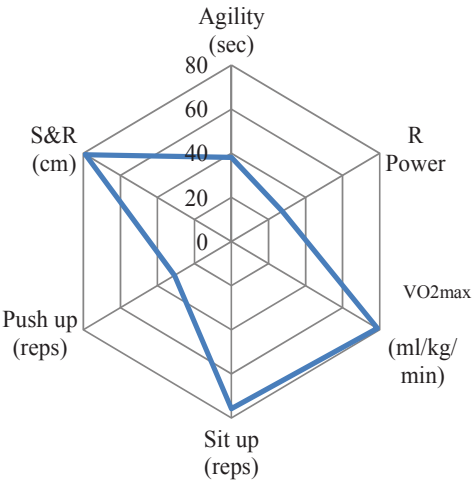

Figure 3: Z-score individual radar plots (in %) of female TKD athlete C.J. - 12 yrs, 34.5 kg

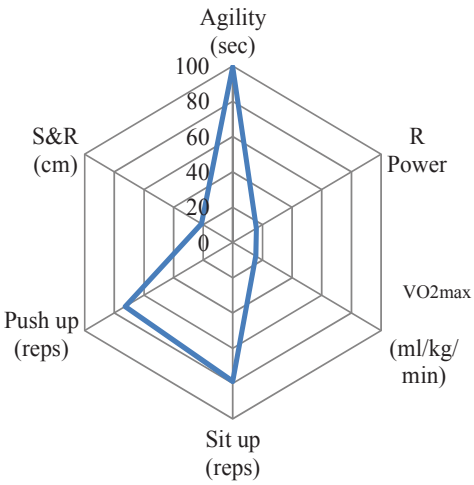

Figure 4: Z-score individual radar plots (in %) of female TDK athlete S.C. - 11 yrs, 36.6 kg

Technical and tactical advice would be to utilize her skills earlier in the first round. The advice from the coach would be to ensure that the athlete controls the game with consistent attacking to defeat the opponent's main characteristics - muscle endurance and agility. Strategically, the athlete has to use her flexibility and trunk muscle endurance to execute a wide range of defending and counterattacking kicks to frustrate the opponent. Athlete C.J. in her fight could be able to proceed to 2nd and 3rd round due to her high aerobic capacity and she could be able to play more than 2 times per day.

Female athlete S.C. (Figure 4) displayed higher level of agility, higher upper body muscle endurance (push-up), the same level of muscle trunk endurance, lesser explosive power (R-power) and very low aerobic power compared to C.J. She can avoid all strong flexible kicks from the opponent by using her very high agility to change directions and attack closely. The player needs to save energy in order to complete all rounds. The coach has to advise the athlete that each time she has the opportunity to collect points she should execute a quick sequence of fast kicks to be able to lead the fight. The greatest advantage for this athlete is her agility and she has to create more of these kicks to counteract the flexible but slow opponent C.J. Aerobic training sessions should be recommended to S.C.

Discussion

The Taekwondo athletes who took part in this study were preparing for their provincial championship. The athletes were very close to their peak performance

and the study was conducted a month preceding the championship. Most of the participants were national medalist, and some qualified to participate in the junior World Championship. Therefore, they were some of the best South African athletes in their categories at the time of data collection, and they could be considered as elite junior athletes. Knowledge of the physical and physiological profile of elite athletes in South African Taekwondo sport is important to determine the ability associated with high performance.

It is well known that TKD athletes regularly reduce their body mass to compete in their desirable, selected weight categories and to optimize their power to weight performance during combat (Tsai, Chou, Chang & Fang, 2011; Brito et al., 2012). The mean values of body mass and BMI recorded in the present study corroborate the values reported by previous studies and recommended to facilitate performance and maintain good health status (Rodriguez, DiMarco & Langley., 2009; Bridge, da Silva Santos, Chaabene, Pieter & Franchini, 2014). It was been found that high VO_{2max} in TDK athletes is related to a decrease in body fat percentage and an increase in lean body mass (Kazemi et al, 2006). According to the international Taekwondo norms body fat percentage has been reported to range between11-14% and 19.5-24% for junior males and females respectively (Bridge, Jones & Drust, 2011). However, the data from the present study showed a higher proportion of body fat, which seems to be related to numerous factors such as diet, competition level, experience, sex and age.

Recent studies with the Wingate test have shown that medalists Taekwondo athletes generate high peak power in the lower limbs (Tornello, Capranica, Chiodo, Minganti & Tessitore, 2013; Bridge et al., 2014). Therefore, TKD athletes require high anaerobic power abilities to manage the energy requirements of the bouts effectively and excellently (Matsushigue, Hartmann & Franchini. 2009; Santos, Franchini & Lima-Silva, 2011). The findings of these studies and our findings on leg relative power are in line with the work of Markovic, Vucetic and Cardinale (2008) and Harris (2014), who concluded that Taekwondo athletes depend on the anaerobic alactic power, and explosive leg power and strength. Compared to data on vertical jump reported by Ghorbanzadeh et al. (2011) and used as criteria for selection of national teams, our results from vertical jump test are higher by 10 cm in males and by 14 cm in females TKD athletes respectively. At present, much emphasis is placed on lower limb speed and power that needs to be significantly improved and which is necessary to generate the required sudden bursts, fast and powerful kicks in Taekwondo performance.

Aerobic fitness was considered previously of a lesser importance for Taekwondo competitive success (Harris, 2014). In fact, high reliance on aerobic power is needed to support and facilitate Taekwondo matches especially during recovery between successive bouts in tournaments (Bridge, McNaughton, Close & Drust,

2013; Campos et al., 2012). A powerful cardio-respiratory system is needed to sustain the metabolic demand. The level of cardiorespiratory fitness in Taekwondo differs in terms of competitions, success, experience and weight category. Recent studies revealed that ideal values of VO_2max scores in junior female Taekwondo athletes were around 31- 41 ml/kg/min (Kim, Stebbins, Chai & Song, 2011), while ideal values for junior male Taekwondo athletes were 41-49 ml/kg/min (Bridge et al., 2012). In combat sports (taekwondo, karate and judo), while energy is generated through anaerobic pathways (alactic and lactic system) in the support of technical and tactical actions in combat, aerobic metabolism and cardiorespiratory fitness are critical for training (Doria et al., 2009; Artioli et al., 2010), and for recovery and the regeneration of energy during tournaments where athletes fight from one stage to the other (Chaabene, Hachana, Franchini, Mkaouer & Chamari, 2012). The cardiorespiratory fitness of the athletes in our study is, therefore, quite comparable with other international combat athletes. Thus, Taekwondo training should include exercise programmes that significantly improve aerobic metabolism to contribute to the athlete's ability to sustain the efforts for the total duration of the combat and sustain the number of matches' up-to the final round while recovering effectively during the rest periods.

Taekwondo athletes just require submaximal muscular endurance to sustain repeated technical and tactical combat activities during competitions, which include kicking, punching, blocking, pushing and footwork (Moir, 2012). The sit-ups and push-up data gave insight into the muscular endurance of the athletes. There were few studies that examined push-ups for upper extremity and trunk muscular endurance of international taekwondo athletes (Toskovic, Blessing & Williford, 2004; Markovic et al., 2005).

Some international studies reported that 60 seconds sit-ups test scores for TKD athletes' ranges between 52 -59 repetitions in males and 48-52 repetitions in females (Moir, 2012; Chiodo et al., 2012). In our study the mean sit-up for the male South African athletes were 48.9±13.8 repetitions which are close to the recommended range. However, the mean score for female athletes was 41.5±12.3 repetitions which are outside the range. In the present study South African female TKD players have shown low levels of muscle endurance. It is suggestive therefore that more upper and lower trunk muscle endurance conditioning needs to be done with the female South African Taekwondo athletes to improve their endurance compared to their male counterparts. Coaches and scientists are encouraged to study and determine the muscle groups which are relevant to the technical and tactical actions performed in fighting.

Flexibility plays a key role in taekwondo competition since it enables athletes to execute high kicks. Studies showed that female TKD athletes possess greater flexibility than their male counterparts (Toskovic et al., 2004). It was noted that

junior Taekwondo athletes produced lower sit and reach test scores than most seniors. Training adaptations and the technical demands of the sport produce higher flexibility scores (Kim, Stebbins, Chai & Song, 2011). This could explain why the senior athletes who have been practicing the sport longer display higher flexibility scores than in juniors (Bridge et al., 2014). While there are a variety of tests which are used to test range of motion or flexibility in TKD athletes, the sit and reach test is the most widely used test in experienced TKD athletes. The other methods such as the front and side leg splits still need extensive research to determine their validity and reliability (Bridge et al., 2014). Markovic et al. (2005) obtained flexibility values of 56.6±5.2 cm in males and 54.8±4.5 cm in females, which are greater than scores from our study by 7.7 cm and 13.3 mm for males and females respectively. Therefore, the coaches have to consider introducing more stretching and flexibility exercises in their conditioning programmes. However, in the training of junior athletes these exercises should be chosen carefully to avoid injuries (Behm et al., 2006). To the best of our knowledge the introduction of Z-score radar plots based on the six most relevant variables (agility, explosive power, VO_{2max}, sit-up, push-up and flexibility) for assessment of the individual performance of TKD athletes was done for the first time. The analysis and interpretation of the individual Z-score was implemented in the current TKD practice to provide coaches with information relevant for designing personilised training programmes. It also enables coaches to give specific instructions to athletes during sparing matches and competitions. The limitations of our study is the small number of participants, but at the time that was the total number of experienced and trained South African junior TKD athletes available for recruitment. Taekwondo is very attractive sport and it is becoming more popular in South Africa and in the continent. Obviously, more experimental studies recruiting large number of athletes are needed.

Conclusions

The fitness variables are key components that contribute to performance and competence of Taekwondo athletes. These variables enable athletes to perform at their best.

The South African junior Taekwondo athletes exhibited: 1) High explosive leg power, but low levels of muscle trunk endurance and flexibility. 2) High body fat percentage 3) high aerobic capacity and high levels of agility. In general, the physical and the physiological profiles of the South African athletes are within the recommended range. These findings support that a new approach focusing on strength and speed/power training combined with high intensity aerobic training has to be applied for further improvement. Regular physical testing and analysis of Z-score radar plots could be used to improve individual performance in Taekwondo.

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