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Physical, physiological and psychological profiles of elite Turkish taekwondo athletes

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Summary

Study aim: To identify the physical, physiological and psychological profiles of elite Turkish taekwondo athletes.
Material and methods: Twelve players of the Turkish national taekwondo team (age = 22.7 ± 2.8 years, BMI = 22.2 ± 1.4 kg/m^2, body fat = 12.8 ± 3.4%) participated in the study. Anthropometric measurements including leg length and foot size were assessed. Maximal oxygen uptake, explosive power of leg extensors, isokinetic peak torque, muscular endurance, anaerobic power, agility, flexibility, maximal speed, reaction time, and postural balance were examined by incremental treadmill running, vertical jump, isokinetic strength, sit-ups and push-ups, Wingate, shuttle run, sit-and-reach, 30-meter sprint, multiple-choice reaction time, and General Postural Stability and Athlete Single Leg stability tests, respectively. Psychological characteristics including mental skills and mood states were evaluated using OMSAT-3 and POMS tests.
Results: VO_2max, isokinetic peak torque and Wingate test mean power values were 54.1 ± 4.4 mL · kg^{-1} · min^{-1}, 191.7 ± 19.2 N · m, and 9 ± 0.7 W/kg, respectively. Postural stability index 0.18 ± 0.06, single leg stability index 0.82 ± 0.11, reaction time 0.344 ± 0.032 s, 10 × 5-m shuttle run 17.09 ± 0.68 s, 30-meter sprint 4.60 ± 0.23 s, and vertical jump 43.5 ± 6.1 cm were the other values reported. The highest scores for the 12 mental skills in OMSAT-3 were for goal setting (6.25 ± 0.45) and self-confidence (6.16 ± 0.45). The lowest score was for Imagery (5.64 ± 0.36). The results of six mood states of POMS showed higher scores on the Vigor-activity, Anger-Hostility and Tension-Anxiety scales and lower scores on Depression-Dejection, Fatigue-Inertia and Confusion-Bewilderment than norms.
Conclusions: The findings of this study revealed the physical, physiological, and psychological characteristics in taekwondo. The results of the tests could be useful for performance assessment of taekwondo players.

Keywords: Maximal oxygen uptake – Explosive power – Mental skills – Talent – Reaction time

Introduction

Although many young athletes display signs of skilled sporting potential, international sporting excellence is scarce [78]. In the world of sport, team or individual, very few can reach the highest level of achievement [27]. Talent identification is the use of tests evaluating physical capability and skill level in talent detection [4]. As taekwondo was incorporated in the 2000 Olympic Games as a medal sport, the zeal among participants, national governments and scientists has gained momentum. As participation rises, the issue of talent becomes very important and opportune [32].

Overcoming a competitor in three semi-continuous rounds with a one-minute rest between rounds by obtaining either more points for delivering allowed kicking and punching techniques to permitted legal scoring areas is the goal of the match [83]. Taekwondo is famous for its high and fast kicks [33]. In championship combats, competitors execute short periods of one to five second attacks interspersed with longer periods of non-fighting activity [73]. Competitors must have the ability to move with high velocity, speed, and power [34] and must be proficient in several aspects of fitness, such as aerobic and anaerobic power, muscular strength, muscular power, flexibility, speed and agility [10, 11, 44]. A successful competitor is the embodiment of magnificent physical attributes, skill, technique, determination, strategy and psychological and physiological readiness [33].

To identify physical, physiological and psychological characteristics, essential requirements for success and an indicator of the lowest standards required to compete at specific levels, such information might be instrumental.

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The purpose of this study was to identify the characteristics of the champions competing at the international level.

Material and methods

Participants and experimental design

The participants in this study were twelve male Turkish national team taekwondo players (age 22 ± 2 years, body mass 72.9 ± 6.9 kg, height 1.82 ± 0.40 m) with a 9 ± 4 years of competition experience. All competed in European Championship and World Championship events on a regular basis and were medal winners at the aforementioned competitions during the last five years. These athletes were at the competitive phase of their periodization (16–21 h of training per week) and they had been steadily practicing supplemental strength and conditioning training for years during both preparatory and competitive periods (minimum 2 hours per week).

All subjects were warned of the test procedures, and the possible risks were all explained. A pre-exercise health screening questionnaire (PAR-Q) [64] was completed before the tests. The first testing session included anthropometric measurements, postural balance and reaction time tests, followed by anaerobic power and flexibility tests. The second testing session included testing of agility, speed, explosive power and muscular endurance. Maximal oxygen uptake and maximal strength were in the third testing session. The fourth testing session involved two questionnaires of mental skills and mood states. Fifteen-minute warm-up activities in order to prepare athletes for the higher intensity activities proceeded each testing session. The subjects of the study had rest periods of approximately 10 minutes or more between each test. There were intervals of at least 36 hours rest between the mentioned four sessions. All tests were performed at the laboratories of Ankara University.

Anthropometric measurements

Body mass, height and weight were measured according to standard definitions [28]. The distance from the midpoint of a line joining the uppermost circumference to the iliac crest down to the minimum circumference above the ankle was defined as leg length. [10, 23]. Bioelectrical impedance analysis of body composition was performed using a bioelectrical impedance analyzer (Tanita TBF 401; Tanita Corp., Japan) in order to measure the percentage of body fat [65].

Wingate test

Anaerobic peak power and mean power were determined by a 30-second Wingate test [30] on a mechanically braked cycle Ergometer (834 E, Monark, Vansbro, Sweden). Seat height was set to suit the subject and toe clips were utilized to prevent foot slippage. Subjects pedaled for five minutes against no load at a pedaling rate of 50 rpm as a warm-up. At the end of each minute of warm-up, they were required to pedal as fast as possible. During the test period, the subjects were asked to pedal as fast as possible from the commencement of the test and to persevere to retain maximum pedaling speed throughout the 30-second period. Constant encouragement was given verbally to subjects throughout the test. The resistance applied was regulated relative to body weight (0.075 × body weight in kg) [49, 79]. Peak power and mean power values were used for statistical analysis. Peak power output was defined as the highest power output reached over a 5-second interval from the six 5-second periods and mean power output was calculated from power over the 30 s duration of the test, in W/kg [20, 30, 59].

Postural stability tests

Postural stability was evaluated using a Biodex Stability System (Biodex Medical Systems, USA). The reliability and accuracy of the Biodex Stability System have already been investigated [5, 62]. The testing protocols consisted of two tests of Athlete Single Leg [5] and General Postural Stability [6] of the Biodex Stability system. During the Athlete Single Leg stability test, the non-dominant leg (supporting leg during kicks) was measured. Participants stood with opened eyes and naked feet on the platform during tests. Overall stability indexes from both tests were recorded.

Multiple-choice reaction time test

The multiple-choice test which measures the time of determination of the three different stimulants (an arrow which shows 3 directions) was used to measure total reaction time (the latency between stimulus onset and muscle contraction onset and end of movement time) with the dominant hand, and reaching to the target at the same time with visual stimulation was applied through Sport Expert Reaction Tester (Tumer Electronic LDT., TUR) [26]. Total reaction time was calculated as the average of 10 responses from 20 measured values, excluding the five lowest and five highest values.

Sit-and-reach and shuttle run agility tests

Flexibility was assessed with the sit-and-reach test [1, 3]. Agility was evaluated with the 10 × 5-m shuttle run speed and agility test [1].

30-meter sprint test

Maximal speed was estimated by 30-meter sprint runs. Running sprints were performed on an indoor running track using a timing gates system (Tumer Electronic LDT., Turkey). All the 30-meter sprint tests were performed on a three-time basis and the average value of each test score was utilized in statistical analysis. Athletes took a rest between each trial for 2 minutes.

Sit-ups and push-ups tests

Muscular endurance was determined through the maximal number of push-ups in 60 seconds and a maximum of sit-ups in 60 seconds [2].

Vertical jump test

The vertical jumping test determined the explosive power of the leg extensor muscles. The test was repeated three times. The rest period varied between each jump, but was estimated to be one minute. The average value of three attempts was used in statistical analysis. By means of the following formula, jumping height was calculated by the flight time as estimated from the force platform recordings (Sport Expert, Tumer Electronic LDT., Turkey) [37, 43]:

$$\text{height of the body center of gravity} = (t^2 \times g)/8,$$

where $g = 9.81\ m/s^2$ and t is flight time.

Isokinetic peak torque

The isokinetic strength test investigated the peak torque of the quadriceps muscles of taekwondo athletes. Athletes were instructed to abstain from any arduous exercise for 36 hours before the tests. A 10-min warm-up was applied before the test. The peak torque (N·m) of the quadriceps muscles during concentric contraction in the dominant leg was measured. Test data were obtained from Cybex Norm (Henley Corp, Sugarland, TX, USA) type isokinetic strength testing equipment. Measurements were taken in the sitting position. Height and length of equipment were adjusted for each athlete. Angular velocities were chosen as 60°/s for 5 repetitions. The one with the highest peak torque value of 5 repetitions was used for further analysis. An angular velocity of 60°/s for 5 repetitions for maximal strength is a common standard in isokinetic measurements [25, 52, 66]. During each contraction, the participants were orally inspired to produce their maximal performance while, at the same time, the examiner checked the temporal evolution of the isokinetic curves on the screen to make sure that the subjects performed at their peak intensity.

Incremental treadmill test

To determine maximal oxygen uptake (VO_2max), a continuous progressive treadmill test to volitional exhaustion was used. The test protocol started on a running treadmill (Cosmed, Gambettola, Italy) at 8 km/h for 3 min as a warm-up followed by an initial speed of 9 km/h with incremental steps of 1 km/h every 1 min and a fixed treadmill grade of 1% until inability to maintain the running speed [42, 45]. Expired air was collected and analyzed using a breath-by-breath gas exchange system (Vmax 229 Cardiopulmonary Exercise System; Sensor Medics, Yorba Linda, CA, USA) which also monitored ECG. The VO_2max corresponded to the highest VO_2 value attained in two consecutive 15 s periods [71]. The other criteria for judging the VO_2max were when at least two out of the three following criteria were met: 1) achieving a VO_2 plateau despite increasing running speed (change in VO_2 at VO_2max ≤150 mL/min), 2) respiratory exchange ratio value higher than 1.10, 3) heart rate within 10 beats per min of age-predicted maximal heart rate [50].

Ottawa Mental Skills Assessment Tool and Profile of Mood States

The fourth testing session, as athletes had recovery time for more than 36 hours, the third version of the Ottawa Mental Skills Assessment Tool OMSAT-3 [21, 22] and Profile of Mood States POMS [48] were used to pool the data. The third version of OMSAT-3 includes 48 items and 12 mental skill groups, categorized under three main conceptual elements. Foundation Skills consists of goal setting, self-confidence and commitment. Psychosomatic Skills includes stress reaction, fear control, relaxation and activation. Cognitive Skills embodies imagery, mental training, focusing, refocusing and competition planning. Each element was designed on a "strongly disagree" to "strongly agree" 7-point Likert scale. Past validation research has demonstrated internal consistency scores ranging from 0.68 to 0.88, with a mean value of 0.78, while intraclass reliabilities ranged from 0.78 to 0.96, indicating strong reliability [22]. For current research, measures of internal consistency estimates (Cronbach's [18] alphas) were 0.82 for the foundation skills scale, 0.81 for the psychosomatic skills scale, 0.80 for the cognitive skills scale and 0.89 for overall.

The Profile of Mood States (POMS) consists of a list of 65 adjectives that measure 6 psychological states (Depression-Dejection, Anger-Hostility, Vigor-Activity, Fatigue-Inertia, Confusion – Bewilderment, and Tension-Anxiety). Respondents indicated the degree to which they felt during the last week using a 5-point Likert scale format (0 = not at all, 1 = a little, 2 = moderately, 3 = quite a bit, 4 = extremely). Validation studies indicate internal consistency (alpha) coefficients for the POMS subscales ranging from 0.84 to 0.95 [48]. Test-retest reliability coefficients ranging from 0.65 to 0.74 are reported [47]. The internal consistency reliability of POMS was evaluated using Cronbach's [18] alpha coefficient. An alpha value of 0.81 was deemed an acceptable sign of scale reliability.

Statistical analysis

The data were analyzed using SPSS 16.0 (SPSS Inc., Chicago, USA) software. The descriptive analysis involved the calculation of the mean and standard deviation.

Results

Anthropometric characteristics of the participants are shown in Table 1. Physiological characteristics included the VO_2max value of 54.1 ± 4.4 (mL · kg^{-1} · min^{-1}). Perceptual motor abilities and physical proficiency abilities' values are presented in Table 2. These variables include isokinetic peak torque, anaerobic peak power, anaerobic mean power, postural stability index, single leg stability index, reaction time, 10 × 5-m shuttle run, 30-meter sprint, vertical jump, sit-and-reach, push-ups and sit-ups.

Table 1. Anthropometric data from Turkish elite male taekwondo athletes (n = 12)

Variable	Mean ± SD
Age [years]	22.7 ± 2.8
Body height [m]	1.82 ± 0.04
Body mass [kg]	72.9 ± 6.9
Body fat [%]	12.8 ± 3.4
BMI [kg/m^2]	22.2 ± 1.4
Leg length [cm]	96.6 ± 2.5
Foot size [cm]	27.4 ± 1.1

BMI: Body mass index.

Table 2. Perceptual motor abilities and physical proficiency abilities of subjects

Variable	Mean ± SD
Peak isokinetic torque [N · m]	191.7 ± 19.2
Anaerobic peak power	
W	893.1 ± 105
W/kg	12 ± 1.4
Anaerobic mean power	
W	673.8 ± 51.8
W/kg	9 ± 0.7
PSi	0.18 ± 0.06
SLSi	0.82 ± 0.11
Reaction time [s])	0.344 ± 0.032
10 × 5-m shuttle run [s]	17.09 ± 0.68
30-meter sprint [s]	4.60 ± 0.23
Vertical jump [cm]	43.5 ± 6.1
Sit-and-reach [cm]	37.5 ± 6.5
Push-ups (R/60s)	45.3 ± 5.5
Sit-ups (R/60s)	55.5 ± 6.5

PSi: Postural Stability index; SLSi: Single Leg Stability index.

Table 3. Descriptive statistics of the Ottawa Mental Skills Assessment Tool OMSAT-3 scales

Scale	Mean ± SD
Goal setting	6.25 ± 0.45
Self-confidence	6.16 ± 0.45
Commitment	6.14 ± 0.50
Stress reactions	5.35 ± 0.45
Relaxation	5.75 ± 0.58
Fear control	6.10 ± 0.62
Activation	5.93 ± 0.33
Focusing	5.95 ± 0.50
Imagery	5.64 ± 0.36
Competition planning	6.10 ± 0.68
Mental practice	5.91 ± 0.71
Refocusing	6.02 ± 0.36

Table 4. Means, standard deviations and internal consistency coefficients for six mood states of POMS

Mood States	Mean ± SD	Alpha
Depression-Dejection	3.83 ± 3.53	0.79
Anger-Hostility	6.83 ± 2.69	0.78
Vigor-Activity	21.66 ± 4.43	0.81
Fatigue-Inertia	4.33 ± 2.57	0.71
Confusion-Bewilderment	3.58 ± 1.31	0.84
Tension-Anxiety	5.83 ± 1.94	0.84

Means and standard deviations for the 12 mental skills in the OMSAT-3 are reported in Table 3. Athletes reported their highest scores, 6.25 ± 0.45 and 6.16 ± 0.45, for goal setting and self-confidence, respectively. Also, athletes scored lowest on Imagery (5.64 ± 0.36). The highest scores between three broader conceptual components of OMSAT-3 were associated with the Foundation skills (6.18 ± 0.38). Cognitive skills were second highest (5.92 ± 0.40) and Psycho-Somatic skills were third (5.78 ± 0.33).

The scores of subjects and internal consistency coefficients in the six mood states of POMS are described in Table 4.

Discussion

According to the results, the age of Turkish elite male taekwondo athletes ranged between 19 and 27 years (22.7 ± 2.8 years). The average age of male taekwondo athletes who participated in the 2004 Olympics has been reported as 26.1 years [34]. This, however, is different from the findings of a study in the 2000 Olympics. The authors reported male winners' average age as 24.4 years [33].

The current study demonstrated 1.82 m (SD 0.04) for height of the athletes and 96.6 ± 2.5 cm and 27.4 ± 1.1 cm for leg length and foot size, respectively. In comparison, the 2000 and 2008 Olympic Games male winners' average height was 1.83 m (SD 0.08) and 1.83 m (SD 0.11), respectively [33, 34]. Markovic et al. [44] investigated the differences between successful and less successful Croatian national taekwondo champions. They discovered that successful athletes were slightly taller (by 5.8 cm) than less successful athletes. Taller athletes have the advantage of longer lower and upper extremities, meaning longer levers supplying them with greater capability to cover a larger area with less energy [34]. In support of the findings of previous research, some authors assume that longer lower extremities may be beneficial in combat sports where kicking techniques are the prevalent means of attack [33, 44]. Supporting the findings of the current study, other authors claim that the length of the upper and lower extremities may directly impact success in taekwondo [44, 60].

Comparing the BMI data of taekwondo players of the current study to those of the same level in a study that investigated 102 athletes in the Sydney 2000 Olympic Games [33], the researchers reported comparable values for BMI to our findings. Their findings imply that the winners are inclined to be younger and taller with BMI of 21.9 (SD 2.4) kg/m^2.

Comparing the body fat percentage values of this study to other elite-level athletes of different countries investigated in similar studies, however, shows that our athletes had lower body fat percentage values [16, 40, 41, 56, 76]. In contrast, the findings of the present study demonstrated higher values compared with the results of some of the previous studies in elite athletes [26, 29, 59, 63]. Compared to the studies in recreational taekwondo players, our athletes had lower values of body fat percentage [49, 72, 74]. This underscores the less important aspect of weight making practices in the younger competitors and/or differences in the training volumes [35]. Taekwondo is primarily concerned with kicking techniques. Having low fat at various body parts, increasing the weight to strength ratio in turn, will surely help the player accelerating and decelerating speedily as it is the nature of the sport [55].

The VO_2max reported in the current study was 54.1 ± 4.4 mL · kg^{-1} · min^{-1}. The VO_2max of male Serbian international taekwondo athletes, according to the study of Cubrilo et al. [19], was lower than our findings (44 ± 3 mL·kg^{-1}·min^{-}1) Another study reported higher values; Italian international taekwondo players had a VO_2max value of 63.2 ± 6.1 mL · kg^{-1} · min^{-1} [16]. A wide range of values has been reported for both national and international groups [8, 10, 12, 15, 40, 82]. Aerobic fitness may affect performance indirectly by helping recovery between the attacks [60].

To efficaciously perform the technical actions in a competition, taekwondo athletes are in great need of muscular power, strength and strength endurance [13, 61, 73]. The current study found 191.7 ± 19.2 N · m for the isokinetic knee extension peak torque of the subjects. A few studies have determined the isokinetic strength of taekwondo players [35, 53, 54, 69]. Bridge et al. [11] propose that although the capability to produce maximum strength may be crucial in taekwondo, it might not lead to success in international competition.

This current study reported higher 60-s sit-up and 60-s push-up tests' performance values than the results of a study that investigated experienced South African taekwondo athletes [46]. Also, higher 60-s sit-up values than international level Brazilian taekwondo athletes were obtained [7]. A range of 48–52 repetitions in one minute has been reported as the 60-s sit-up test score for national and international level male taekwondo athletes in the literature [11]. Upper limb endurance characteristics of players may support techniques and tactics during a match.

The foundations for the Wingate test indicate how important anaerobic power is for taekwondo athletes. Supporting the findings of this study, several authors have also reported the same [10, 29, 41, 60, 59]. To productively manage the energy requirements of the competition, the importance of high anaerobic power ability especially for lower limbs to produce high peak power is visible. In a study [29], the authors reported a higher peak power output of 14.7 W/kg in the Czech national team taekwondo players compared to the present study. The Turkish elite taekwondo athletes in the current study had higher anaerobic peak power and mean power than is evident in some of the other countries' national teams. The values were higher than the values of Portuguese [59], Czech [29], and Taiwanese [41] elite athletes.

Elite taekwondo players possess good postural balance performance [9, 58]. This research found overall indexes of 0.18 ± 0.06 and 0.82 ± 0.11 for Postural Stability and Single Leg Stability tests, respectively. A shorter index represents less sway on the platform and hence superior balance control [77]. Overall indexes obtained from the current study were lower than the findings of a study that investigated well-trained taekwondo athletes in the bipedal stance Postural Balance test [77]. Present research supports the studies conducted with elite taekwondo athletes [9, 58] and is in line with the findings of Leong et al. [39]. They also reported that those amateur taekwondo athletes were better than sedentary people in balance performance. Pons Van Dijk et al. [57] claimed that taekwondo training amends postural control. The high number of high kicks during training results in higher values of single leg stance test in the taekwondo athletes. Maintaining stability in conditions such as performing kicks is what taekwondo athletes are known for. This is very beneficial for them and their risk of injuries with falls during practice plummets [24]. On the other hand, from the perspective of balance maintenance during kicking in taekwondo combat and losing points from falls during competitions, it is crucial to investigate the balance performance so as to guide the training method to ameliorate their balance [39]. In addition, balance performance tests in taekwondo talent identification programs or to identify elite players are obligatory.

Several studies on groups of well-trained or international level taekwondo athletes presented different results for reaction time. They clarify that success in taekwondo is tantamount to a shorter than average reaction time [17, 26, 29, 80]. Miller and Sadowski [51] reported shorter reaction time in a group of senior taekwondo athletes with medals than the current study. In contrast, a study on elite Iranian taekwondo players demonstrated longer reaction time compared to the present research [31]. The findings of Vieten et al. [80] indicate a significant difference in the reaction time between the members of the national taekwondo team and those adopting taekwondo for recreational purposes. According to Chung et al. [17], professional taekwondo athletes in response to visual stimuli have a shorter total reaction time compared with sedentary people, whereas in response to audio stimuli they have a longer reaction time than amateur athletes. They imply that the professionals may focus their visual or audio attention on the combat. In the current study, both visual and audio stimulants were used to measure reaction time.

In taekwondo speed and its role are immeasurably important [74]. 20-m sprint [44], 30-m sprint [60], and 6-s sprint tests [68] have been used to determine speed values of taekwondo athletes. Results of the studies in elite Belgian senior [81] and Polish junior well-trained medal-winner [60] taekwondo athletes showed longer 30-m sprint performance times than findings of the current study. However, Korean elite athletes have been found to have slightly shorter time values compared to our study [38]. Additionally, using field-based testing methods some studies have examined the agility characteristics in novice female athletes, including 50-m (10 × 5-m) shuttle run sprint tests [35, 36], and have reported higher performance values than the current study. To the best of our knowledge, there are no literature reports regarding 10 × 5-m agility performance in elite-level athletes. Findings of the present study underscore the importance of both speed and agility in taekwondo and could suggest that these aspects of fitness may define success in international competitions.

This research reported 43.5 ± 6.1 cm for squat jump. A number of authors state that taekwondo players' power in explosive lower extremities is what characterizes this sport [14, 16, 34, 44, 49, 74]. In line with this study, the mean squat jump performances reported for national and international competitors in the literature varies in the range 35.8–45.4 cm for males and 23.7–29.8 cm for females [11]. With a view to practitioners' level of experience, differences in lower limb muscular power have been observed. Experienced recreational male taekwondo practitioners had higher squat jump than novice taekwondo athletes [74].

A number of studies have measured flexibility of taekwondo athletes using the sit-and-reach flexibility test [26, 35, 68, 74]. We found 37.5 ± 6.5 cm for subjects. The results support the findings of Heller et al. [29]. They reported that professional Czech taekwondo players had higher explosive leg power and were more flexible than their non-athletic counterparts. Considering the nature of the technical actions performed in taekwondo such as high kicks, it is clear how important the role of flexibility is.

The current research is one of the rare studies assessing mental skills of international taekwondo players. According to the results, athletes reported their highest scores for goal setting and self-confidence, and lowest for Imagery. The highest scores between three broader conceptual components of OMSAT-3 were associated with the Foundation skills, Psycho-Somatic skills were the second highest and Cognitive skills were third. As far as the mental skills of taekwondo players at any level of competition are concerned, these are limited data. Sotoodeh et al. [67] reported that the professional taekwondo players showed the highest scores for self-confidence and goal setting and lower scores in refocus and stress reaction. They also reported that professional players used game planning, goal setting, activation, relaxation, self-confidence and commitment more effectively than non-professional players. However, in refocusing and stress reaction nonprofessional players performed better than professionals.

Only a few studies of mood states have, thus far, been developed specifically for taekwondo athletes, and to our knowledge, almost no studies for elite international competitors. Terry and Lane [70] provides POMS norms for an athletic sample (n = 2086) categorized under the level of competition (international standard athletes, n: 622; club level athletes, n: 628 and recreational athletes, n: 836). Taekwondo was not among the population of the athletes represented in this sample. Our study reported higher scores on the Vigor-activity, Anger-Hostility and Tension-Anxiety scales and lower scores on the Depression-Dejection, Fatigue-Inertia and Confusion-Bewilderment scales than norms developed by Terry and Lane [70]. The study of Toskovic et al. [75] on the effects of taekwondo training in the mental health of novice taekwondo practitioners indicates high scores on the positive Vigor-activity scale and low scores on the negative POMS scales.

Conclusion

In conclusion, this study revealed the physical, physiological, and psychological characteristics in taekwondo. The knowledge from the study provides information on fitness parameters of taekwondo for coaches. The presented testing methods and results of the tests could be used for the assessment of performance. They could help coaches to design training programs for taekwondo players and evaluate training adaptations throughout the training phases. The findings of the study could be useful data for performance comparison of high-performance athletes and identification of talented players.

Conflict of interest: Authors state no conflict of interest.

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