ORIGINAL ARTICLE

Profile of an ITF Taekwon-do Female Champion Team in Terms of Somatotype and Body Composition

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
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Abstract

Background & Study Aim: The ITF is working on creating "champion model" that determine high performance in taekwon-do. A number of sources state that sport potential and chances of success can be determined based on an athlete's body build and somatic type. The aim of this study was to characterise body build and body composition of an ITF taekwon-do female champion team and to determine common somatic traits in female taekwon-do fighters with highest performance in the discipline.

Material & Methods: Study participants comprised the Polish National ITF Women's Taekwon-do Team (7 juniors: 16-18 years, 11 seniors: 19-30 years). The Heath-Carter typological classification was used to assess participants' somatotypes. Body composition was measured using bioelectrical impedance analysis. Obtained data were statistically analysed using the Statistica 10 software package.

Results: High homogeneity in terms of body build and body composition was observed among participants, most had the desired somatotype for martial artists- with a dominance of the mesomorphy component (juniors' somatotype: 3.50 - 4.44 - 3.07; seniors' somatotype: 3.50 - 4.44 - 3.18) and average body height and body mass (169.31±4.14 cm; 60.23±6.12 kg). Each body build component was related to sports performance- positive correlation was found for the following parameters: arm length (r = 0.66), pelvis width (r = 0.60), hip width (r = 0.51), and hand width (r = 0.59).

Conclusions: Female taekwon-do champions are characterised by average body height, body mass, and body fat. Their body build and body composition are symmetrical. Top-level sports performance is frequently determined by pelvis width, hand width, and arm length.

Key words: anthropometric measurements, champion model, combat sports, elite athletes, Heath-Carter method

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Anthropometric measurements - the word anthropometry comes from the Greek words *anthropos*, meaning "man," and *metron*, meaning "measure". The branch of anthropology concerned with comparative measurements of the human body and its parts. The field is also referred to as "anthropometric measurement".

Heath-Carter method – the Sheldon's technique of somatotyping modified by Heath and Carter, used to appraise body shape and composition. The somatotype is defined as the quantification of the present shape and composition of the human body. It is expressed in a three-number rating representing endomorphy, mesomorphy and ectomorphy components respectively, always in the same order. Endomorphy is the relative fatness, mesomorphy is the relative musculo-skeletal robustness, and ectomorphy is the relative linearity or slenderness of a physique [12].

Master model – a hypothetical system that imitates selected (the most important and the best) traits of the original, that is, a future master of a given sports discipline [9].

Somatotype – the quantification of the present shape and composition of the human body. It is expressed in a three-number rating representing endomorphy, mesomorphy and ectomorphy components respectively, always in the same order. Endomorphy is the relative fatness, mesomorphy is the relative musculo-skeletal robustness, and ectomorphy is the relative linearity or slenderness of a physique. For example, a 3-5-2 rating is recorded in this manner and is read as three, five, two. These numbers indicate the magnitude of each of the three components. Ratings on each component of 0.5 to 2.5 are considered low, 3 to 5 are moderate, 5.5 to 7 are high, and 7.5 and above are very high [12].

INTRODUCTION

Today, sport is a combination of theory and practice that promotes professionalism, highly trained staff, modern and effective methods of training and control, and a constant improvement of one's qualifications. Best-performing athletes are an elite; they are individuals selected on the basis of a professional selection [1]. The increased competition in sport and the increased popularity of sport have resulted in the need to create effective methods of selecting athletes and spotting talent in order to optimise achieving success in each discipline [2].

The fundamental selection criterion in competitive sport is an appropriate level of physical fitness and individual motor abilities pertinent to a given type of effort. However, researchers tend to focus more and more on body build and underline its importance in sport competition. On the one hand, somatic build depends on the type of effort involved; on the other hand, somatic build contributes to the effectiveness of performed exercises and predisposes athletes to competing in a particular sport discipline. Long-term observation indicates that the successful sport elite in a given sport discipline display similar somatic traits, and that their somatotype differs greatly from persons not engaged in sport [3-6].

The fact that for centuries, sport competitions have been divided according to sexes to balance the chances of winning indicates indisputably that predispositions and body build play an important role in sport performance [7,8].

Creating (based on forecasts) a program and plan for a long-term training and later, plans for athletes' individual development, should involve specifying an aim to be achieved. This aim is the champion model, that is, a hypothetical system that imitates selected (the most important and the best) traits of the original, that is, a future champion of a given sports discipline [9]. Researchers have for years been working on creating such somatic, morphological, and motor champion models that would be derived from the level of physical fitness and body build traits that determine high performance in individual sport disciplines [10,11]. The successful creation of such models would result in a more efficient selection of athletes as well as a more efficient process for spotting and developing young talents. A number of sources state that sports potential and chances of success can be determined with high reliability based on an athlete's body build and somatic type [12]. In Australia, an attempt was made to prove that a good method of sport talent selection results in high effectiveness of the selected athletes. Researchers selected women for a new football team they had created. The selection followed previously defined criteria (concerning anthropometric and physiological characteristics and the level of physical fitness). Selected women participated in a short training conducted by specialists. After the training, several women were recruited for professional teams; some were even recruited to the national team. The researchers proved that a proper selection increases the likelihood of a team achieving success and that assessing somatic build to determine predispositions to engagement in a given sport discipline is of crucial importance [13]. A study was conducted in the Czech Republic that aimed to determine the national sport potential based on common physical traits of a given society. The study found that somatic traits that characterise Czechs predispose them to successful performance in rowing, javelin throw, decathlon, high jump, and the discus [14].

Available literature on the subject includes publications on various sport disciplines. Their authors have provided guidelines that allow for, in their opinion, selecting athletes that would continue successes of the best-performing athletes. For instance, a champion model has been created based on the results of a study conducted in several countries among top-class rugby players from national teams. The article devotes a considerable amount of attention to the results of body build and composition measurements in which many common traits of physical build were observed among the participants [15,16]. A study on judo found that endomorphy and mesomorphy are dominant among successful athletes. Theoreticians often indicate that when selecting athletes, coaches should make decisions based on the candidates' physical similarity to top-class athletes, as this may increase the chances of success [17,18].

A prevailing opinion among publications on martial arts states that an appropriate level of physical fitness only determines success when coupled with the desired traits of physical development [19-22]. Articles on taekwondo frequently indicate that athletes who perform well have a similar, specific body build and somatotype that stand in sharp contrast to persons not engaged in sport. However, authors of these articles do not specify which traits of physical development are characteristic for such athletes [23]. Few publications attempt to determine the champion model in taekwondo, and a majority of such models was created for WTF taekwondo athletes [24], which is an Olympic discipline, as opposed to ITF taekwondo, which is the subject of this article. Moreover, most available studies were conducted among low-ranking

athletes, thus they do not provide reliable models and do not contribute to the improvement and systematisation of athlete selection methods.

In ITF taekwon-do, just as in many other disciplines, athletes compete within particular weight categories, which immediately establishes an arbitrary and permanent connection between sport and body build [25] and causes certain difficulties in creating a body build and somatotype model for taekwondo martial artists. In addition, athletes often modify their body proportions before combat, for instance, by reducing body mass, which results in changes to the entire body composition. Furthermore, ITF taekwon-do includes as many as five events – formal patterns, sparring, special techniques, power test and traditional sparring(the latter of which was officially introduced at the European Championships in 2009 and the World Championships in 2011) – with the movement technique alone comprising over 3200 basic techniques [26-28]. This creates another difficulty within the subject, as an athlete in this discipline can either choose to be versatile and take part in all events or instead specialise in one or two events. Such a choice has also a direct influence on the development of an athlete's physical traits. However, there is no doubt that an athlete's somatic and morphological traits play a major role in taekwondo-specific effort, which involves frequent, rapid movements, high kicks, and precise strikes [29,30] that depend on such factors as speed and frequency of movements, reaction time, motor coordination, and muscular strength, including explosive power.

Apart from inherent predispositions, the human body's response to training is also an important consideration. Thorough, systematic, and appropriately planned and monitored training not only leads to an increase in individual motor abilities, but also contributes to the desired changes in physiological processes and somatic build. Well-designed training results in the natural selection and elimination of specimens that are unable to cope with a given type and intensity of effort [31,32]. However, an athlete who passes preliminary selections and whose body responds to training in the desired manner undergoes adaptation and, as an ultimate result of these processes, acquires a body build specific for athletes of a given sport discipline. An appropriate body build is an important element of future specialisation, e.g. when deciding in which event an athlete will perform best.

Despite a great number of related difficulties, studies on the subject and attempts to create a champion model for taekwondo are important and may contribute to an increase in the effectiveness of athlete selection. However, study participants should be selected with care: they should comprise top-class athletes who achieve the best results in a given discipline on numerous occasions.

In view of the considerations detailed above, the aim of this study was to characterise body build and body composition of an ITF taekwon-do female champion team and to determine common somatic traits in best-performing female athletes in this discipline.

MATERIAL AND METHODS

Procedures

Anthropometric measurements were conducted among all study participants. Their somatic build type was determined and their tissue composition was analysed to determine the athletes' somatic characteristics.

Assessment began with the measurement of participants' length and width parameters and body girth. Standard tools were used for the assessment: an anthropometer (Holtain) for measuring body height and armspan, an anthropometric caliper (Baseline) for measuring body diameter, a tape measure for measuring body girth, and a skinfold caliper (Saehan) for measuring skinfold.

The Heath-Carter method was used to determine participants' body build. The method is based on the classical concept of three components of body build introduced by Sheldon. The share of the three components, that is, endomorphy, ectomorphy, and mesomorphy, was determined according to procedures described in *The Heath-Carter Anthropometric Somatotype. Instruction Manual* [33]. A special computer programme called Somatotype Calculations and Analysis was used to analyse results concerning the classification of somatotypes determined through the Heath-Carter method [34].

Body composition was measured using bioelectrical impedance analysis (BIA) with a Tanita BC-418 analyser. The following parameters were measured: fat mass (FAT% [%] and FAT MASS [kg]), fat free mass FFM [kg], total body water (TBW) [kg], and predicted muscle mass (PPM) [kg]. The use of an array of eight electrodes allowed for an assessment of body composition according to segments, that is, left and right arms and legs and the torso.

All assessments, that is, anthropometric measurements and body composition measurements, were conducted for both sides of the body. Somatic

Taekwon-do ITF – an informed use of one's body in combat; a taekwon-do fighter's body has reached its peak capacity through consistent and intense physical and mental training. Taekwon-do is a martial art that mainly involves striking the opponent. To put it simply, it is an unarmed fighting style created to aid in self-defence. In addition, taekwon-do constitutes an original system of education that approaches human physical and mental development in a versatile manner. It combines Eastern traditions with Mediterranean culture and revolves around human instincts and natural needs. Translated literally, *tae* means jumping, flying, performing fighting techniques using one's legs; *kwon* means "fist" or to strike or destroy with one's hand; and *do* indicates an art or a path and the proper behavioural norms created and developed by ancient scholars [30,31].

FAT% – The percentage of total body weight that is fat.

FAT MASS – Total weight of fat mass in kg, lb in the body.

FFM – Fat Free Mass is comprised of muscle, bone, tissue, water, and all other fat free mass in the body.

PMM – Predicted Muscle Mass means bone-free lean tissue mass (LTM)

TBW – Total Body Water is the amount of water (expressed as lb, kg, or st.lb) retained in the body. TBW is said to comprise between 50% - 70% of total body weight. Generally, men tend to have higher water weight than women due to a greater amount of muscle.

Table 1. Medals won by Polish ITF Taekwon-do fighters at the European Championships in Skövde (Sweden)

Competition Individual												
	Medals	1. Pattern		2. Sparring						3. Special technique	4. Power test	Total
		II dan	III dan	50 kg	56 kg	62 kg	68 kg	75kg	+75kg			
Senior	Gold					1	1					2
	Silver				1	1						2
	Brown	2	1	1	1		1	1	1	1	1	10
		1. Pattern I dan		2. Sparring						3. Special technique	4. Power test	Total
				45 kg	50 kg	55 kg	60 kg	65 kg	+65 kg			
Junior	Gold							1				1
	Silver	1						1				2
	Brown	1				1				2		4
Competition Team												
	Medals	1. Pattern		2. Sparring		3. Special technique			4. Power test		5. Traditional sparring	Total
Senior	Gold			1		1			1			3
	Silver											
	Brown											
	Medals	1. Pattern		2. Sparring		3. Special technique			4. Power test		5. Traditional sparring	Total
Junior	Gold					1			1			2
	Silver			1							1	2
	Brown											

symmetry and asymmetry in participants' body segments were determined. Further analysis involved comparing somatic parameters between juniors and seniors using measurement values related to the dominant side of the body. Assessments were conducted in the morning (between 7:30 a.m. and 9:00 a.m.) before the first meal and in the same conditions for all participants.

Statistical analysis

The STATISTICA 10 software package was used for the statistical analysis of the results. Descriptive statistics (mean ± standard deviation) were calculated for each participant. The obtained data were divided into two groups according to the participants' age (juniors or seniors). Normality of distribution was determined using the Shapiro-Wilk test. Due to the sample size, the Mann-Whitney *U* test (U M-W) was conducted to determine significant differences between the dependent variables of the juniors and seniors. The Wilcoxon matched-pairs test was applied to compare mean values of measurements for both sides of the body (body composition). The Spearman's rank correlation coefficient was used to determine correlations between somatic characteristics and sport performance. The level of statistical significance was set at $p<0.05$, $p<0.01$, and $p<0.001$.

Material

Study participants comprised the entire International Polish Team in Taekwon-do (ITF) of women: 7 juniors aged 16-18 years (16.71±0.70 years) and 11 seniors aged 19-30 years (25.18±3.46 years). Body height ranged between 165 and 173 cm (169±5.66 cm) in juniors and between 164 and 179 cm (170.27±4.27 cm) in seniors. Body mass ranged between 65.8 and 67.2 kg (66.5±0.99 kg) in juniors and between 51.3 and 70.9 kg (60.76±5.91 kg) in seniors. Juniors' training experience ranged between 6 and 9 years (7.43±1.05 years) and seniors' training experience was appropriately longer: between 11 and 18 years (14.27±2.63 years).

The assessment was conducted during the direct sport preparation period prior to the European Championships in Skovde, Sweden (May 2013), during a meeting of the Polish team of women. The Polish athletes won 28 medals in the Championships: 11 won by juniors and 17 won by seniors. Table 1

Table 2. Comparison of somatic parameters in juniors and seniors from an elite female taekwondo team (in) and correlations between body parameters (for the entire sample) and sport performance (r)

Parameters	All (n=18)	Spearman's rank correlation coefficient	Juniors (n=7)	Seniors (n=11)	U M-W
	X ± SD	r (sport result to body parameters)	X ± SD	X ± SD	p
Body height [cm]	169.31 ± 4.14	0.32	169 ± 5.66	170.27± 4.27	0.79
Body mass [kg]	60.23 ± 6.12	-0.25	66.5 ± 0.99	60.76 ± 5.91	0.19
BMI	21.06 ± 1.64	0.15	21.1 ± 2.3	21.04 ± 1.86	0.79
Length values [cm]					
Arm	72.67± 2.17	0.66	72.29 ± 1.59	72.91 ± 2.44	0.72
Upper arm	31.17± 1.61	0.32	31.19 ± 0.91	31.15 ± 1.92	0.79
Forearm	23.12± 1.24	0.32	22.93 ± 0.32	23.25 ± 1.56	0.86
Hand	18.38± 1.25	0.21	18.17 ± 1.06	18.51 ± 1.34	0.21
Leg	92.89± 3.25	0.19	90.94 ± 3.06	94.13 ± 2.71	0.17
Hip	46.49 ± 1.76	0.12	45.64 ± 1.75	47.02 ± 1.54	0.59
Crus	40.31± 1.99	0.28	39.17 ± 1.91	41.03 ± 1.68	0.044*
Foot	24.67± 0.87	0.48	24.43 ± 0.67	24.82 ± 1.01	0.19
Bone breadths [cm]					
Shoulders	38.29 ± 1.62	0.006	38.13 ± 1.03	38.29 ± 1.62	0.6
Chest	26.79 ± 1.56	0.21	25.64 ±1.25	26.79 ±1.56	0.19
Pelvis	29 ± 0.96	0.6	28.43 ± 0.56	29.00 ±1.62	0.26
Hips	32.79 ± 1.31	0.51	32.36 ± 0.99	32.79 ± 1.31	0.47
Humerus	6.00 ± 0.37	0.34	6.07 ± 0.42	5.82 ± 1.26	0.16
Forearm	4.99 ± 0.67	0.03	4.86 ± 0.23	4.78 ±1.16	0.66
Hand	9.69 ± 0.44	0.59	7.43 ± 0.56	7.05 ± 1.55	0.006**
Femur	9.17 ± 0.63	0.12	9.64 ± 0.44	9.28 ± 2.03	0.22
Foot	24.67 ± 0.62	0.29	9.29 ± 0.52	8.83 ± 1.91	0.008**
Girth values [cm]					
Chest	87 ± 5.25	0.003	85.57 ± 3.49	87.0 ± 5.3	0.41
FlexedArm	27.36 ±1.84	0.08	27.17 ± 2.15	27.47 ± 1.81	0.6
Hip	56.77 ± 3.45	0.016	57.36 ± 4.38	56.39 ± 3.09	0.60
Calf	36.57 ± 2.18	-0.07	37.53 ± 3.05	35.95 ± 1.39	0.53
Skinfolds [mm]					
Triceps	13.11 ± 2.45	0.07	13.29 ± 2.98	13.0 ± 2.19	0.93
Subscapular	10.36 ± 1.94	0.07	10.43 ± 1.4	10.31 ± 2.28	0.72
Supraspinale	10.75 ± 4.43	0.11	10.14 ± 3.13	11.14 ± 5.2	0.79
Calf	6.11 ± 11.42	0.15	6.71 ± 3.95	5.73 ± 1.42	1.0

*Statistical significance p<0.05; **Statistical significance p<0.01

Table 3. Mean values of individual components of somatotype in study participants.

Somatic component	Participants			U M - W
	All	Juniors	Seniors	p
	X ± SD	X ± SD	X ± SD	
Endomorph	3.5 ± 0.73	3.50 ± 0.6	3.50 ± 0.11	0.37
Mesomorph	4.44 ± 0.09	4.44 ± 0.07	4.44 ± 0.91	0.53
Ectomorph	3.14 ± 0.98	3.07 ± 1.18	3.18 ± 0.76	0.92
Somatotype	3.5 – 4.44 – 3.14	3.5 – 4.44 – 3.18	3.5 – 4.44 – 3.07	0.59

shows a detailed description of the results according to discipline, weight category, age category, individual competition and team competition.

The World Championships in Benidorm, Spain (October 2013), also proved to be successful for the Polish team: juniors won 5 medals and seniors won 9 medals. As a result, Poland garnered first place in the general classification of both the European and the World Championships.

RESULTS

Table 2 presents anthropometric characteristics of the female champion team, including a comparative analysis of juniors and seniors.

Analysis of study results found no statistically significant differences between the dominant and non-dominant side of the participants' bodies. Statistical differences were observed during comparative analysis of the two groups.

Despite considerable differences in participants' age and training experience, significant differences were found only in crus length ($p<0.05$) and hand and foot width ($p<0.01$). Seniors had longer cruses; juniors had wider feet and hands.

Moreover, the analysis found that individual body build components were correlated with the participants' sport performance. A significant positive correlation was observed for arm length ($r = 0.66$), pelvis width ($r = 0.66$), hip width ($r = 0.51$) and hand width ($r = 0.59$) (Table 2).

Table 3 presents the participants' somatotype characteristics. No significant differences were noted between juniors and seniors. The two groups were especially uniform in terms of the share of endomorphy and mesomorphy components despite differences in age and training experience. A slightly higher share of ectomorphy was also observed in seniors, but the difference was statistically insignificant. Mesomorphy dominated over the other body build components in both groups (Table 3). The shares of ectomorphy and endomorphy were similar in both groups.

Figure 1 shows individual somatotypes for each participant. A majority of the study participants displayed the most desired somatotype for athletes of combat sports, with the dominance of mesomorphy over other body build components. According to the detailed classification into somatotypes, two athletes (11%) were mesomorphic endomorphs, five (28%) were endomorphic mesomorphs, four (22%) were balanced mesomorphs, two (11%) were ectomorphic mesomorphs, one (7%) was a mesomorphic ectomorph and three (17%) were placed in the exact centre of the somatogram (central somatotype), (Figure 1).

The arithmetic mean of body components in study participants (4-4-3) indicated the endomorphic mesomorph somatotype.

Analysis of participants' body composition (without taking into account the division into segments) showed a lack of statistically significant differences between the two groups. Fat mass content (FAT%) amounted to 17.44±5.38%, which corresponded to 10.72±4.08 kg of total body mass. Fat free mass (FFM) amounted to 49.51±3.65 kg and total body water (TBW) equalled 36.24±2.68 kg.

Conversely, statistically significant differences were observed during segmental analysis of the composition of arms and torso in juniors and seniors. A significantly higher amount of FFM and predicted muscle mass (PPM) was found in the right arm (U M-W; FFM: $p=0.01$, PMM: $p=0.02$) and in the left arm (U M-W; FFM: $p=0.01$, PMM: $p=0.02$) in seniors. Seniors also showed a significantly higher FFM (U M-W; $p=0.004$) and PMM (U MW; $p=0.004$) in the torso than juniors (Table 4).

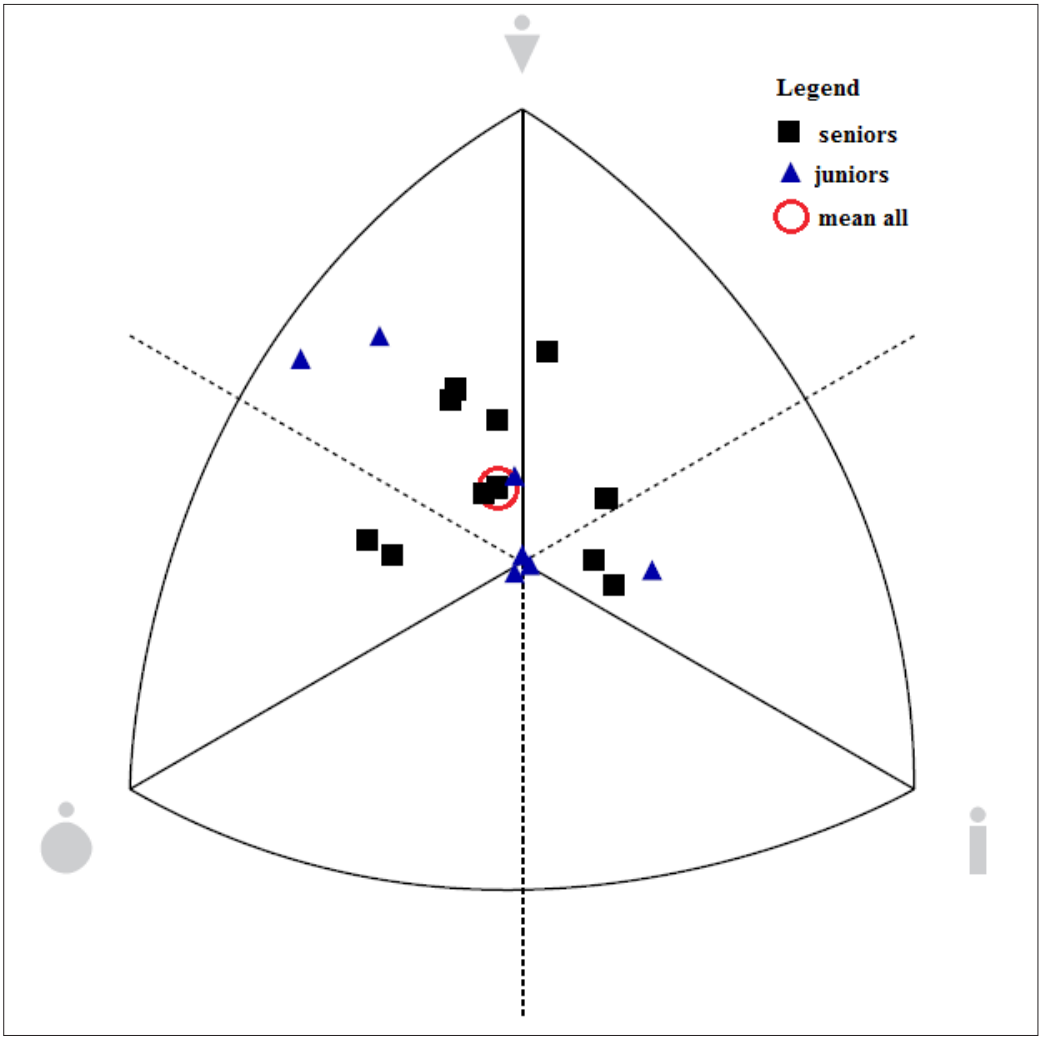

Figure 1. Somatotypes of female taekwon-do fighters from the Polish National Team

The two groups displayed no statistically significant differences in individual parameters between left and right arms and legs.

Legs were the body segment with the highest adiposity. Arms and torso showed a lower value of FAT% than other segments (Figure 2).

In addition, a correlation was found between FFM in the torso (r = 0.61) and participants' age and between PPM in the torso (r = 0.62) and participants' age ($p>0.05$) (Figure 3).

DISCUSSION

A champion model in competitive sports should reflect the desired aim. It is important to establish a set of crucial desired traits in athletes engaged in particular disciplines. However, for such a set to be established and constitute a reliable tool in athlete selection, champions in each discipline should be studied, that is, athletes who are not only the best among peers and repeatedly achieve success and high results, but also have a extensive training experience.

With the aforementioned considerations in mind, the results of this study constitute an important step on the path to increasing the effectiveness of selection in ITF taekwon-do and provide interesting observations and conclusions. Participants of this study are female athletes from the Polish National Team who at the time held the first place in the general classification of the European and World Taekwondo Championships; to use sport terminology, the participants are ITF taekwon-do champions. The participants' characteristics confirm the thesis that members of a sport elite who achieve successes in a given sport discipline have similar body builds. A high homogeneity was observed among study participants in terms of body build and body composition regardless of the age group (juniors

Table 4. Composition of individual body segments in seniors and juniors

Segment of the body	FAT [%]	FAT MASS [kg]	FFM [kg]	PMM [kg]
	X±SD	X±SD	X±SD	X±SD
All				
Right leg	24.00±4.08	2.68±0.67	8.34±0.61	7.87±0.59
Left leg	23.57±4.55	2.62±0.71	8.37±0.64	7.89±0.60
Right arm	13.56±5.32	0.43±0.29	2.58±0.28	2.41±0.25
Left arm	13.47±5.89	0.43±0.22	2.58±0.32	2.41±0.29
Trunk	14.03±6.02	4.64±2.28	27.59±2.01	26.38±1.94
Juniors				
Right leg	25.37±3.12	2.86 ± 0.61	8.24 ± 0.59	7.76 ± 0.58
Left leg	25.26±3.43	2.80±0.65	8.23±0.69	7.74±0.64
Right arm	15.99±5.63	0.47 ± 0.21	2.37 ± 0.24*	2.23 ± 0.21*
Left arm	16.16±6.03	0.47±0.24	2.34±0.26*	2.20 ± 0.25*
Trunk	17.43±5.25	5.66 ± 2.18	25.97 ± 1.66*	24.81±1.59*
Seniors				
Right leg	23.13± 4.08	2.57 ± 0.71	8.40 ± 0.52	7.94 ± 0.49
Left leg	22.49± 4.64	2.50 ± 0.18	8.46 ± 0.21	7.98 ± 0.2
Right arm	12.0±4.82	0.40 ± 0.20	2.72 ± 0.21*	2.53 ± 0.2*
Left arm	11.75±4.78	0.40 ± 0.19	2.74 ± 0.24*	2.55 ± 0.22*
Trunk	11.86±5.86	4.00 ± 2.31	28.63 ± 1.38*	27.38±1.34*

*Statistical significance between juniors and seniors ($p<0.05$)

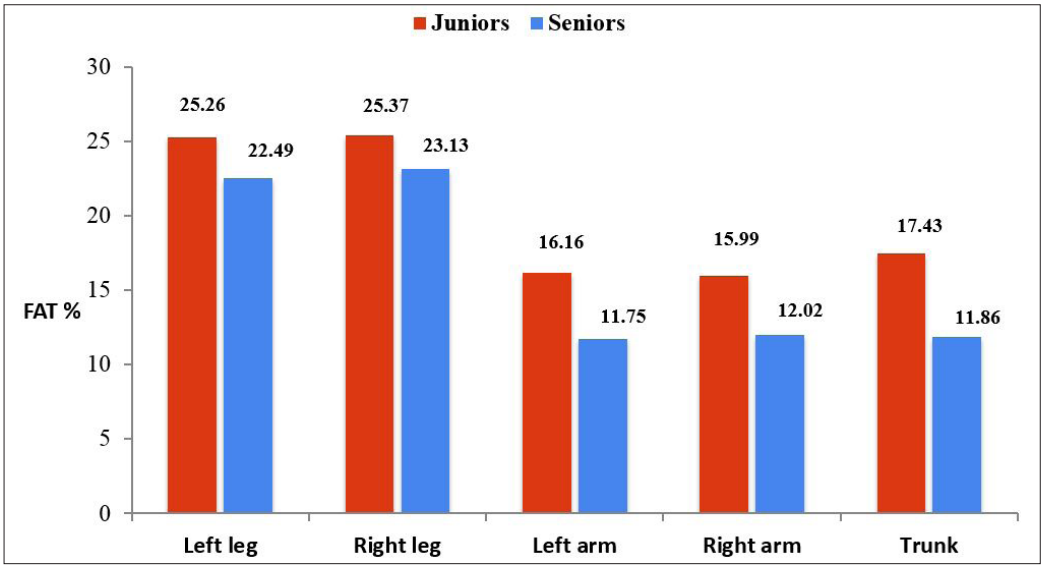

Figure 2. Body fat percentage (FAT%) in individual segments of the body in study participants.

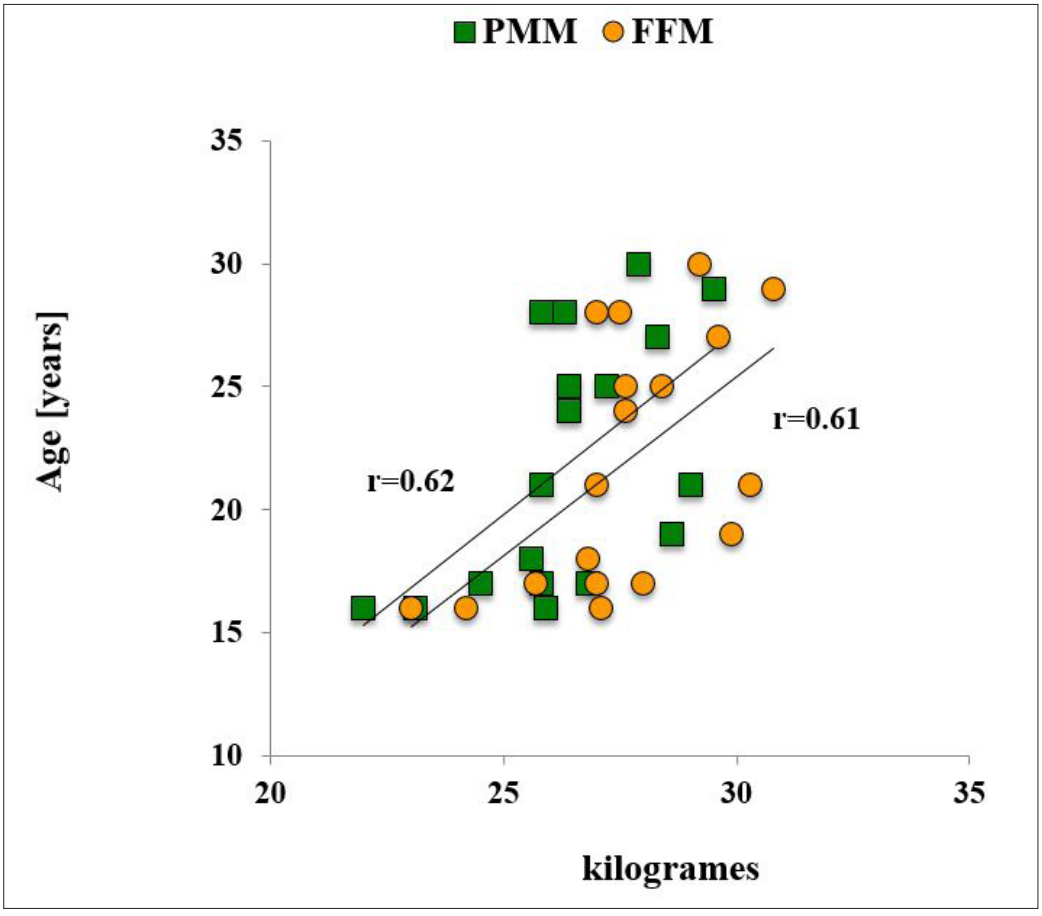

Figure 3. Correlation between predicted muscle mass (PPM) in the torso and participant age and between fat free mass (FFM) in the torso and participant age.

or seniors). The participants had an average body height (169.31±4.14 cm) in comparison to the population of Polish women aged 20-29 years (Central Statistical Office, 2004). Athletes who won medals in three or four events showed similar somatotypes. Two seniors and one junior who participated in three or four events won a medal in each event. They had very similar somatotypes, located close to the group mean. These somatotypes were 4-4-3, 4-5-3, and 3-4-3. These results underline the fact that the achievement of top sports results and the versatility of athletes predisposed to most ITF taekwon-do events correlate with the mean somatotype typical for elite athletes. In team events, seniors won a total of three gold medals in four events, and juniors won two gold medals and one silver medal (Table 1). Legs were found to be the body segment with the highest adiposity, while arms and torso showed a similar, low amount of fat. Statistical analysis showed that the individual components of body build affected participants' performances. Athletes with a wider pelvis (r = 0.6), wider hips (r = 0.51), wider hands (r = 0.59) and longer arms (r = 0.66) achieved better results, as judged by the number of medals won at European and World competitions. Measurements of both sides of the body showed no statistically significant differences in juniors and in seniors: both groups had a symmetric somatic build.

The literature on this subject includes few publications that conduct a complete analysis of body build and body composition in ITF taekwon-do athletes. Available studies were mainly conducted among low-ranking athletes, which only slightly broadens our knowledge on how to conduct an effective selection of athletes in a given sport discipline. The results of such studies are frequently incomplete: authors do not include all anthropometric measurements, do not describe participant body composition in detail, and do not present their somatotypes, which makes comparing results difficult.

The only comparable and reliable study (that includes a detailed description of participants and the discipline involved and uses similar methods) that the authors of this article were able to find concerns

athletes from the Czech National ITF Taekwon-do Team, who, in addition to the men, included 12 women aged 16-23 years with training experience of at least 4 years. Most women from the Czech team achieved success at international championships and held high positions in international rankings. They were similar to the participants of this study in terms of body height and body mass (Czech athletes: 168±5 cm and 62.3±7.4 kg; Polish athletes: 169.31±4.14 cm and 60.23±6.12 kg). Similar values were also observed in girth of biceps, hip, and ankle (Polish athletes: relaxed biceps girth: 27.36±1.84 cm, hip girth: 56.77±3.45 cm, ankle girth: 36.57±2.18 cm; Czech athletes: relaxed biceps girth: 27.2±1.9 cm, hip girth: 57.1±3.4 cm, ankle girth: 36.9±1.8 cm). Polish athletes showed a slightly higher FAT% (17.44±5.38%) compared to Czech athletes (15.4±5.1%) [9].

A study conducted by Turkish researchers among male and female ITF taekwon-do athletes indicates that mean body height and body mass of female taekwondo fighters aged 14 years equalled 161.1±8.6 cm and 54.7±8.5 kg, respectively, which was lower than the juniors from the Polish National Team assessed in this study (169.00±5.66 cm and 66.50±0.99 kg). However, the Turkish researchers did not specify their study participants' sport achievements, training experience, and at what stage of their career the study was conducted, which is why such papers are unable to constitute reliable reference material [35].

Another study on a similar subject was conducted among athletes from the German Taekwondo Association, most of which belonged to the German National Team. Its authors also did not specify whether its participants were ITF taekwon-do or WTF taekwondo fighters. German female athletes were similar in terms of body height (167.3±3.2 cm) to Polish female athletes (169.31±4.14 cm). The former also showed a slightly lower body mass (57.8±5.4 kg) and FAT% (15.8±2.5%) than the latter (body mass: 60.23±6.12 kg, FAT%: 17.44±5.38%). Both groups of athletes displayed an athletic, though slim, body build and a low or average body height. A majority of their somatotypes indicated a mesomorph-endomorph body build, which, according to the German authors, is characteristic for successful athletes in the discipline. A few athletes from the German group, despite the dominance of the aforementioned somatotype, differed considerably from the average; in the case of the Polish athletes, the somatogram showed a similarity of body build. The German researchers explained this through differences in weight categories and the particular events in which the athletes specialised. A note was provided that a given weight category is strictly related to the type of body build displayed by winners within that weight category. J. Fritzsche and C. Raschka also noted a certain regularity that confirms the findings of this study: the older the athlete and the longer her training experience, the lower amount of fat mass she has [36].

Another study was conducted among juniors of the American National Taekwondo Team; however, its authors did not specify whether its participants were ITF taekwon-do or WTF taekwondo fighters. An analysis of American female juniors showed that ectomorphy (3.41±1.01) and mesomorphy (3.24±1.03) were the dominant components of their body build, while the Polish athletes showed a dominance of the mesomorphy (4.44±0.07) and endomorphy (3.50±0.6) components, that is, they displayed a higher muscle mass and a more athletic body build than the American athletes. In addition, the American athletes had varied somatotypes: despite the dominance of the ectomorphy comportment, the somatotypes of individual athletes were dispersed in the somatogram, while the somatotypes of the Polish athletes were clearly clustered in the mesomorphy area. Moreover, the American juniors were smaller (160.82±10.46 cm) and had lower body mass (50.58±10.41 kg) than the Polish athletes [37]. A study by the same author, Pieter, and Taaffe, found that seniors from the American National Taekwondo Team also displayed a dominance of the ectomorph-mesomorph body build type, with component magnitudes of 3.98 and 3.23, respectively. By comparison, Polish seniors showed a mesomorph-endomorph somatotype (4.44±0.91 and 3.50±0.11, respectively), as did Polish juniors [38].

The literature much more frequently includes studies on fighters in WTF taekwondo, that is, an Olympic discipline primarily involving full contact, which is not present in ITF taekwon-do. ITF taekwon-do is a more traditional form, focused on philosophy and founded on a strong tradition of martial arts. It involves competition in events with vast technical differences, and thus constitutes a complex form in which light contact is predominant and technique is imperative. WTF is a decidedly more aggressive discipline that only involves sport rivalry and combating the opponent in which leg techniques are predominant. It comprises fewer events, and the scoring system, fighting style, and rules differ greatly from those found in ITF taekwon-do. Nonetheless, both disciplines are still taekwondo, which originated from Korean martial arts tradition. For this reason, athletes from both disciplines should be compared to provide a broader perspective on the subject of somatic similarity according to the discipline in question.

Results of a study conducted among female members of the Croatian WTF Taekwondo National Team seem interesting. The Croatian athletes achieved successes in international competitions, including the Olympic Games. A comparison of somatic characteristics shows that the Croatian and Polish athletes had similar body height (Polish athletes: 169.31±4.14 cm; Croatian athletes: 168.0±6.6 cm), body mass (Polish athletes: 60.23±6.12 kg; Croatian athletes: 60.1±9.0 kg), and FAT% (Polish athletes: 17.44±5.38%; Croatian athletes: 16.5±2.7%). In addition, the authors of the aforementioned study noted that athletes with high performance are taller and have a lower amount of fat tissue than athletes with lower performance. Furthermore, despite a lower FAT%, their total body mass and FFM are higher, which may indicate that athletes with better results in sport have a higher muscle mass (counted via the number of medals won at international competitions). This study found that seniors from the Polish National Team who performed better than juniors also showed a lower FAT% and a higher PMM than juniors. Authors of the study conducted among Croatian athletes also emphasise the importance of limb reach, stating that the longer the reach, the more effective the athlete. This was confirmed by this study: athletes with a longer arm reach, as indicated by arm length, performed better (r = 0.66) [39].

To provide contrast, the authors of this article decided to include the results of a study conducted among the Turkish National WTF Taekwondo Team that comprised 16 women, 6 of whom had won medals at the World Championships and 11 of whom had won medals at the European Championships. The team placed high in international rankings. The Turkish athletes had a similar training experience to Polish athletes (Turkish athletes: 10 years; Polish athletes: 11 years) and a similar body mass (60.31±8.32 kg) and were slightly taller (172.0±6.45 cm). However, body composition was considerably different between the two teams. Polish athletes had a higher fat mass in legs than Turkish athletes (right leg in Polish athletes: 2.68±0.67 kg, left leg: 2.62±0.71 kg; right leg in Turkish athletes: 1.99±0.98 kg, left leg: 1.98±0.98 kg). On the other hand, both teams had a similar body mass (right leg in Polish athletes: 8.34±0.61 kg, left leg: 8.37±0.64 kg; right leg in Turkish athletes: 8.32±1.1 kg, left leg: 7.87±1.15 kg). Moreover, Turkish athletes had a much lower FAT% than the Polish athletes (Polish athletes: 17.44±5.38% which comprised 10.72±4.08 kg of total body mass; Turkish athletes: 11.19±1.58%, which comprised 5.74±2.8 kg of total body mass). The comparison found that Polish athletes were more symmetrical than Turkish athletes. The latter displayed a dominance of mesomorphy similar to the former. Many authors consider such a somatotype the most desired in combat sports athletes. However, the majority of the Turkish team showed the mesomorph-ectomorph somatotype, while the Polish team showed the mesomorph-endomorph somatotype (Turkish athletes: mesomorphy 5.08±1.25, ectomorphy 3.63±1.14, endomorphy: 2.40±0.86; Polish athletes: mesomorphy 4.44±0.09, ectomorphy 3.14±1.01, endomorphy: 3.50±0.75). In terms of arm and leg reach, the Polish team had a longer arm reach than the Turkish team, as indicated by mean arm length (Polish athletes: 72.67 cm; Turkish athletes: 60.24 cm), while leg reach was similar in both teams (Polish athletes: 92.89 cm; Turkish athletes: 92.52 cm), as was calf girth (Polish athletes: 6.57±2.18 cm; Turkish athletes: 36.00±2.41 cm) [40].

In sum, the results of this study and an analysis of the literature on this subject produce interesting findings concerning body build and body composition traits that are characteristic for masters of a given discipline. All ITF taekwon-do athletes mentioned in this study had achieved considerable international successes and showed a similar body height and body mass, that is, the mean values of both parameters were similar, and similar girths of arms and legs. Furthermore, most athletes who had won medals displayed a somatotype with a dominance of the mesomorphy component, which indicates an athletic build. Their somatotypes were very similar and their amount of fat tissue was normal (the amount corresponded to the middle of the normal range). In addition, the athletes showed a symmetric body build.

It should be emphasised here that in top-level competitions, special factors determine who wins first place. It was found that as far as somatic build is concerned, parameters that determine the winner frequently comprise pelvis width, arm length, and hand width.

A comparison of study participants with WTF taekwondo fighters allowed for the following observations: all athletes, regardless of specialization, were similar with respect to body height and body mass and had a similar leg reach. Despite a dominance of mesomorphy in the somatotype of both groups and a similar amount of muscle mass, WTF athletes showed a significantly lower amount of fat mass than the ITF athletes in this study. This may be related to the fact that a speed- and endurance-based effort predominates in WTF taekwondo. Moreover, it was noted that in studies conducted among taekwondo

athletes that provided no information regarding the athletes' successes or their affiliation with either WTF or ITF, the athletes were smaller and lighter and had a lower muscle mass and highly varied somatotypes compared to the Polish athletes in this study.

CONCLUSIONS

The conducted analysis allowed for a profile of current world champions in ITF taekwon-do to be created in terms of somatotype and body composition. The analysis also found common somatic traits typical for elite athletes. Study participants displayed average values of body height and body mass, an average amount of fat tissue (corresponding to the middle of the normal range), and symmetric body build and body composition. A robust body build with a dominance of the mesomorphy component was also found to be a common trait among study participants. Athletes participating in three or four events who achieved top results in their respective weight categories showed a similar somatotype. This concerns seniors participating in the weight categories of up to 56 kg and up to 62 kg. It is important to note that the somatotype exhibited by these athletes corresponds to the mean value of the somatotype typical for elite athletes. The conducted research also allowed for the conclusion that pelvis width, hand width, and arm length are some of the factors that determine achieving top ranks at international competitions.

This study constitutes an introduction to thorough research as well as a gathering of results that could in the future be compared to the results presented here. The collected empirical data enable researchers to improve the effectiveness of athlete selection in ITF taekwon-do by creating a champion model for the discipline related to somatotype and body composition.

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COMPETING INTERESTS

The authors declare having no competing interests.

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