

Normative values of elite taekwondoists

AMEL MEKIĆ¹, ELVIRA NIKŠIĆ², ALEN ČUKURIJA³, EDIN BEGANOVIĆ⁴, EROL VREVIĆ⁵

^{1,3,4}Faculty of Sport and Physical Education, University of Sarajevo, BOSNIA AND HERZEGOVINA

²Faculty of Educational Sciences, University of Sarajevo, BOSNIA AND HERZEGOVINA

⁵Faculty of Sport and Physical Education, University of Montenegro, MONTENEGRO

Published online: February 28, 2022

(Accepted for publication February 15, 2022)

DOI:10.7752/jpes.2022.02048

Abstract

Indisputably, sport today plays a very important role in society and is marked by a kind of social popularity. Events that directly affect the sport, such as the Olympics, world championships, and continental championships, have huge ratings. The aim of this paper is to present the normative characteristics of elite taekwondoists. The sample consisted of 40 male respondents, who were participants in the European Senior Championships in the Olympic categories. The sample of variables consisted of 13 anthropometric points measured with appropriate instruments, and 2 points were related to the achieved placement and weight category of the competitors. Based on the obtained results, there were differences between male weight categories. They were visible at all measured anthropometric points. The biggest difference was noticeable in the percentage of body fat and muscle mass, where the lowest weight categories had a slightly lower percentage of adipose tissue, while the highest weight categories had slightly higher muscle mass. Between the categories of up to 58 kg and up to 68 kg, there was one significant difference in the shin length (cm). Between the categories of up to 58 kg and up to 80 kg, there were differences in 2 variables (skin fold of the back and length of the shin), while there were no significant differences for up to 68 kg and up to 80 kg. Significant differences between the categories of up to 58 kg and over 80 kg occurred in 6 to 9 variables (triceps skin fold, back skin fold, abdominal skin fold, body fat, thigh length, and shin length). Between the categories of up to 68 kg and over 80 kg, we observed a difference between 2 variables (skin fold of the back and body fat), and we observed the same differences between the categories of up to 80 kg and over 80 kg. The obtained normative values can help trainers in the planned transition from a lower to a higher weight category, whose precondition is growth and development, taking into account the health of young taekwondo athletes.

Key words: taekwondo, weight categories, anthropometry, body composition, Bosnia and Herzegovina

Introduction

Today, taekwondo is a physical activity with a fight against an opponent that includes self-defense, so today's training programs are increasingly focused on hand and foot motor skills, as well as on the morphological characteristics of the individual engaged in this activity (Šerović, Pleša – Bosnar, Dolani, 2004). The beginnings of taekwondo are represented by martial arts that are known for high, fast, and strong kicks, which Korean peasants used in the distant past as a defense against attackers. Taekwondo has grown from a traditional Korean martial art (Taekyon - whose origins date back 1500 years) to a modern Olympic sport. The Korean martial art recognizable by its high, fast, and strong kicks is called taekwondo. Taekwondo competitions can be conducted in 4 different disciplines, and they are: 1) techniques (pomse), 2) sports wrestling (kyorugi), 3) strength test (kyupka), and 4) self-defense (hosinsul). Based on the criteria of dominant energy processes, taekwondo belongs to the group of anaerobic sports that are of high intensity and are characterized by fast, frequent, and short-term actions. Good motor performance on the left and right side of the body is important for success in these activities (Čular, Tomljanović, Strbad, 2010). Different body weights show 32 significant differences between people who engage in this activity, and therefore, it is recommended that the process of physical exercise represented by this activity is individualized (Segedi and Seretić, 2014; Dizon and Grimmer-Somers, 2012). Taekwondo is an individual sport in which movements are practiced in advance (attack-counter attack), but their performance depends on the opponent's reactions. High automatization of movements, which requires a competitor to react as quickly as possible in certain situations is essential for achieving top results (Čular et al., 2013). Competitions for this activity consist of very short-term strokes, which are high-intensity movements that require a supply of anaerobic energy (Fong, Chung, Ng, Ma, Chow, Tsang, 2014). In taekwondo, several technical elements are used, and a division into basic and specific elements is made. The basic elements of taekwondo include the following. 1. The technique in taekwondo makes it easier to take appropriate action during an opponent's attack, make appropriate use of the power at its disposal, increase speed, and reduce fatigue. This is the basis of this sport and is easy to adopt. 2. Forms represent a fight against an imaginary opponent in which the trainee moves according to a precisely defined scheme and performs a predetermined series of defensive and offensive

movements and techniques. 3. Wrestling - the lower limit in wrestling is 9 years of age, when participants become younger cadets, but there are competitions for children to try this sport. The basic combat techniques include attitudes, movements, blocks, punches, feints, and falls (Horvat, Miholić, Ćosić, 2016).

Materials and methods

Participants

The study included a sample of 40 participants (competitors) of the European Championship for seniors in Olympic categories held in Sarajevo. The Olympic categories included 4 categories. Male categories included up to 58 kg (n=11), up to 68 kg (n=7), up to 80 kg (n=17), and over 80 kg (n=5).

Sample of variables

The measuring instruments used in the study included a set of 13 variables for measuring anthropometric characteristics in taekwondoists, as well as fat and muscle mass, which can be used to show normative values of seniors with 2 points for each category and achievement. To assess the anthropometric characteristics, 13 variables were measured: body height (TV), body weight (TM), body mass index (ITM - BMI), tricep skin folds (KNT), bicep skin folds (KNB), back skin folds (KNL), abdominal skin folds (KNS), thigh skin folds (KNN), shin skin folds (KNP), fat percentage (PM), muscle mass (MM), thigh length (DN), and shin length (DP). The given characteristics were measured with the following instruments: a caliper, anthropometer, altimeter, and inbody scales.

Research Design

Anthropometric variables were measured according to standard procedures of the International Society for the Advancement of Kinanthropometry (ISAK) (Marfell-Jones et al. 2006). Based on the variables of BH and BW, BMI [BMI = BH (kg) / BW (cm)²] was calculated. BMI values for both subsamples were classified into 4 nutritional levels, according to the recommendations of the Centers for Disease Control and Prevention from 2000 (Kuczmarski et al., 2000); see Table 1.

Table 1. Categorization of nutrition based on percentiles

BMI ≥	95th percentile	Obesity
BMI =	85-95th percentile	Obesity tendency
BMI =	5-85th percentile	Normal nutrition
BMI ≤	5th percentile	Malnutrition

Centers for Disease Control and Prevention, 2000 (Kuczmarski et al., 2002)

Body composition was measured using an InBody720 scale (Aandstad, et al., 2014). The validity of determining the body composition with InBody720 scales on a sample of children has been positively evaluated in previous studies (Lim et al., 2009; Tompuri et al., 2015). The study was approved by the Ethics Commission of the Faculty of Education, University of Sarajevo (World Medical Association, 2013). All parents were informed in advance about the implementation of the research, which explained the purpose and goal of the study. Therefore, the research was supported by all parents via written consent.

Statistical Analysis

All data collected were processed by descriptive statistics methods. To determine the differences between the categories in antropometric characteristics, the T-test for independent samples was used. The statistical program for personal computers SPSS for Windows version 20.0 was used for data processing. The level of inference was set at $p < 0.05$.

Results

In this section, the normative values of elite taekwondoists obtained in this study are presented. The results shown in all tables confirmed that all variables had a normal dispersion of data distribution. For all variables, the standard deviation was 3–5 times smaller than the arithmetic mean, which suggests a good distribution of data. The results show significant differences between weight categories in the men, and the largest difference in body composition was noticeable between the lowest and highest weight categories for each variable, where the lowest weight category showed a slightly lower percentage of subcutaneous adipose tissue, while the highest weight category showed a slightly higher muscle mass. An increase in category increased all obtained values of arithmetic means (AS) and standard deviations (SD). According to the results, the difference in muscle mass was 5.68 kg between men's weight categories of up to 58 kg and up to 68 kg, 4.43 kg between men's weight categories of up to 68 kg and up to 80 kg, and the difference was 5.42 kg between men's weight categories of up to 80 kg and over 80 kg. The body weights for the categories of up to 58 kg and up to 68 kg with the arithmetic means (AS) of 58.19 kg and 68.27 kg were more than the allowed category, which showed that competitors in these two weight categories were not measured immediately before weighing but before and after the official weigh-in for the competition. However, for the category of up to 80 kg, the arithmetic mean (AS) was 78.16 kg, which shows that competitors in this weight category weighed 1.84 kg less than the upper limit of

the category. Not all respondents were measured at the same time, i.e., some respondents were measured before and some after the official competition scales. Additionally, from Table 4, in the category over 80 kg, the arithmetic mean (AS) was 92.16 kg from which we can conclude that most of the respondents were in the weight category over 87 kg who were working on the World Cup. All weight categories except the weight category over 80 kg had random weighing, where some of the competitors were selected at random, and it was held just before the competition. A competitor at random weighing may weigh 5% more than his weight category, e.g., if that person is in the category of up to 68 kg, the competitor at random weighing may weigh a maximum of 71.40 kg to pass the scale. Based on the results, for all male weight categories, the normal percentage of subcutaneous adipose tissue prevails for top athletes; here, the arithmetic mean (AS) for the lowest category was 7.65%, and for the highest, it was 13.28% in which the percentage increased by 0.28% with a projected range of 6–13%.

Table 2. Normative values of anthropologic characteristics of taekwondo fighters in the weight category of up to 58 kg

Weight category -58 (n=11)	Min	Max	AS	SD	Skewness	Kurtosis
Age	17	25	19.73	2.83	1.34	0.53
Hight (cm)	166	182	173.73	5.08	0.23	-0.89
Body mass (kg)	54	60	58.19	1.75	-1.95	4.96
Tricep skin folds h. (mm)	3	8	4.64	1.75	0.82	-0.40
Bicep skin folds h. (mm)	3	5	3.55	0.69	0.93	0.08
Back skin folds (mm)	6	10	7.18	1.17	1.42	2.72
Abdomen skin folds (mm)	3	14	6.45	3.05	1.60	3.31
Thigh skin folds (mm)	4	12	7.45	2.66	0.45	-0.95
Shin skin folds (mm)	2	12	4.36	2.84	2.18	5.74
BMI	18	21	19.31	0.99	-0.28	-0.23
Body fat (%)	3	16	7.65	3.39	1.52	3.72
Muscle mass (kg)	28	33	30.41	1.61	-0.31	-0.36
Thigh length (cm)	39	50	44.11	3.62	0.23	-0.93
Shin length (cm)	43	48	45.33	1.50	0.41	0.26
Area	3	23	13.46	7.06	-0.08	-1.75

Legend: Min – minimum values; Max – maximum values; AS – arithmetic mean; SD – standard deviation

Table 2 shows that the normative values for the weight category of up to 58 kg were set for a sample of 11 respondents with the final placement in the tournament from 3rd to 23rd place. The participants had an average height of 173.73 cm (SD 5.08), an average body weight of 58.19 kg (SD 1.75), a body mass index (BMI) of 19.31 kg/m² (SD 0.99), and a body fat percentage of 7.65% (SD 3.39). The normative skin fold values for the category of men of up to 58 kg were: triceps 4.64 mm (SD 1.75), biceps 3.55 mm (SD 0.69), back 7.18 mm (SD 1.17), abdomen 6.45 mm (SD 3.05), thighs 7.45 mm (SD 2.66) and shins 4.36 mm (SD 2.84). Measures of distribution form (SKEW and KURT) were within normal distribution values except for body mass variables (there was at least one high score) and skin fold of the shin (there was at least one high score). Based on the measures of the range, the maximum value was kg, and the weighing was typically after the official weighing for the competition.

Table 3. Normative values of anthropologic characteristics of taekwondo fighters in the weight category of up to 68 kg

Weight category -68 (n=7)	Min	Max	AS	SD	Skewness	Kurtosis
Age	18	26	20.71	2.69	1.43	2.22
Height (cm)	178	187	182.43	3.36	-0.37	-0.82
Body mass (kg)	68	69	68.27	0.47	0.79	0.48
Tricep skin fold h. (mm)	3	7	4.71	1.50	0.26	-0.97
Bicep skin fold h. (mm)	3	6	4.29	1.25	0.68	-1.10
Back skin fold (mm)	6	10	8.14	1.57	-0.68	-1.16
Abdomen skin fold (mm)	5	15	8.71	3.40	1.09	1.02
Thigh skin fold (mm)	5	11	7.71	2.43	0.07	-1.87
Shin skin fold (mm)	2	14	5.57	4.04	1.89	3.87
BMI	20	22	20.53	0.85	0.79	-0.92
Body fat (%)	3	12	7.27	3.55	-0.04	-1.63
Muscle mass (kg)	34	38	36.09	1.50	0.26	-1.02
Thigh length (cm)	42	49	45.20	2.78	0.48	-1.08
Shin length (cm)	46	54	50.00	3.65	0.00	-3.30
Area	6	24	15.86	6.18	-0.25	-0.41

Legend: Min – minimum values; Max – maximum values; AS – arithmetic mean; SD – standard deviation

As shown in Table 3, the normative values of the weight category of up to 68 kg were obtained for a set of 7 respondents with final placements in the tournament from 6th to 24th place. The participants had an average height of 182.43 cm (SD 3.36), an average body weight of 68.27 kg (SD 0.47), a body mass index (BMI) of 20.53 kg/m² (SD 0.85), and a body fat percentage of 7.27% (SD 3.55). The normative skin folds for the category of men up to 68 kg were: triceps 4.71 mm (SD 1.50), biceps 4.29 mm (SD 1.25), back 8.14 mm (SD 1.57), abdomen 8.71 mm (SD 3.40), thighs 7.71 mm (SD 2.43), and lower legs 5.57 mm (SD 4.04). Measures of distribution form (SKEW and KURT) were within normal distribution values except for the variables skin fold of the back (there was at least one high score) and skin fold of the shin (there was at least one high score). Based on the measures of the range, the maximum value was 69 kg, and the weighing was typically after the official weighing for the competition.

Table 4. Normative values of anthropologic characteristics of taekwondo fighters in the weight category of up to 80 kg

Weight category -80 (n=17)	Min	Max	AS	SD	Skewness	Kurtosis
Age	17	29	21.65	4.03	0.68	-0.75
Height (cm)	181	199	187.47	5.00	0.80	-0.06
Body mass (kg)	69	84	78.16	3.44	-0.81	1.44
Tricep skin fold h. (mm)	2	10	5.24	2.31	0.58	-0.53
Bicep skin fold h. (mm)	2	6	4.06	1.30	0.07	-0.90
Back skin fold (mm)	6	13	9.18	2.38	-0.02	-1.49
Abdomen skin fold (mm)	3	23	9.35	5.24	1.07	1.34
Thigh skin fold (mm)	5	19	8.59	3.76	1.50	2.38
Shin skin fold (mm)	2	14	5.47	2.96	1.61	3.20
BMI	19	25	22.24	1.50	-0.53	0.15
Body fat (%)	5	16	9.07	2.88	0.98	1.17
Muscle mass (kg)	37	45	40.52	1.82	0.12	0.96
Thigh length (cm)	43	53	47.87	2.85	0.20	-0.63
Shin length (cm)	47	54	49.93	1.75	0.58	0.90
Area	2	27	14.35	8.32	-0.17	-1.25

Legend: Min – minimum values; Max – maximum values; AS – arithmetic mean; SD – standard deviation

As shown in Table 4, the normative values of the weight category -80 kg were obtained for a set of 17 respondents with final placements in the tournament from 2nd to 27th place. The participants had an average height of 187.47 cm (SD 5.00), an average body weight of 78.16 kg (SD 3.44), a body mass index (BMI) of 22.24 kg/m² (SD 1.50), and a body fat percentage of 9.07% (SD 2.88). The normative skin fold values for the weight category of up to 80 kg were: triceps 5.24 mm (SD 2.31), biceps mm 4.06 (SD 1.30), back 9.18 mm (SD 2.38), abdomen 9.35 mm (SD 5.24), thighs 8.59 mm (SD 3.76), and shins 5.47 mm (SD 2.96). Measures of distribution form (SKEW and KURT) were within normal distribution values except for body mass variables (there was at least one high score) and skin fold of the shin (there was at least one high score). Based on the measures of the range, the maximum body weight was 84 kg, and typical weighing was after the official weighing for the competition. If we take into account that competitors had random weighing just before the competition, which was more in relation to their category, the respondents who weighed 84 kg belonged to the up to 80 kg weight category.

Table 5. Normative values of anthropologic characteristics of taekwondo fighters in the weight category of over 80 kg

Weight category +80 (n=5)	Min	Max	AS	SD	Skewness	Kurtosis
Age	17	29	22.00	4.47	0.98	1.51
Height (cm)	187	193	189.60	3.13	0.54	-3.25
Body mass (kg)	85	101	92.16	5.82	0.56	0.19
Tricep skin fold h. (mm)	4	15	7.60	4.34	1.74	3.36
Bicep skin fold h. (mm)	3	8	5.20	1.92	0.59	-0.02
Back skin fold (mm)	10	21	14.20	4.44	1.01	0.27
Abdomen skin fold (mm)	5	15	11.40	4.04	-1.25	0.95
Thigh skin fold (mm)	7	14	11.00	2.55	-0.91	2.00
Shin skin fold (mm)	2	8	5.00	2.24	0.00	0.20
BMI	24	27	25.58	1.20	-0.12	-2.98
Body fat (%)	6	24	13.28	7.04	0.60	-0.06
Muscle mass (kg)	39	55	45.94	5.71	0.80	1.99
Thigh length (cm)	44	49	46.80	1.79	-0.82	2.36
Shin length (cm)	49	53	50.20	1.64	1.74	3.25
Area	1	12	8.40	4.39	-1.66	2.80

Legend: Min – minimum values; Max – maximum values; AS – arithmetic mean; SD – standard deviation

Table 5 shows that the normative values of the weight category of +80 kg were obtained from a sample of 5 respondents with final placements in the tournament from 1st to 12th place. The respondents had an average height of 189.60 cm (SD 3.13), an average body weight of 92.16 kg (SD 5.82), a body mass index (BMI) of 25.58 kg/m² (SD 1.20), and a body fat percentage of 13.28% (SD 7.04). The normative skin fold values for the weight category of over 80 kg were: triceps 7.60 mm (SD 4.34), biceps 5.20 mm (SD 1.92), back 14.20 mm (SD 4.44), abdomen 11.40 mm (SD 4.04), upper leg 11.00 mm (SD 2.55), and shin 5.00 mm (SD 2.24). Measures of the form of distribution (SKEW and KURT) were within the normal distribution values except for the skin fold of the triceps (there was at least one high score) and skin fold of the abdomen (there was at least one high score). Based on the measures of the range, the maximum body weight was 92.16 kg, and most respondents from this weight category belonged to the category of over 87 kg, which is done in all other competitions but not for Olympic standard men's weight categories. There was no random weighing for this category.

Table 6. Demonstration of significant differences between weight categories in men for certain anthropological measures

Seniors	Category (kg)		
	-58	-68	+80
Tricep skin fold h. (mm)			** from -58
Bicep skin fold h. (mm)			
Back skin fold (mm)		** from -58	** from -80, -68 and -58
Abdomen skin fold (mm)			** from -58
Thigh skin fold (mm)			
Shin skin fold (mm)			
Body fat			** from -80, -68 and -58
Thigh length (cm)			** from -58
Shin length (cm)	** from -58	** from -58	** from -58

** - significantly higher than $p < 0.001$

Table 6 shows that there were no significant differences between male weight categories of up to 58 kg, up to 68 kg, and up to 80 kg. We observed only significant differences between these weight categories and the weight category over 80 kg. From the results, there was one significant difference between the categories of up to 58 kg and up to 68 kg in the variable length of the shin (cm). Between the categories of up to 58 kg and up to 80 kg, there were differences in 2 variables (skin fold of the back and length of the shin), while there were no significant differences between up to 68 kg and up to 80 kg. Significant differences between categories up to 58 kg and over 80 kg occurred in 6 to 9 variables (tricep skin fold, back skin fold, abdominal skin fold, body fat, thigh length, and shin length). Between the categories of up to 68 kg and over 80 kg, we observed a difference between 2 variables (skin fold of the back and body fat), and we observed the same differences between the categories of up to 80 kg and over 80 kg.

Discussion

Because of the aerobic abilities required for taekwondo, it is very important to have a low percentage of subcutaneous adipose tissue, as shown by the results and conclusions of prior studies (Gao et al., 1998). Rapid weight loss affects cognitive performance and mood, and these parameters can affect performance in martial arts because they require concentration, qualitative assessment, and a certain level of skill (Hall & Lane, 2001; Landers et al., 2001). In a survey conducted on a sample of 30 top Chinese taekwondo athletes (competitors), Gao (2001) confirmed that the dominant somatotype is of proportional stature with well-developed muscles, skeletal musculature, and a very small percentage of subcutaneous adipose tissue (Abdossaleh, Azadeh, Kh, M.h, 2008). When Chan et al. (2003) surveyed 20 athletes, who were members of London taekwondo clubs, they concluded that female taekwondo athletes tend toward endomorphism (6.3 ± 1.5) more than men (4.2 ± 1.1). There are not many differences between mesomorphic and ectomorphic components ($P > 0.05$) between females and males. In a comparison of elite taekwondo athletes, gender differences in somatotype were visible, regardless of the quality of the level of the surveyed taekwondo athletes (competitors) (Chan, Willy, Monoley, 2003). Research conducted by Marković et al. (2005) examined differences between successful taekwondo representatives and less successful taekwondo representatives from Croatia. Research shows that successful TKD team members can achieve a significantly higher maximum running speed as opposed to less successful TKD team members. They have significantly higher anaerobic capacity, as well as a lower heart rate.

They have a better lateral mobility, higher explosive power, and a slightly lower percentage of subcutaneous adipose tissue (2.3%) than less successful Croatian national team members (Marković, Duraković-Mišigoj, Trninić, 2005). Research conducted by Kazemi et al. (2006) included 124 taekwondo competitors who participated in the 2004 Olympic Games in Athens (Greece). Based on their results, the medal winners were slightly higher and had a slightly lower body mass index (BMI) than other competitors at these Olympic Games. Competitors scored most of their points by using attacking (offensive) techniques on the opponent's body. The analyzed results show that in 2004 in Athens, there were more warnings and negative points than in the previous

games at the 2000 Olympics in Sydney (Australia), which the authors of the study interpreted as a more aggressive approach of the competitors in the fight (Kazemi, Waalen, Morgan, White, 2006). Research was conducted by Čular et al. (2010) on 26 male beginners in a taekwondo school at the club St-kwan Split, who were ages between 8 and 11 years who train three times (3x) a week for one hour (1h). The measured variables included body height (TV), body weight (TT), percentage of adipose tissue (PMT), endurance in hinged height (IVZ), one-legged lifting with the right foot on the Swedish bench (JPDNŠK), and one-legged lifting with the left leg on the Swedish bench (JPLNŠK). This study showed that the one-legged lift test on the Swedish bench has good metric characteristics, regardless of whether the test was applied on the dominant or non-dominant leg. The one-legged lift test on the Swedish bench is simple in terms of performance, equipment used and simultaneous testing of multiple subjects.

As such, it could be applied in the assessment and programming of transformation processes and the development and equalization of leg muscle strength in taekwondo athletes/fighters. The results of this study indicate the possibility of defining the differences in the strength of the dominant and non-dominant leg. It can also be concluded that there are certain problems in determining the dominant leg. Future works should more precisely terminologically define and construct measuring instruments for quality identification of this problem (Čular, Tomljanović, Strbad, 2010). Chular et al. (2010) studied 57 taekwondo athletes of the age of 10 (± 2). Motor skills were measured on both sides of the body (right and left). The motor skills when performing semicircular and circular kicks was also assessed for the same criterion.

The T-test indicated that there are differences in performing leg techniques and in the flexibility test. According to the regression analysis, among other things, in male athletes, there was a high correlation between the motor skills on both sides of the body and in performing foot movements (Čular, Miletić, Miletić, 2010). The majority of young male competitors fit the mesomorphic ectomorph (43.33%) and mesomorphic endomorph (23.33%) category. Analysis of variance (ANOVA) showed no statistically significant differences in somatotype according to gender. Petterson, Ekström and Berg (2013) stated that a reduction in body mass due to physical dominance over the opponent is often observed in combat sports. A quick reduction in body weight is unhealthy, especially if it occurs shortly before a weigh-in because, as stated by Utter et al. (2012), there is not enough time to compensate for the lost body water, which is the main cause for the virtual weight loss. The obtained normative values can help coaches in the planned transition from a lower to higher weight category, a precondition of which is growth and development, taking the health of young taekwondo athletes into consideration. Anthropometric characteristics and body compositions of the Croatian taekwondo competitors in the cadet age group (from 10 to 14 years) by weight category (+65kg, -65 kg, -61 kg, -57 kg, -53 kg, -49 kg, -45 kg, -41 kg, -37 kg, and -33 kg) showed that the mean values of the measured variables increased in proportion to the weight category. The largest range, i.e., variability of results, was observed for body height for the category of -61 kg (176.7 ± 6.9). All mean values for male participants in terms of body fat percentage were variable in all respects (Čular et al., 2017).

The authors determined the normative values of body composition and anthropometric characteristics of senior Croatian taekwondo competitors of both genders, according to weight category. The respondents consisted of 137 participants in the state senior taekwondo championship. The examined sample was divided into two subsamples: male seniors ($n = 73$) and female seniors ($n = 64$). Variables were measured and divided into two groups according to their role: morphological measures (body height, body weight) and variables that define body composition (body mass index, body fat (%), body fat (kg), muscle mass (kg), lean body mass (kg), total body water (kg), and basal metabolism (kJ)). The obtained results, which were the mean value, variability (SD), and value ranges (MIN-MAX), are Croatian reference values for anthropometric characteristics and physiques for seniors and competitors in taekwondo for different weight categories (+87g, -87 kg, -80 kg, -74 kg, -68 kg, -63 kg, -58 kg, and -54 kg). The average measured values increased in proportion to the weight category. The largest range, i.e., variability of results, was found for body fat (%), (kg) and muscle mass (kg) (Čular, Bešlija, Kezić, 2020).

Conclusion

We observed significant differences between weight categories in taekwondo in men, and the largest differences in body composition was found between the lowest and highest weight categories for each variable, where the lowest weight category showed a slightly lower percentage of subcutaneous adipose tissue and the highest weight category showed slightly higher muscle mass. With increasing category, all obtained values increased in terms of arithmetic mean (AS) and standard deviation (SD). Based on our results of all anthropometric points, arithmetic means (AS), and standard deviations, we can make a training plan and program for each weight category to achieve top results within a certain category.

The results showed the norms of all variables, and based on the results, we can make a training plan and program, diet plan, and list of additional supplements for each individual to achieve values in the arithmetic mean (AS), which are necessary for a top result. Our obtained normative values can help trainers in planning and transition from a lower to a higher weight category, given the health of the taekwondo fighter. In addition to a direct scientific contribution for describing the characteristics of competitors in terms of their physique and composition, the importance of this study is the possible control of body weight in taekwondo competitors.

Acknowledgments

The authors would like to thank Falcon Scientific Editing (<https://falconediting.com>) for proofreading the English language in this paper.

References

- Aandstad, A., Holtberget, K., Hageberg, R., Holme, I., Anderssen, SA. (2014). Validity and reliability of bioelectrical impedance analysis and skinfold thickness in predicting body fat in military personnel. *Military Medicine*, 179(2): 208- 217. <https://doi.org/10.7205/MILMED-D-12-00545>
- Abdossaleh, Z., Azadeh, G., Kh, E., M.h, G. (2008). *A survey of the psychical fitness of the male taekwondo athletes of the Iranian national team*. Facta universitatis. Tehran: Physical Education and Sport.
- Chan, K., Willy, P., Monoley, K. (2003). Kinanthropometric profile of recreational taekwondo athletes. *Biology of Sport, Volume 20, Number 3*, 175-179.
- Čular, D., Tomljanović, M., Strbad, M. (2010). Neke metrijske karakteristike testa za procjenu snage dominantne i nedominantne noge kod polaznika taekwondo škole u motoričkim sposobnostima učenika uključenih u rad školskog športskog društva. U Zborniku radova 19. ljetne škole kineziologa Republike Hrvatske „Individualizacija rada u područjima edukacije, sporta, sportske rekreacije i kineziterapije” [Some metric characteristics of the test for assessing the strength of the dominant and non-dominant leg in taekwondo school students in the motor skills of students involved in the work of the school sports association. In the Proceedings of the 19th Summer School of Kinesiology of the Republic of Croatia "Individualization of work in the fields of education, sports, sports recreation and kinesitherapy"]. (72–78). Zagreb: Croatian Kinesiology Association.
- Čular, D., Miletić, Đ., Miletić, A. (2010). Influence of dominant and non-dominant body side on specific performance in taekwondo. *Kinesiology*, 42. (2.), 184-193. Preuzeto s <https://hrcak.srce.hr/62906>
- Čular, D., Milić, M., Bilić Pavlinović, A., Katić, R., Kuvačić, G., Vrdoljak, J. (2013). Somatotype of young taekwondo competitors. *Research in physical education, sport and health*, 2(2), 27-33. UDC:796.856.012.1-053.6(497.5)
- Čular, D., Milić, M., Bešlija, T. (2017). Normative values of anthropometric characteristics and body composition in croatian cadets taekwondo competitors. *Research in physical education, sport and health*, 6(2), 3-7. UDC: 796.856.012.1:572.087.1(497.5)
- Čular, D., Bešlija, T., Kezić, A. (2020). Normative values of anthropometric characteristics and body composition in senior croatian taekwondo competitors, *Acta Kinesiológica* 14, 1: 5-8.
- Dizon, J.M.R., Grimmer-Somers, K. (2012). Making Filipino Taekwondo Athletes Internationally Competitive: An International Comparison of Anthropometric and Physiologic Characteristics. *Journal of Sports Medicine & Doping Studies*, 2(1), 105– 112. DOI: 10.4172/2161-0673.1000105
- Fong, S.S., Chung, J.W., Ng, S.S., Ma, A.W., Chow, L.P., Tsang, W.W. (2014). Differential postural control and sensory organization in young tennis players and taekwondo practitioners. *Motor control*, 18(2), 103–111. doi: 10.1123/mc.2012-0117
- Gao, B., Zhao, Q., Liu, B. (1998). Measurement and evaluation on body composition and figure of taekwondo athlete. *Journal of Xi'an Institute of physical Education*, 15, 29-33.
- Gao, B. H. (2001). Research on the somatotype features of Chinese elite male taekwondo athletes. *Sport Science*, 21, 58-61.
- Hall, C. J., Lane, A. M. (2001). Effects of rapid weight loss on mood and performance among amateur boxers. *British journal of sports medicine*, 35(6), 390-395. DOI: [10.1136/bjism.35.6.390](https://doi.org/10.1136/bjism.35.6.390)
- Horvat, V., Miholić Jenko, S., Čosić, M. (2016). Taekwondo u predškolskoj dobi. *Kineziologija i područja edukacije, sporta, sportske rekreacije i kineziterapije u razvoju hrvatskoga društva* [Taekwondo in preschool age. *Kinesiology and the fields of education, sports, sports recreation and kinesitherapy in the development of Croatian society*] (pg. 608-613). Poreč: Croatian Kinesiology Association.
- Kazemi, M., Waalen, J., Morgan, C., White, AR. (2006). A profile of olympic taekwondo competitors. *J Sports Sci Med*. 1;5(CSSI):114-121. PMID: 24357983; PMCID: PMC3863920.
- Kuczmarski, R., Kuczmarski, MF., Roche, AF. 2000 CDC Growth Charts: Background for Clinical Application. *Top Clin Nutr*. 2002; 17(2): 15- 26. <https://doi.org/10.1097/00008486-200203000-00006>
- Landers, D. M., Arent, S. M., & Lutz, R. S. (2001). Affect and cognitive performance in high school wrestlers undergoing rapid weight loss. *Journal of Sport and Exercise Psychology*, 23(4), 307-316. <https://doi.org/10.1123/jsep.23.4.307>.
- Lim, JS., Hwang, JS., Lee, JA., Kim, DH., Park, KD., Jeong, JS., et al. (2009). Cross-calibration of multi-frequency bioelectrical impedance analysis with eight-point tactile electrodes and dual-energy X-ray absorptiometry for assessment of body composition in healthy children aged 6-18 years. *Pediatrics International*, 51: 263–8. <https://doi.org/10.1111/j.1442-200X.2008.02698.x>
- Marfell-Jones, M, Olds, T, Stew, A, Carter, L. (2006). *International Standards for Anthropometric Assessment*. Australia: The International Society for the Advancement of Kinanthropometry. <https://doi.org/10.4324/9780203970157>

- Marković, G., Duraković-Miišigoj, Đ., Trninić, S. (2005). Fitness Profile of Elite Croatian Female Taekwondo Athletes. *Collegium antropologicum* 29 (1), 93-99. CROSBID: 198726
- Pettersson, S., Ekström, M. P., Berg, C. M. (2013). Practices of weight regulation among elite athletes in combat sports: a matter of mental advantage? *Journal of athletic training*, 48(1), 99-110.
- Segedi, I., Seretić H. (2014). Razlike u motoričkim i funkcionalnim sposobnostima sportaša. U Zborniku radova 23. ljetne škole kineziologa Republike Hrvatske "Kineziološke aktivnosti i sadržaji za djecu, učenike i mladež s teškoćama u razvoju i ponašanju te za osobe s invaliditetom" [Differences in motor and functional abilities of athletes. In the Proceedings of the 23rd Summer School of Kinesiology of the Republic of Croatia "Kinesiological activities and facilities for children, students and youth with developmental and behavioral disabilities and for persons with disabilities"] (154–158). Zagreb: Croatian Kinesiology Association.
- Šerović, A., Pleša-Bosnar, V., Dolanić, A. (2004). Utjecaj nekih morfoloških i funkcionalnih mjera na maksimalnu silu i brzinu nožnog udarca u taekwondo-u (ITF). U Zborniku radova 13. ljetne škole kineziologa Republike Hrvatske "Vrednovanje u području edukacije, sporta i sportske rekreacije" [Influence of some morphological and functional measures on the maximum force and speed of a kick in taekwondo (ITF). In the Proceedings of the 13th Summer School of Kinesiology of the Republic of Croatia "Evaluation in the field of education, sports and sports recreation"] (34–39). Zagreb: Croatian Kinesiology Association.
- Tompuri, T. T., Lakka, T. A., Hakulinen, M., Lindi, V., Laaksonen, D. E., Oskari Kilpeläinen, T., Jääskeläinen, J., Lakka, H-M., & Laitinen, T. (2015). Assessment of body composition by dual-energy X-ray absorptiometry, bioimpedance analysis and anthropometrics in children: the Physical Activity and Nutrition in Children study. *Clinical Physiology and Functional Imaging*, 35(1), 21-33. <https://doi.org/10.1111/cpf.12118>
- Utter, A. C., McAnulty, S. R., Riha, B. F., Pratt, B. A., & Grose, J. M. (2012). The validity of multifrequency bioelectrical impedance measures to detect changes in the hydration status of wrestlers during acute dehydration and rehydration. *The Journal of Strength & Conditioning Research*, 26(1), 9-15.
- World Medical Association. World Medical Association Declaration of Helsinki Ethical Principles for Medical Research Involving Human Subjects. *JAMA*, 2013 Nov. 27; 310(20): 2191-2194. doi:10.1001/jama.2013.281053. PMID: 24141714