Int. J. Morphol.,
41(2):612-617, 2023.

Anthropometric Variability of European Taekwondo Champions

Variabilidad Antropométrica de los Campeones Europeos de Taekwondo

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BABIC, M.; MARINOVIC, M. & CULAR, D. Anthropometric variability of European taekwondo champions. *Int. J. Morphol., 41(2)*:612-617, 2023.

SUMMARY: World Taekwondo (WT) as an Olympic sport gained much more attention than before, and there is a growing need for precise and specific profiles of successful taekwondo competitors. Aim of this investigation was to determine body composition, somatotype, and selected anthropometric parameters/indexes of elite taekwondo champions and medal winners on the most demanding taekwondo tournaments in the World. The sample for this research consisted of n=16 (n=4 male; n=12 female) elite taekwondo champions, n=8 juniors and n=8 seniors, who were European (n=13), and World (n=3) champions of European descent. Data was collected longitudinally for seven years since 2015. Obtained results revealed specific (absolute) phenotype of taekwondo champions, following: PI (11.50 female; 11.85 male), HWR (43.96 female; 44.47 male) and BMI (19.96 female; 22.04 male). Further analysis shows that champions have greater values of body height, and have slightly greater ectomorphy and mesomorphy values in regard to other elite competitors. Presented research is the first publication of referent values for the general anthropometric dataset, and such results represent the anthropometric variability of European WT champions.

KEY WORDS: Morphology; Taekwondo champions; Profile; Modal characteristics; Talent identification.

INTRODUCTION

Taekwondo presents a modern combat Olympic sport, with over 180 participating countries around the World, while the Croatian competitors are currently positioned within the 6th place in the overall country ranking (World Sport Ranking, 2022). Such data suggest there is a high relative ranking value in comparing results with other countries. Further, scientists noticed and observed great, but still growing total height trends of coastal Croats, naming the Croatian coast as the „Coast of giants“ (Grasgruber *et al*., 2019), which could be related to I2a Y-haplogroup frequently found among Dinaroids, who primarily populate coastal Croatia, Bosnia & Herzegovina and Montenegro (Rootsi *et al*., 2004; Pericic *et al*., 2005; Battaglia *et al*., 2009). There is surely a certain correlation between body linearity and success in Olympic taekwondo (Kazemi *et al*., 2009; Babic *et al*., 2022). Other scientists however did not find any significant evidence (Wheeler *et al*., 2012), so there is still an open question: Do specific phenotype affects success in taekwondo? Interesting research conducted by Scamardella *et al*., in 2020 revealed there is a linear trend within the World Taekwondo Championships toward the greater body heights of champions, from year to year. The selected trend became even more important in the context of past and present decade's rule changes in World Taekwondo. Taekwondo became a specific sport where height plays a great role in competitivity, and height as an anthropometric characteristic is closely related to maturity and is part of it (Babic *et al*., 2021). Further, international taekwondo athletes possess low levels of body fat and a somatotype that characterizes a blend of moderate musculoskeletal tissue and relative body linearity (Bridge *et al*., 2014). Profiles and referent values of taekwondo competitors already exist and were observed by searching the literature (Cular *et al*., 2017, 2020, 2021). Speaking of elite-level competitors there are recent investigations on the anthropometric profile of taekwondo competitors within the last European senior championship

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Received: 2023-01-12 Accepted: 2023-02-11

(Mekic *et al*., 2022), but on male sample only, and without success-dependent differentiation. The appropriate morphological profile of such elite competitors, as well as of taekwondo champions separately, could and should be utilized in further talent identification processes in taekwondo clubs and national teams. Therefore, aim of this research is to comprehend the anthropometric data of elite taekwondo champions.

MATERIAL AND METHOD

Participants and variables. Overall sample of participants is consisted of n=16 elite taekwondo competitors, n=12 of them are female and n=4 of them are male. According to age categories, n=8 of participants are senior category, while n=8 of them are juniors/youth. Speaking of weight categories, there are seven categories in female (-46 kg, -49 kg, -55 kg, -57 kg, -59 kg, -62 kg, -67 kg, +68 kg), and three categories in male subsample (-68 kg, -78 kg, -80 kg). There is an equal number of juniors and seniors according to sex. All participants are of Croatian and Caucasian origin and compete within the Croatian Taekwondo Federation and World Taekwondo competition systems. Speaking of sample quality, n=13 of them are European champions, while n=3 of them are World champions (of European descent).

Sample of variables was composed of: birth year (BY), weight category (WC), body height (BH), body weight (BW), body mass index (BMI), relative age quartile (Q 1-4), TR (tissue resistance, Ohm), fat mass (FMI), fat-free mass (FFM), ponderal index (PI), height/weight ratio (HWR), relative bone mass (BM%), relative muscle mass (MM %), relative fat mass (FM %), total body water (TBW), sarcopenic index (SMI), absolute muscle mass (MM), absolute bone mass (BM), basal metabolism rate (BMR), endomorph component (ENDO BIA), mesomorph component (MESO BIA), ectomorph component (ECTO BIA).

Experimental approach and further estimations. Prior to measurements, air humidity in the laboratory was set to 40% and air temperature to 22 C degrees. Anthropometric variables were measured according to standard procedures of the International Society for the Advancement of Kinanthropometry (ISAK) (Marfell-Jones *et al*., 2006), and the process was conducted in „Cro sports talent lab" laboratory, in Split, Croatia. Examinees were measured individually, with an empty stomach and 0.5 kg of clothes dressed on. Examinees have 9±2.7 years of taekwondo training experience, and were measured on the peak of their sports careers from 2015 to 2022. Before the study was conducted, all participants and their parents had been informed and were officially requested for written consent by their club coaches, who obtained them. Subjects were informed via the official websites of the participating clubs about the study that would be conducted as part of the Croatian Science Foundation Project Grant No. [IP-2020-02- 3366]. Measurements were conducted by the team members and anthropologists from the mentioned project.

Ethical approval for this research is obtained through the specified (IP-2020-02- 3366) project, approved by the Ethics Committee and in accordance with the Ethical codex of the Croatian Science Foundation. Research has been conducted in accordance with the principles expressed in the Declaration of Helsinki.

Body height was measured with Martin Anthropometer ± 0.01 kg scale, while the body composition parameters were assessed with TANITA diagnostic scale (BC 418). Ponderal index (BW/BH3; Florey, 1970), sarcopenic index (MM/BH2; Janssen *et al*., 2000), body mass index (BW/BH2; Himes & Dietz, 1994) and height/weight ratio (BH · 100/BW · kg–3) were calculated afterward. Somatotype values of meso and endomorph were calculated with the formula proposed by Anisimova *et al*. in 2015. Mentioned authors found a way for calculating endomorphic and mesomorphic somatotype values using bioimpedance parameters. The Ectomorph component was simply calculated as the ratio between height and weight (Heath & Carter, 1967).

Methods of data analysis included the calculation of descriptive statistical indicators: mean values (Mean), standard deviation (SD), minimum result (Min), and maximum result (Max).

RESULTS AND DISCUSSION

Table I represents the anthropometric referent values of female continental champions in combat taekwondo. Value growth throughout the table follows weight categories, and values are immune to age categories. Previous investigations (Boraczynski *et al*., 2017) revealed a linear proportional trend, where the growth of BM, BH, FFM and absolute skeletal muscle mass significantly correlates with the growth of absolute maximal power output (Pmax) (r= 0.951; r=0.840; r= 0.953; r= 0.939). However, there is still a significant difference in the occurrence of developmental periods between sexes. Nikolaidis *et al*. (2016) analyzed sex- and age-related differences among taekwondo competitors and results confirmed already known sex-dependent pubertal occurrence. While the male sample had progressive growth of BM, BH, BMI, mean power (Pmean, W kg-1), flexibility (sit and reach-

Table I. Raw data of the female champions (n=12).

*WC	-46 kg	-49 kg	-55 kg		-57 kg		-59 kg	-62 kg	-67 kg		+68 kg	
AC	S	J	J	J	S	S	J	S	S	J	J, S	S
BW (kg)	37.00	49.70	55.20	62.10	60.80	57.20	66.70	56.60	66.50	64.50	71.10	78.80
BH (m)	1.57	1.72	1.75	1.83	1.71	1.71	1.80	1.75	1.77	1.63	1.80	1.80
BMI ($kg \cdot m^{-2}$)	15.01	16.80	18.02	18.54	20.79	19.56	20.59	18.48	21.23	24.28	21.94	24.32
TR (Ohm)	756	736	697	806	718	615	727	706	632	642	629	532
FMI (kg)	6.00	5.60	9.60	11.40	12.50	6.20	17.20	10.30	10.80	19.50	13.70	14.30
FFM (kg)	31.00	44.10	45.70	50.70	48.30	51.00	49.50	46.30	55.70	45.00	57.50	64.50
PI ($kg \cdot m^{-3}$)	9.56	9.77	10.30	10.13	12.16	11.44	11.44	10.56	11.99	14.89	12.19	13.51
HWR ($cm \cdot kg^{-3}$)	47.12	46.78	45.96	46.21	43.49	44.38	44.38	45.58	43.69	40.64	43.45	41.99
BM%	4.05	4.43	5.07	4.19	3.95	4.55	3.75	4.06	4.36	3.72	4.22	4.06
MM%	79.73	84.31	77.72	77.46	75.49	84.62	70.46	77.74	79.40	66.05	76.65	77.79
FM%	16.30	11.30	17.30	18.40	20.60	10.90	25.80	18.20	16.30	30.30	19.20	18.10
TBW (kg)	22.70	30.00	33.50	37.10	35.40	37.30	36.20	33.90	40.80	32.90	42.10	47.20
MM (kg)	29.50	41.90	42.90	48.10	45.90	48.40	47.00	44.00	52.80	42.60	54.50	61.30
BM (kg)	1.50	2.20	2.80	2.60	2.40	2.60	2.50	2.30	2.90	2.40	3.00	3.20
SMI ($kg \cdot m^{-2}$)	5.11	5.65	5.71	6.33	6.87	7.25	5.93	6.30	7.47	6.85	7.35	8.46
ENDO BIA	1.59	2.08	2.39	3.06	4.06	2.67	3.74	2.69	3.49	5.60	3.73	4.00
MESO BIA	2.70	2.49	2.77	1.94	3.60	3.81	2.87	2.83	3.69	5.44	3.64	4.78
ECTO BIA	5.91	5.66	5.06	5.25	3.25	3.91	3.91	4.78	3.40	1.17	3.22	2.15
BMR (kcal)	1182	1428	1449	1548	1468	1493	1642	1502	1722	1611	1698	1930

Legend:*-each column is one examinee, WC- weight category, AC- age category, C- cadet, J- junior/youth, S- senior, BW- body weight, BH- body height, BMI- body mass index, TR- tissue resistance (Ohm), FMI- fat mass (kg), FFM- fat free mass (kg), PI- Ponderal index, HWR- height/weight ratio, BM%- relative bone mass, MM%- relative muscle mass, FM%- relative fat mass, TBW- total body water (kg), MM- absolute muscle mass (kg), BM- absolute bone mass (kg), SMI- Sarcopenic index, ENDO, MESO, ECTO BIA- somatotype values via Bioimpedance, BMR- basal metabolism rate(kcal)

SAR), agility (10x5 m) until the senior age, female competitors stabilized their values much earlier, at cadet age category around 14th year. Therefore, a greater BH, BW and FFM values, as well as absolute and relative amounts of generated power will be expected among male competitors of the same post-pubertal and mature age as female ones. Speaking of female morphology, Table I reveals that the champion level of elite taekwondo surely demands a specific highly-trained lean ectomorphic body within all age categories.

Table II represents the anthropometric referent values of male continental champions in combat taekwondo. This referent value table should be updated with other male weight categories to gain a full perspective. Compared with mean values within their weight and age category (Cular *et al*., 2020, 2021) the first champion in Table II has somewhat lower results in BH, BW, BH, FMI, FM%, MM and TBW than his opponents in -68 kg category within Croatian taekwondo federation. On the other hand, the second junior in Table II (-78 kg) has the better values compared to other Croatian competitors. However, senior champions (-80 kg) seem to be taller for 12 cm, with body composition measures similar to the results of their opponents in Croatia. Recent anthropometric analysis of male competitors within the European senior WT championship (Mekic *et al*., 2022) is probably the most compatible sample to compare with obtained male senior results. Moreover, values reported by Mekic *et al*. (2022) within the -80 kg category (n=17) on the last European WT championship (2021) were the following: BH- 187.47 ± 5.00; BW- 78.16 ± 3.44; BMI- 22.24 ± 1.50; FM%- 9.07 ± 2.88; MM- 40.52 ± 1.82.

Table II. Raw data of anthropometric values within the sample of male champions (n=4).

WC	-68 kg	-78 kg	-80 kg	
AC	J	J	S	S
BW (kg)	70.70	81.90	73.80	80.40
BH (m)	1.73	1.91	1.93	1.90
BMI ($kg \cdot m^{-2}$)	23.62	22.45	19.81	22.27
TR (Ohm)	561	506	546	564
FMI (kg)	9.40	5.60	2.20	11.20
FFM (kg)	61.30	75.20	71.60	69.20
PI ($kg \cdot m^{-3}$)	13.65	11.75	10.27	11.72
HWR ($cm \cdot kg^{-3}$)	41.84	43.98	46.01	44.02
BM%	3.82	4.52	4.34	4.35
MM%	82.89	87.30	92.68	81.72
FM%	13.30	8.20	3.00	13.90
TBW (kg)	44.90	49.00	52.40	50.70
MM (kg)	58.60	71.50	68.40	65.70
BM (kg)	2.70	3.70	3.20	3.50
SMI ($kg \cdot m^{-2}$)	9.09	9.38	8.54	8.50
ENDO BIA	4.20	2.36	1.48	2.97
MESO BIA	4.99	3.70	2.77	3.31
ECTO BIA	2.05	3.61	5.10	3.64
BMR (kcal)	1790	2314	2095	2215

Compared with the champions within the -80 kg category in Table II, champions seem to have significantly greater values of MM, slightly better values of BH and BMI, while the FM% and BW seem approximately equal. A similar investigation was performed by Kazemi *et al*. (2006), where differences between Olympic games (2000, Sydney) taekwondo champions and others were observed. Olympic champions in comparison with other qualified competitors had slightly lower mean values of age (24.4 ± 3.3 to 25.2 ± 4.3), BW (73.4 ± 12.1 to 73.7 ± 14.3) and BMI (21.9 ± 2.4 to 22.8 ± 3.3), with the greater BH (1.83 ± .08 to 1.79 ± .08). Reported results are in agreement with senior values represented in Table II, while the European champions still have greater BH values compared to analyzed Olympic champions. Such BH variation could be explained through a population logic, as Europe has the tallest population, and secondly as a consequence due to the recent tactical changes and taekwondo rule transitions in elite taekwondo. There is also research (Górski & Orysiak, 2019) conducted on the six senior members of the Polish national team. Authors reported mean values for age (20.0 ± 3.2), BH (185 ± 8.5), BW (75.3 ± 10.9), BMI (21.9 ± 2.2), FMI (9.5 ± 3.7), FM% (12.3 ± 3.3), MM (62.5 ± 7.4) and FFM (65.8 ± 7.8). Compared to obtained results of senior European champions (Table II), there is no significant difference between values in BW, BMI, FMI, FM, but continental champions have moderately greater values of BH, MM and FFM. With above-average body heights and fat-free mass, male taekwondo champions seem to be structurally superior to their opponents.

Table III. Descriptive values within the female sample (n=12).

	Mean	Min	Max	SD
BW (kg)	60.52	37,00	78.80	10.72
BH (m)	1.74	1.57	1.83	0.08
BMI ($kg \cdot m^{-2}$)	19.96	15.01	24.32	2.81
TR (Ohm)	683.00	532.00	806.00	74.94
FMI (kg)	11.43	5.60	19.50	4.36
FFM (kg)	48.28	31.00	64.50	7.81
PI ($kg \cdot m^{-3}$)	11.50	9.56	14.89	1.59
HWR ($cm \cdot kg^{-3}$)	44.47	40.64	47.12	1.96
BM%	4.20	3.72	5.07	0.37
MM%	77.28	66.05	84.62	5.14
FM%	18.56	10.90	30.30	5.38
TBW (kg)	35.76	22.70	47.20	6.19
SMI ($kg \cdot m^{-2}$)	6.61	5.11	8.46	0.95
MM (kg)	46.58	29.50	61.30	7.83
BM (kg)	2.53	1.50	3.20	0.44
ENDO BIA	3.26	1.59	5.60	1.08
MESO BIA	3.38	1.94	5.44	0.99
ECTO BIA	3.97	1.17	5.91	1.44
BMR (kcal)	1556.08	1182.00	1930.00	185.97

Legend: Mean- mean value, Min- minimum value, Max- maximum value, SD- standard deviation.

Body heights of female champions are above-average in regard to mean female heights in coastal Croatia (1.68 m) (Grasgruber *et al*., 2019). Further, female champions have slightly greater BH values (Tables I and III) than other taekwondo competitors in cadet, junior and senior categories (Cular *et al*., 2017, 2020, 2021). Previously conducted investigations of morphologic features among Croatian national taekwondo team members (Markovic *et al*., 2005) revealed values of BH, BW, FM% and MM, divided into two (n=6/n=7) subgroups by their previous competitive success. Group A (A), consisted of medalists and champions in at least one European/World championship or Olympic games proved to have moderately greater values of BH (by 5.8 cm) as well as values of maximum running speed, ventilatory anaerobic threshold, explosive power, anaerobic alactic power and lateral agility. Following, A compared to Group B also had less amount of FM% (-2.3 %). Compared to the results of this research exposed in Tables I and III, both groups of female champions have similar values of BH (A- 171.1 ± 5.4; Table III - 174 ± 0.8), BW (A- 62.3 ± 8.1; Table III - 60.52 ± 10.72), FM% (A- 15.3 ± 2.0; Table III - 18.56 ± 5.38) and MM (A- 51.8 ± 5.7; Table III - 46.58 ± 7.83). A slightly higher mean BH value (by 2.9 cm) among champions in Table III could be explained by 15-year span between measurements and the tendency toward greater BHs in general population, but especially in taekwondo selection. A longitudinal tendency toward taller champions in WT championship was already observed by Scamardella *et al*. in 2020. Onwards, somatotype analysis reveals that successful female competitors tend toward ectomorphy with a high mean value of ECTO BIA (3.97), and the highest score of 5.91, while mesomorphy tends to be the second most important somatotype factor for success in female taekwondo. Compared to the results of female taekwondo practitioners featured in the review conducted on taekwondo somatotyping results by Penna-Sanchez *et al*. (2022), female European champions have significantly greater ECTO value (3.97 to 2.70) while ENDO (3.26 to 3.1) and MESO (3.38 to 3.40) seem to be similar. Taekwondo tactics in female taekwondo often rely on safer but effective technique combinations in the front-rear axis, as well as on morphologic superiority"- the length of the legs. There is also a strong (tactical) tendency toward the front-leg techniques, attacks and defenses within female taekwondo. As the front leg kicking occurs without significant body rotations, longitudinality of the skeleton and belonging lower limbs are therefore producing the main synergistic impact to the taekwondo scoring success.

Male somatotype values (Table IV) seem to be structurally different in regard to female ones (Table III). Mesomorph component in combination with the medium or high ectomorph values are therefore the most important

somatotype components for success in male taekwondo. Peña-Sanchez *et al*. (2022), in their recent review reported mean male taekwondo somatotype (2.3 – 3.8 – 3), with lower values of ENDO and ECTO compared to European male champions. Higher values of the mesomorph component within the male sample occurs due to different combat tactics, stratified by sex. Male competitors use much more physiologically demanding techniques and technique combinations, e.g. jumping kicks, rotation kicks, jumping rotation kick. Therefore, male competitors need more relative muscle mass in order to maintain such tactics deductible. Consequently, relative fat values are low, with the extreme value of 3 %. In regards to the female champions, there are surely predictable differences in values of fat mass/fat-free mass due to hormonal differences. However, ponderal index, body mass index and height/weight ratio as relative measures seem to be very similar regardless of age and weight category, and such physical constitution seems to be a desirable phenotype of elite WT taekwondo competitors and champions.

Table IV. Descriptive values of the male sample (n=4).

	Mean	Min	Max	SD
BW (kg)	76.70	70.70	81.90	5.33
BH (m)	1.87	1.73	1.93	0.09
BMI ($kg \cdot m^{-2}$)	22.04	19.81	23.62	1.60
TR (Ohm)	544.25	506.00	564.00	26.69
FMI (kg)	7.38	2.20	11.20	3.91
FFM (kg)	69.33	61.30	75.20	5.89
PI ($kg \cdot m^{-3}$)	11.85	10.27	13.65	1.39
HWR ($cm \cdot kg^{-3}$)	43.96	41.84	46.01	1.70
BM%	4.26	3.82	4.52	0.30
MM%	86.15	81.72	92.68	4.98
FM%	9.60	3.00	13.90	5.09
TBW (kg)	49.25	44.90	52.40	3.22
SMI ($kg \cdot m^{-2}$)	8.88	8.50	9.38	0.43
MM (kg)	66.05	58.60	71.50	5.50
BM (kg)	3.28	2.70	3.70	0.43
ENDO BIA	2.75	1.48	4.20	1.14
MESO BIA	3.69	2.77	4.99	0.94
ECTO BIA	3.60	2.05	5.10	1.25
BMR (kcal)	2103.50	1790.00	2314.00	227.37

Legend: Mean- mean value, Min- minimum value, Max- maximum value, SD- standard deviation.

CONCLUSION

Today's modern taekwondo is surely one of the height-dependent combat sports, as leg linearity dictates advantage to some extent. Such attributes are especially effective within the passive frontal tactics, characteristic for female competitors. Ectomorphic component is the most desirable trait among kyorugi competitors, while males also tend toward higher values of mesomorphic component (Babic *et al*., 2022). Male champions seem to have lean highly-trained and muscular bodies, which enable executions of elite techniques and advanced tactic solutions. Female champions tend to have lean and ectomorphic bodies adequate for combat in the frontal axis. Regardless of sex, taekwondo champions have specific phenotypes characterized by the following indexes: PI (F=11.50; M=11.85), HWR (F=44.47; M=43.96) and BMI (F=19.96; M=22.04), while those values represent a mean physical constitution of a successful taekwondo athlete. Value of this data occurs in the rarity of analysis conducted on champions. This paper represents the first publication of referent values for the general anthropometric dataset of European taekwondo champions. This research should be extended with a greater male/overall sample. Further work should also include motor and functional tests of champions to reveal their overall anthropological status.

ACKNOWLEDGMENTS. This work was supported by the Croatian Science Foundation under Project Grant No. [IP-2020-02- 3366]. The sponsors did not have any role in the study design, data collection, analysis, decision to publish, or preparation of the manuscript.

BABIC, M.; MARINOVIC, M. & CULAR, D. Variabilidad antropométrica de los campeones europeos de taekwondo. *Int. J. Morphol., 41(2)*:612-617, 2023.

RESUMEN: World Taekwondo (TW) como deporte olímpico ha logrado una mayor importancia, y existe una creciente necesidad de contar con perfiles precisos y específicos de competidores exitosos de TW. El objetivo de esta investigación fue determinar la composición corporal, el somatotipo y parámetros/índices antropométricos seleccionados de campeones de TW de élite y los ganadores de medallas en los torneos de TW más exigentes del mundo. La muestra para esta investigación consistió en n=16 (n=4 hombres; n=12 mujeres) campeones de TW de élite, n=8 juniors y n=8 seniors, que eran europeos (n=13) y mundiales (n=3), campeones de ascendencia europea. Los datos se recopilaron longitudinalmente durante siete años desde 2015. Los resultados obtenidos revelaron un fenotipo específico (absoluto) de los campeones de TW, a continuación: PI (11,50 mujeres; 11,85 hombres), HWR (43,96 mujeres; 44,47 hombres) e IMC (19,96 mujeres; 22,04 hombres). Un análisis más detallado muestra que los campeones tienen mayores valores de altura corporal y tienen valores de ectomorfia y mesomorfia ligeramente mayores con respecto a otros competidores de élite. La investigación presentada es la primera publicación de valores de referencia para el conjunto de datos antropométricos generales, y dichos resultados representan la variabilidad antropométrica de los campeones europeos de TW.

PALABRAS CLAVE: Morfología; Campeones de Taekwondo; Élite; Características modales; Identificación de talentos.

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