Anthropometric Characteristics of Elite Male Taekwondo Athletes According to Weight Category and Performance Level

Emek Can[1], Emine Kutlay[2], Manuel Sillero Quintana[3] Craig Alan Bridge[4]

[1]*Institute of Health Sciences Ege University, 35040 Izmir, Türkiye*
[2] *Faculty of Sport Sciences, Ege University, 35040 Izmir, Türkiye*
[3]*Faculty of Physical Activity and Sport Sciences (INEF Madrid), Universidad Politécnica de Madrid, 28040 Madrid, Spain*
[4]*Sports Nutrition and Performance Research Group, Edge Hill University, St Helens Road, Wilson Centre Ormskirk L39 4QP, UK*

ABSTRACT

The aim of this study was to: 1) compare the anthropometric characteristics of elite male taekwondo athletes between selected weight categories using the 'full' International Society for Advancement of Kinanthropometry (ISAK) profile; and 2) compare the index of sitting height/stature ratio, and lower-limb segment lengths between standards of competitors. Thirty-two elite male taekwondo athletes volunteered to take part and they were categorised according to five competition weight categories (<58, <63, <68, <74, and <87kg). Anthropometric measurements were performed according to the ISAK profile protocol (42 measures), and the data were compared between the weight categories. Athletes were also divided into two groups based upon their previous success and selected variables were compared between the groups. Significant differences were identified in a range of anthropometric variables between athletes' weight categories, including percentage of body fat [%BF], skinfold thickness, measurement girths, lengths and widths, and somatotype components. Such differences were generally more notable between the lighter (<58kg) and heavier (<63, <68, <74, and <87kg) weight categories, with lighter weight categories tending to exhibit lower %BF, skinfold thickness, smaller/shorter specific limb girths, breadths, and lengths, and lower endomorphy when compared with their heavier weight counterparts. International level athletes displayed significantly lower sitting height/ stature ratio, and greater iliospinale and tibiale laterale height than their national level counterparts ($p < 0.05$). The findings of this study provide focused reference values to assist preparations for selected weight categories within the sport, and they offer a framework to support talent identification programmes.

Key words: Anthropometry, taekwondo, weight categories, somatotype, combat sports, body composition.

Corresponding author. *Institute of Health Sciences Ege University, 35040 Izmir, Türkiye*
canpersonaltraining@gmail.com

INTRODUCTION

Taekwondo is an Olympic combat sport practiced by an estimated >80 million people worldwide (World Taekwondo Federation 2022). Senior male World Taekwondo (WT) competitions are held according to weight categories designated as <54, <58, <63, <68, <74, <80, <87, >87 kg (World Taekwondo Federation, 2020). Taekwondo contests feature full-contact combat between two opponents, with a prominent emphasis on kicking techniques to the torso and head. In this sport, a range of physical, technical, tactical, physiological, and psychological characteristics can determine athletes' success (Falco et al., 2009; Heller et al., 1998; Sadowski et al. 2012). Several anthropometric characteristics have also been linked with performance in taekwondo. These include height, body mass index (BMI), body fat percentage (%BF), and limb length (Kazemi et al., 2006; Markovic et al., 2015; Scamardella et al., 2020; Mirali et al., 2021). As such, anthropometric variables are routinely collected alongside other physical components of fitness to assist athletes' preparations for competition (Bridge et al., 2014). These variables may also serve as a valuable composite of talent identification (Norjali et al., 2019).

Body composition is an important anthropometric variable that might contribute to success in taekwondo competition. Elite international level taekwondo athletes tend to exhibit relatively low levels of %BF, albeit marked variation in %BF has been observed between competitor standards, genders, and age groups (Bridge et al., 2014; Pieter & Taaffe, 1990; Pieter & Bercades, 2009). Mirali et al. (2021) have recently identified differences in %BF between WT weight categories in elite male competitors. The lighter weight divisions (< 54 and < 58kg) tended to display lower %BF and skin fold thickness when compared with their heavy weight (< 80 and > 87kg) counterparts (Mirali et al. 2021). Whilst these novel findings are valuable to support athletes' competition preparations (e.g., weight-making practices), existing data are confined to the total sum of 8 skinfolds and concomitant estimates of %BF. More comprehensive evaluation of the skinfold thickness at each discrete measurement site might advance our understanding of regional fat distribution, and thereby offer more specific reference values for specific weight categories within the sport (Franchini et al., 2014).

Somatotype is another important a variable collected during routine testing in taekwondo, and it may be used for talent identification. Research has identified that 'ectomorphic mesomorph' is the archetypal somatotype exhibited by male taekwondo competitors (Bridge et al., 2014); but more recently it has been discovered that these characteristics may be modulated by competitors' weight category. For instance, athletes in lighter taekwondo weight divisions (<54 and <58kg) were categorised as 'mesomorphic ectomorph', whereas heavier weights (<68, <74 and 80kg) displayed 'ectomorphic mesomorph' character (Mirali et al., 2021). This novel observation is, however, currently confined to a single study, and hence it remains unclear whether this trend extends to other taekwondo populations and/or if it can be replicated (Halperin et al., 2018). Importantly, existing research into the somatotype and anthropometric variables of taekwondo athletes between weight categories has been performed using 'restricted' International Society for Advancement of Kinanthropometry (ISAK) profiles (Mirali et al., 2021). Research evaluating the 'full' ISAK profile (42 measures) between weight categories in taekwondo is needed to offer more comprehensive understanding and provide more focused reference values for specific variables, such as limb girths, widths, and lengths.

There has been considerable debate surrounding the importance of stature and limb length in achieving success in taekwondo (Bridge et al., 2014; Heller et al., 1998; Scamardella et al., 2020). Whilst it has been assumed that stature and the length of the lower extremities may be conducive to achieving success, existing evidence remains inconclusive (Kazemi et al., 2013; Markovic et al., 2005; Sadowski et al., 2012). Recently, however, sitting height/stature ratio has been identified as a promising alternative measure capable of discerning differences in the stature of the head and trunk, and legs between standards of competitors in taekwondo (Mirali et al., 2021). This ratio was found to be lower in international compared with national level competitors (Mirali et al., 2021). Nevertheless, this novel observation is founded on a single recent investigation. As such, it would be valuable to determine if this trend extends to other taekwondo populations and whether it is reproducible to enhance validity of this construct (Halperin et al., 2018). Likewise, more detailed evaluation of specific lower limb segments (e.g. iliospinale and tibiale-laterale length) would conceivably offer more thorough understanding and more specialised reference values.

The aims of this study were to: 1) compare the anthropometric characteristics of elite male taekwondo athletes between selected weight categories using a 'full' ISAK profile; and 2) compare the index of sitting height/stature ratio, and specific lower limb segments between standards of competitors. It was hypothesized that the anthropometric characteristics would vary between weight categories in taekwondo, and that international level athletes would exhibit lower sitting height/stature ratio, and longer iliospinale and tibiale-laterale lengths than national level counterparts.

METHOD

Participants

Thirty-two elite WT senior male taekwondo athletes (mean age: 20 ± 3.5 years with 4-10 years of training experience, and actively training 4-6 days/week and 1.5-2 hours/day) agreed to participate. The study was approved by Ege University Scientific Research Ethics Committee in the Faculty of Medicine (Approval No:16-3/1) in accordance with the Declaration of Helsinki Ethical Principles for Medical Research Involving Human Subjects. Written informed consent was obtained from all the participants prior to data collection.

Experimental Approach

Participants were divided into five groups according to their competition weight categories (<58, <63, <68, <74, and <87kg). Variables attained from the 'full' ISAK profile (42 measures) were compared between weight categories. Athletes were also divided into two groups based upon their previous success; 'international' (World Championships or International medallists) or 'national' taekwondo athletes (national medallists) (Mirali et al., 2021). The sitting height/ stature ratio, and iliospinale and tibiale-laterale lengths were compared between the national and international (international n = 25 and national n = 7) athletes to determine whether this variable might be able to discriminate between athletes' success.

Procedures

Anthropometric measurements were taken according to the 'Full' ISAK profile protocol (Stewart et al., 2011) by an accredited ISAK Level III anthropometrist in the Kinesiology Laboratory of Ege University, Faculty of Sport Sciences at the beginning of the season - in the morning. The technical error of measurement (TEM) was lower than 7.5 % for each skinfold area and lower than 1.5 % for the other measurements (Marfell-Jones et al., 2022). Body mass, stature, sitting height, and arm span were measured with a precision of 0.1 kg and 0.1 cm (Seca 769, Germany).

Skinfold thicknesses of the triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, front thigh, and medial calf regions were measured with a calibrated skinfold calliper (nearest 0.2 mm, Holtain Ltd., UK.). Skinfold thickness was calculated using both the Σ6 (Triceps + subscapular + supraspinal + abdominal + front thigh + medial calf), and Σ8 skin fold measures. Percentage of body fat (BF%) was determined using the following formula: (0,1051 (Triceps + subscapular + supraspinal + abdominal + front thigh + medial calf) + 2,585) (Yuhasz, 1974).

Body Mass Index = [(BMI (kg) / Stature (m^2)], Waist/Hip Ratio = Waist girth (cm) / Hip girth (cm) and Sitting height ratio (cm) / stature (cm) were calculated. Girths of head, neck, arm (relaxed), arm (flexed and tensed), forearm (maximum), wrist (distal styloids), chest (mesosternal), waist (minimum), gluteal (hips), thigh (1 cm gluteal), thigh (mid-troch-tib. lat), calf (maximum) and ankle (minimum) regions were measured with a steel measuring tape (Cescorf Brasil, 0.1 cm distinction) (Perini et al., 2005). Length measurements of acromiale-radiale, radiale-stylion, midstylion-dactylion, iliospinal height, trochanterion height, trochanterion-tibiale laterale, tibiale laterale height and tibiale mediale-sphyrion tibiale regions were performed with a segmometer (Cescorf Brasil, 0.1 cm distinction). Breadth measurements of biacromial, A-P abdominal depth, biiliocristal, foot length, transverse chest, A-P chest depth, humerus, bi-styloid and femur regions were measured with large and small sliding callipers (Holtain Ltd., UK).

Somatotype components of athletes were determined and classified according to the 13-somatotype category method (Carter & Heath, 1990). Measurements were taken on the right side of the body during the off-season. By using Microsoft Office Excel 2007 program, data recording and consistency between measurements were ensured.

Statistical analysis

The statistical software IBM Statistical Package for the Social Sciences (SPSS) v.15.0 (SPSS, Chicago, IL, USA) was used to analyse all statistical data. According to weight categories, all data are presented as mean and standard deviation. After confirming that the data were normally distributed by the Shapiro-Wilk test, a repeated one-way ANOVA was implemented to identify differences in the dependent variables and partial eta squared (η^2) were used to calculate the effect size for ANOVA. Subsequent comparisons between weight categories were performed using the post hoc Tukey test. An independent *t* test was used to compare the physical characteristics between national and international athletes. The level of significance was set at $P < .05$.

RESULTS

Descriptive anthropometric and somatotype variables between weight categories are presented in table 1. One-way ANOVA identified significant differences in several demographic, anthropometric and somatotype variables between weight categories.

Demographic variables

Body mass increased significantly across each of the weight categories (table 1). BMI was significantly lower in the <58kg weight category when compared with the <74, and <87kg categories. BMI was lower in the <63kg compared with the <58kg category. Sitting height and arm span was significantly lower in the <58 and 63kg categories compared with the <74kg category. Arm span was significantly lower in <74kg compared with the <68kg category, but significantly higher in the <74kg compared with <58 and <63kg categories. There were no significant differences in age and stature between the weight categories.

Skinfolds

The lightest weight category (<58 kg) exhibited significantly lower sum of six skinfolds and BF% than heavier weight divisions (<68, <74, and <87 kg), and lower sum of eight skinfolds compared with <63, <68, <74, and <87 kg divisions (table 1). Skinfold thickness of subscapular, iliac crest and supraspinale were also significantly lower in <58kg compared with <63, <68, <74, and <87kg categories. The <58kg category also displayed significantly lower abdominal skinfolds compared with <68, <74, and <87 kg categories, and significant lower triceps skinfold compared with <74 and <87 kg categories. No significant differences were observed in the remaining skinfold variables between weight categories (table 1).

Girth, breadth, and length measurements

Neck and relaxed arm girths were significantly smaller in the <58kg category compared with <68, <74, and <87kg categories (table 1). Smaller neck girth was also evident in the <63 kg category compared with the <58 and <74kg category. The <58kg category displayed smaller arm (flexed and tensed), maximum forearm, and calf girths when compared with <68, <74, and <87kg categories. The <74kg category displayed significantly greater arm (flexed and tensed) and calf girths than <63 and <68 kg categories. The <58kg category also demonstrated significantly smaller waist (minimum) and thigh (1cm gluteal) girths compared with the <74kg category.

In terms of limb length, the <58kg category displayed significant shorter acromiale-radiale, radiale-stylion, iliospinal height, trochanter-tibiale laterale, and tibial mediale-sphyrion tibial lengths compared with <74 and < 87kg categories (table 1). The <63kg category displayed significantly shorter acromiale-radiale and iliospinal height than the <74kg category. The tibiale lateral and trochanterion height were also significantly shorter in the <58kg category when compared with the <74kg, and <87kg categories, respectively.

In terms of breath, the <58kg category demonstrated significantly smaller biiliocristal breath than the <68, <74, and <87kg categories, and smaller humerus breadth than the <63, <68, <74, and <87kg categories (table 1). Biiliocristal breadth was significantly greater in the <74kg category than in the <63 and <68kg categories, and biacromial breadth significantly lower than in <63 compared with <74kg category. No other significant differences were identified between breadth measurements.

Somatotype

The lightest weight category (<58kg) displayed significantly lower endomorphy than the <63, <68, <74, and <87kg categories. The <63kg categories also exhibited significantly lower endomorphy than the heavier <68 and <74kg categories. Significantly higher ectomorphy was observed in the <68 and <74kg categories compared with the <58kg. No significant differences in mesomorphy were identified between the weight categories (table 1). A 'mesomorph-ectomorph' and 'endomorphic mesomorph' somatotype feature was observed in the athletes

Comparison between standards

International level athletes had significantly longer iliospinale height, tibiale laterale height and significantly lower sitting height/stature ratio than national athletes (p<.05; table 2).

DISCUSSION

The aims of this study were to: 1) compare the anthropometric characteristics of elite male taekwondo athletes between selected weight categories using a 'full' ISAK profile; and 2) compare the index of sitting height/stature ratio, and lower limb segments between standards of competitors. In accord with the study hypothesis, a considerable number of anthropometric characteristics displayed marked variation between senior male WT weight categories. Such differences were most notable between the lighter (<58kg) and heavier weight categories (<63, <68, <74, and <87kg), albeit with some variation evident between specific variables. For the first time, the use of the full 'ISAK' profile provided more comprehensive information concerning the variation in specific anthropometric variables between weight categories (e.g. regional skinfold thickness, sitting height, and limb girths, widths, and breadths), and thereby offers more focused reference values for different weight categories within the sport. A further important finding was that measures of sitting height/ stature ratio and lengths of specific lower limb segments (iliospinale and tibiale-laterale lengths) were able to effectively discriminate between standards of taekwondo competitors. These findings have implications for both competition preparations and talent identification.

The estimated range of %BF from the sum of six skinfolds (~6-10%) in the current study is within the lower range of values reported in international male taekwondo athletes in previous studies (Olds & Kang, 2000; Heller et al., 1998; Rivera et al., 1998; Mirali et al., 2021), albeit there is some inherent variation in the measurement methods, predictive equations, and training phase (Bridge et al., 2014). Nevertheless, there was a trend for lower %BF and skinfold thickness in the lighter weight categories compared with heavy weight counterparts in the present study. More specifically, the %BF and sum of six skinfolds were significantly lower in the <58kg category when compared with the heavier <68, <74, and <87 kg categories, and the sum of eight skinfolds significantly lower than in the <63, <68, <74, and <87kg categories. Mirali et al. (2021), despite displaying higher overall %BF and sum of eight skinfolds than in the present study, also observed a trend for lower %BF and skinfold thickness in lighter weight categories. More specifically, they discovered significantly lower %BF and sum of eight skinfolds in the <54 and <58kg categories compared with their heavy weight (<80 and >87kg) counterparts. More precise comparison of the significant differences between the studies is, however, challenging due differences in the weight categories included for analysis. The observed differences in %BF between the weight categories may reflect variation in the requirements to 'make the weight' for competition and/or differences in the activity requirements of matches (Rydzik et al., 2021).

For the first time, we report the skinfold thickness for each measurement site between selected taekwondo weight categories. Differences in the sum of 8 skinfolds between weight categories seem to correspond more with differences in skinfold thickness of the trunk regions as opposed to distal areas. For instance, the subscapular, iliac crest, and supraspinale skinfold thickness were significantly lower in the <58kg category when compared with the <63, <68, <74, and <87kg categories, and the abdominal skinfolds were lower compared with the <68, <74, and <87kg categories. Apart from triceps skinfold, no significant differences were evident in the biceps, front thigh, and medial calf skinfold thickness between the weight categories. No comparative data exists between weight categories in taekwondo. Differences in specific site skinfold thickness have been observed in analogous combat sports such as karate and judo, but they do not appear generalisable and they contain divergent weight categories (Slankamenac et al., 2021; Franchini et al., 2014). The regional differences observed in skinfold thickness across measurement sites and between weight categories observed in the current study may therefore offer more specific reference values to assist competition preparations and 'weight making' practices exclusively in taekwondo. This seems particularly prudent given that the measurement of skinfolds is promoted as a more reliable and accurate outcome of body composition assessment when compared with the conversion of skinfolds to %BF (Kasper et al., 2021).

Body shape and limb length might conceivably influence technical execution in taekwondo (Falco et al., 2009), and girth measurements might reflect specific physiological adaptations (Friedl et al., 1994). Whilst some studies have measured limb girths, breadths, and lengths in taekwondo (Heller et al., 1998), the present study is the first to consider a comprehensive evaluation these variables using the 'full' ISAK profile between weight categories. There was a trend for increased/greater limb girths, breadths and lengths as the weight categories increased, but only selected variables reached statistical significance. Comparable trends have been observed across weight categories other combat sports (Slankamenac et al., 2021; Franchini et al., 2014), but the differences between specific categories do not appear generalisable between combat sports; nor are the weight classification boundaries wholly compatible.

In the present study, girths of several upper (neck, arm tense, arm relaxed, forearm) and lower body (calf) regions were significantly smaller in the <58kg category compared with the heavier <68, <74, and <87kg categories. There was also evidence of significant increases in arm (tensed) and calf girths as the weight categories increase between <68, <74 and <87kg. The thigh and waist girths were also smaller in the <58 compared with <74kg categories. These findings could reflect greater musculature and/or fat mass in the heavier weights, which may be a function of the divergent combat activity requirements, training regimes, and/or nutritional strategies (Bridge et al., 2011; Menescard et al., 2021). The <58kg also displayed significantly smaller biiliocristal and humerus breadths, than the <68, <74, and, <78kg categories, and the <63, <68, <74, and <87kg categories, respectively. The <63 and 68kg category exhibited significantly smaller biacromial breadth than <74kg category. These data suggest greater upper body linearity in the lightweight categories. In terms of limb lengths, the lighter <58kg weight category displayed significant shorter upper (acromiale-radiale, radiale-stylion) and lower (iliospinal height, trochanter-tibiale laterale, and tibial mediale-sphyrion tibial) body limb lengths compared with the heavier <74 and < 87kg categories. These differences could play a role in the technical and tactical strategies selected during matches (Falco et al., 2009; Santos et al. 2011; Menescard et al., 2021).

Previous studies demonstrate that elite male taekwondo athletes typically display 'ectomorphic mesomorph' character. In the present study, lighter < 58, and <63kg weights displayed significantly lower endomorphy than the heavier <63, <68, <74, and <87kg; and <68, <74kg categories, respectively. There was also a tendency for higher mesomorphy in the heavy <87kg category compared with most lighter categories, although such differences did not reach statistical significance. There was a tendency for lower ectomorphy in the <87kg category compared with lighter categories, but again failing to reach statistical significance (table 1). Ectomorphy was significantly higher in the <68 and <74kg compared with the <58kg category, but such data seemed somewhat variable between weight categories. Trends for higher endomorphy and mesomorphy compare favourably with recent research, but variable ectomorphy between weight categories is incongruent (Mirali et al., 2021). In the present study, the <58, <63, <68 and < 74kg may be classified as ‘mesomorph-ectomorph’ suggesting more equal proportions muscular-skeletal tissue and linearity, with lower degree of fatness. Whereas <87kg category displayed ‘endomorphic mesomorph’ character, suggesting a predominance of muscular-skeletal tissue, with lower degree of fatness, and relative linearity. The <63kg category classification is similar to those reported in recent research, but the ‘mesomorph-ectomorph’ character displayed by <58, <68, and < 74kg is slightly different to the ‘mesomorphic ectomorphic’ reported by Mirali et al., 2021. This variation seems to represent small differences between the ectomorphic and mesomorphic components (<0.5 units; table 1). Further comparisons between studies are difficult due to differences in the weight categories included, but such differences might also reflect variation training and nutritional practices, or even populations/genetics (Peeters et al., 2007).

There has been considerable debate surrounding the importance of stature and limb length in achieving success in taekwondo (Bridge et al., 2014; Heller et al., 1998; Scamardella et al., 2020). Recently, sitting height/stature ratio has been identified as a promising measure capable of discerning differences in the stature of the head and trunk, and legs between standards of competitors in taekwondo (Mirali et al., 2021). In the present study, this ratio was significantly lower for international athletes compared with their national level counterparts. This is the first attempt to validate the construct via ‘direct replication’, a process regarded as essential to increase the confidence of novel methods in sports science research (Halperin et al., 2018). For the first time, the present study also identified significantly greater iliospinale and tibiale laterale height in the international compared with the national level athletes. This extends our understanding of specific differences in lower limb segments between these groups and hence may offer more precise reference values for talent identification programmes.

The present study has several strengths and limitations. This is the first study to examine the ‘full’ ISAK profile (42 measures) between weight categories in elite male competitors, hence it offers more precise reference points for several important variables within the sport. Nevertheless, several weight categories were omitted (<54, <80, >87kg) from the current study due to difficulties in recruiting enough elite level male athletes within each category. The attempt to include elite international male athletes also resulted in the inclusion of relatively low numbers within specific weight categories. Finally, the generalisability of the current findings to other taekwondo populations (e.g. females, and youth competitors) remains to be established.

CONCLUSION

This study demonstrates that several anthropometric characteristics displayed marked variation between weight categories in elite male competitors. For the first time, detailed information on the differences in anthropometric variables between weight categories using the ‘full’ ISAK profile is presented. These data provide more focused reference values to assist preparations (conditioning and ‘weight-making’ practices) for selected weight categories within the sport. A further key observation was that the sitting height/stature ratio, and the length of specific lower limb segments (iliospinale and tibiale laterale height) were capable of discriminating between athletes levels of success/standards. These data may collectively serve to support talent identification programmes with the sport.

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Table 1. Descriptive Anthropometric Characteristics for Male Taekwondo Athletes According to Weight Categories (means±SD).

Variables (n=32)	Weight Categories <58 kg (n=5)	<63 kg (n=4)	<68 kg (n=11)	<74 kg (n=6)	<87 kg (n=6)	P value	η^2
Demographic Characteristics							
Age (years)	19.9±1.0	19.3±1.4	20.5±2.5	20.4±3.2	20.6±0.8	.866	.04
Body mass (kg)	57.7±3.6	63.1±0.6	68.0±2.4	74.4±4.4	87.9± 6.9	.001*	.87
Stature (cm)	171.6±5.6	173.9±3.9	179.4±4	184.0±5.5	186.0±7.1	.216	.18
Sitting height (cm)	91.1±0.7	89.1±3.2	92.0±3.6	96.0±2.3 ^{b}	96.3±3.4	.002*	.46
Arm span (cm)	176.4±4.5	169.6±7.4	188.2±4.1	181.1±7.4 $^{\beta}$	186.1±6.6	.001*	.50
BMI (kg/m^2)	21.1±0.8 $^{\gamma}$	19.6±1.2	21.1±1.2	22.0±1.2	25.5±2.6	.001*	.63
Skinfolds (mm)							
Σ6	35.7±3.6 $^{\Delta}$	39.5±8.5	46.4±15.8	44.2±12.4	68.1±17.0	.005*	.41
Σ8	46.6±5.9 $^{\gamma}$	52.6±11.5	60.6±21.5	56.9±15.6	91.5±21.6	.003*	.43
Body fat (%)	6.3±0.4 $^{\Delta}$	6.7±0.9	7.5±1.6	7.2±1.3	9.7±1.8	.005*	.41
Triceps	4.9±0.8 †	5.3±0.8	6.9±2.3	6.3±2.0	9.9±4.1	.018*	.34
Subscapular	6.7±0.4 $^{\gamma}$	6.8±1.3	7.8±1.3	7.4±0.7	11.0±2.1	.001*	.58
Biceps	2.9±0.5	2.8±0.1	3.5±1.4	2.9±0.4	4.3±0.9	.081	.25
Iliac Crest	8.1±2.2 $^{\gamma}$	10.0±3.5	10.7±4.8	9.8±3.6	18.9±4.2	.001*	.47
Supraspinale	4.2±0.5 $^{\gamma}$	5.1±0.7	5.5±1.3	5.2±1.2	9.7±2.2	.001*	.68
Abdominal	8.3±2.4 $^{\Delta}$	8.4±4.1	10.5±4.6	10.8±4.2	18.7±6.7	.006*	.40
Front thigh	7.9±2.7	6.6±0.9	9.4±4.7	8.8±4.0	11.7±2.7	.279	.16
Medial calf	5.9±1.7	5.0±1.0	6.2±2.8	5.6±1.6	7.1±2.6	.651	.08
Girths (cm)							
Head	54.7±0.7	55.1±1.2	55.7±2.3	56.3±0.8	56.9±1.4	.216	.15
Neck	36.0±1.0 $^{\gamma}$	34.4±1.0 $^{\eta}$	36.1±1.4	36.7±1.0	39.1±1.0	.001*	.63
Arm (relaxed)	27.0±0.8 $^{\gamma}$	25.6±2.2	27.8±1.4	28.5±0.5	31.5±2.4	.001*	.60
Arm (flexed and tensed)	29.6±2.0 $^{\Delta}$	27.2±2.7	30.2±1.2	31.2±0.6 $^{\theta}$	33.4±1.5	.001*	.61
Forearm (maximum)	25.0±1.1 $^{\Delta}$	24.1±1.4	25.4±1.0	26.0±0.4	29.4±4.3	.002*	.46
Wrist (distal styloids)	16.1±1.1	16.3±0.5	15.9±1.1	17.0±0.3	19.5±4.4	.088	.25
Chest (mesosternale)	85.9±4.9	91.8±4.5	88.1±14.4	95.1±4.1	98.7±6.1	.145	.21
Waist (minimum)	72.2±2.9 $^{\varepsilon}$	70.2±3.2	71.4±11.5	76.2±4.1	85.5±4.5	.010*	.37
Gluteal (hips)	88.4±1.8	92.5±2.2	89.1±14.1	96.6±1.7	101.6±5.6	.071	.26
Thigh (1cm gluteal)	52.3±1.6 $^{\eta}$	50.2±0.8	52.5±8.8	56.6±1.9	60.8±4.2	.029*	.32
Thigh (mid-troch-tib. Lat.)	46.8±1.0	49.2±2.3	48.1±8.1	51.7±1.6	55.5±4.7	.071	.26
Calf (maximum)	35.2±0.6 $^{\Delta}$	32.0±4.5	36.8±1.0	37.5±0.8 $^{\theta}$	40.6±2.4	.001*	.62
Ankle (minimum)	21.0±1.0	21.9±0.6	23.3±0.9	23.4±0.4	23.4±5.1	.301	.15
Lengths (cm)							
Acromiale-radiale	32.6±0.9 †	33.1±1.6 $^{\eta}$	35.0±1.7	34.9±1.9	36.8±1.5	.003*	.44
Radiale-stylion	25.9±1.7 †	24.6±0.6	26.7±1.1	27.0±1.1	28.5±1.8	.001*	.49
Midstylion-dactylion	20.6±0.4 $^{\eta}$	18.9±0.4	19.9±0.2	20.3±0.4	21.0±0.5	.007*	.39
Iliospinal height	97.0±2.2 †	96.8 ± 6.3 $^{\eta}$	101.3±2.5	105.2±6.1	107.3±4.3	.001*	.47
Trochanterion height	87.5±1.6 §	88.2 ± 5.2	90.8±3.6	94.8±3.8	95.8±5.0	.007*	.39
Trochanter-tibiale laterale	41.7±1.3 †	41.7 ± 2.6	43.2±2.3	43.4±1.6	46.2±2.5	.014*	.35
Tibiale lateral height	46.0±1.2 $^{\eta}$	45.8 ± 2.8	48.3 ± 2.5	50.6±2.3	51.9±4.9	.009*	.38
Tibial mediale-sphyrion tibial	37.2±1.1 †	37.8 ± 1.7	41.6 ± 2.7	41.6±1.6	43.9±3.4	.001*	.46
Breadths (cm)							
Biacromial	39.4±1.0	38.0 ± 1.5 $^{\eta}$	40.1 ± 1.8	41.9±1.7	40.4±1.6	.039*	.66
A-P abdominal depth	17.1±0.4	18.1±0.5	17.7±2.2	18.3±2.3	19.1±2.9	.597	.09
Biiliocristal	26.0±1.7 $^{\Delta}$	24.1 ± 0.5	26.6 ± 1.0	27.4±1.3 $^{\theta}$	29.0±1.1	.001*	.66
Foot length	26.4±1.1 $^{\eta}$	25.5 ± 2.1	26.6 ± 0.6	27.4±1.0	27.8±1.1	.021*	.33
Transverse chest	27.6±1.3	28.0±0.8	30.4±3.2	29.7±2.3	30.4±1.7	.165	.20
A-P chest depth	17.3±2.0	18.0±2.4	17.9±1.3	19.2±0.7	19.3±1.0	.145	.01
Humerus	6.6±0.3 $^{\gamma}$	6.7 ± 0.2	6.8 ± 0.2	6.8±0.2	7.3±0.4	.001*	.48
Bi-styloid	6.3±2.1	5.4±0.3	5.3±0.3	5.7±0.1	6.8±1.5	.263	.17
Femur	8.6±0.3	9.3±1.5	9.1±1.0	9.9±0.2	9.7±1.8	.421	.12
Somatotype							
Endomorphy	1.4±0.2 $^{\gamma}$	1.6 ± 0.4 $^{\varepsilon}$	1.8 ± 0.5	1.6±0.5	2.8±0.8	.001*	.48
Mesomorphy	3.0±1.5	4.2 ± 0.8	3.6 ± 0.9	3.9±0.8	4.3±1.3	.364	.14
Ectomorphy	3.2±0.6 $^{\varepsilon}$	4.0±0.9	3.6±0.8	3.5±0.8	2.1±1.3	.022*	.33

kg: kilogram, **cm:** centimeter, **mm:** milimeter, **BMI:** Body Mass Index (Body Weight (kg)/Height (m^2), **Σ6:** The sum of six skinfolds (Triceps + subscapular + supraspinale + abdominal + front thigh + medial calf), **Σ8:** The sum of eight skinfolds.

^{b} Significantly Different ($p<.05$) From weights <58 kg, <63 kg

$^{\beta}$ Significantly Different ($p<.05$) From weights <58 kg, <63 kg, <68 kg,

$^{\gamma}$ Significantly Different ($p<.05$) From weights, <63 kg, <68 kg, <74 kg, <87 kg

$^{\Delta}$ Significantly Different ($p<.05$) From weights <68 kg, <74 kg, <87 kg

$^{\varepsilon}$ Significantly Different ($p<.05$) From weights <68 kg, <74 kg

† Significantly Different ($p<.05$) From weights <74 kg, <87 kg

$^{\eta}$ Significantly Different ($p<.05$) From weight <74 kg,

$^{\theta}$ Significantly Different ($p<.05$) From weights <63 kg, <68 kg

§ Significantly Different ($p<.05$) From weight <87 kg

Table 2. Length of extremities and Sitting Height/Stature ratio between groups of success (means±SD).

Variables	International (n=25)	National (n=7)	P value
Iliospinale Height (cm)	103.2±2.0	97.1±3.7	.025
Tibiale Laterale Height (cm)	49.5±3.4	45.9±2.5	.010
Sitting Height/Stature Ratio (%)	0.51±1.1	0.52±0.9	.027

Cm: centimeter

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