Anthropometric characteristics of elite male taekwondo players based on weight categories

Abstract

Purpose: The aim of this study was to investigate the anthropometric characteristics of elite taekwondo players based on weight categories, and to determine if the length of the lower extremities might influence player's success-level. A total of 59 elite male taekwondo players (22.02 ± 3.07 years) participated in this study.

Methods: All anthropometric assessments were performed according to the standards and methodology of the International Society for Advancement of Kinanthropometry. The 18 anthropometrical variables were measured for each athlete and compared between 7 different weight categories. The players were also divided into two groups (national and international) and the ratios of sitting-height to stature were compared.

Results: There were significant differences ($p < 0.05$) between weight divisions in stature, body mass index, percentage of body fat, endomorphy, and mesomorphy, which were greater ($p < 0.05$) in heavy weight groups than light weight groups, and ectomorphy, which was greater ($p < 0.05$) in very light weight groups compared with the other weights. There was no significant difference in lean mass index ($p > 0.05$) between weight groups. Sitting height/stature ratio was significantly different ($p < 0.05$) between the two groups, where the international group had longer lower extremities than the national group.

Conclusion: The findings of this study provide a valuable framework to support talent identification programmes and the development of specialised preparatory strategies for different weight divisions with the sport.

Key words: Anthropometry, combat sports, weight division, somatotype, lower limbs, body fat

Declarations

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Conflicts of interest/Competing interests (The authors declare that we have no conflict of interest and a relevant statement is provided within the acknowledgement section)

Ethics approval (The research has been conducted ethically according to international standards, which conform to the ethical standards laid down in the 1964 Declaration of Helsinki)

Consent to participate (All subjects were informed of the test procedures, benefits and potential risks, and written informed consent was attained from all participants using an institutionally approved informed consent form)

Consent for publication (The authors declare that we have consent to publish in journal Journal of Science in Sport and Exercise)

Availability of data and material (there is no problem to share data and material)

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Introduction

Taekwondo is a combat sport that has regularly featured in the Olympic Games. Taekwondo contests characterise weight-restricted full-contact combat between two opponents, with a prominent emphasis on the execution of kicking techniques. There are several important physical components of fitness that have been shown to be strongly related to performance in taekwondo (Čular et al., 2013). Anthropometric characteristics are one of those components, which have the potential to influence taekwondo athletes success in competition (Nikolaidis et al., 2015; Sadowski, Gierczuk, Miller, Cieśliński, et al., 2012). Previous studies have shown that height, body mass, body mass index (BMI), and body fat percentage (%BF) are some of the anthropometric characteristics related to performance in taekwondo (Campos et al., 2012; Kazemi et al., 2006). For example, Marković et al. (2005) showed that elite taekwondo athletes tended to be taller and have lower %BF compared with none-elite athletes.

Today, understanding of the anthropometric and physiological profiles of athletes is important to support talent identification programmes (Duncan et al., 2006) and to permit the development of specialised preparatory strategies for different populations within the sport (Bridge et al., 2014; Bridge et al. 2011). Along with basic anthropometric characteristics, somatotype analysis might be valuable in both contexts since variation in taekwondo athletes somatotypes have been identified between different standards of athletes, age groups and genders (Kazemi et al., 2013). Previous research has reported that 'ectomorphic mesomorph' is the typical somatotype in male competitors (Bridge et al., 2014; Carter et al., 1990); however, few studies have explored this factor in taekwondo athletes in relation to weight categories. It is possible that athletes in different taekwondo weight divisions might exhibit unique somatotype characteristics, which reflect the varied metabolic and activity requirements of specific weight divisions (Bridge et al., 2011).

Body composition is another important anthropometric characteristic that might influence success in taekwondo competition (Sadowski, Gierczuk, Miller, Cieśliński, et al., 2012). In general, international taekwondo players tend to exhibit relatively low %BF, but there is evidence of variation in the %BF between standards of competitors, genders, and age groups. A substantial proportion of taekwondo athletes 'cut' their body mass to compete within their desired weight classes (da Silva Santos et al., 2016; Janiszewska & Przybyłowicz, 2020), which might also partially explain the observed differences in %BF between taekwondo athletes. There have been no concerted attempts, however, to describe the %BF of taekwondo athletes across the entire range of World Taekwondo (WT) weight categories. Differences in the requirements to 'make the weight' for competition between lighter and heavier weight divisions is likely to influence athlete's %BF.

It is presumed that stature and/or longer lower extremities may be conducive to achieving success in taekwondo, but existing evidence remains inconclusive. Research has either reported no clear (significant) differences in stature between competitors' level of success (Sadowski, Gierczuk, Miller, & Cieslinski, 2012; Sadowski, Gierczuk, Miller, Cieśliński, et al., 2012) or trends for greater stature in successful athletes when compared with their less successful counterparts (Kazemi et al., 2013; Marković et al., 2005). Sitting height/stature ratio might be an alternative anthropometrical procedure capable of differentiating between the stature of the head and trunk, and the length of the legs (Malina et al., 2004), but it has never been applied to discern between levels of success in taekwondo.

The aims of this study therefore were to: (1) determine the anthropometrical factors of taekwondo athletes with respect to weight category using a valid and reliable method (ISAK); and (2) compare the index of sitting height/stature ratio between national and international players representing different levels of success. It was hypothesised that the anthropometric characteristics of taekwondo athletes would vary between weight divisions; and that international level taekwondo athletes would display lower sitting height/stature ratio when compared with their less-successful national level counterparts.

Methods

Participants

Fifty-nine elite male taekwondo athletes (mean + SD age: 22.02 ± 3.07 [17-30] years) with national or international ranking participated in this study. The project was approved by the Sport Science research institute (IR.SSRC.REC.1398.015). All subjects were informed of the test procedures, benefits and potential risks, and written informed consent was attained from all participants using an institutionally approved informed consent form. For those subjects under the age of 18 years, parental or guardian signed consent was obtained to perform the anthropometrical measures. This research was performed in compliance with the 1964 Helsinki Declaration.

Design and procedures

Male taekwondo players were recruited for the study and their anthropometric characteristics were assessed using accepted ISAK methods. The players were categorised into seven of the eight senior male WT weight classes (<54, <58, <63 <68, <74, <80, <87 and >87 kg). Unfortunately, sufficient numbers of players from the (<87kg) weight division could not be recruited and hence this division was omitted from the study. Anthropometric measures were compared between players competing within the remaining seven different weight categories at the 13th Championships of the Premier League Cup –2015. This approach allowed us to detect any differences in the anthropometric variables between weight categories and identify any characteristics that may be unique to specific weight divisions. Participants were also divided into two groups based upon their previous success; ‘international’ players (including Olympic, World Championships or International medals) and ‘national’ players (those who have national medals). The players sitting to standing height ratios were compared between the ‘national’ and ‘international’ (international n = 17 and national n = 41) players to determine whether this variable might be able to discriminate between players levels of success.

Measurements were completed using the standardized techniques adopted by ISAK using the same measurer, an anthropometrist accredited by the ISAK. The technical error of measurement (TEM) was always lower than 7.5% for each skinfold region and lower than 1.5% for the other measurements, which were acceptable (Perini et al., 2005). Anthropometric variables included height, eight skinfolds (biceps, triceps, subscapular, suprailiac, supraspinale, abdominal, front thigh and medial calf), five girths (upper arm relaxed, upper arm flexed and tensed, waist, gluteal and maximum calf), and two breadths (humerus bi-epicondylar and femure bi-epicondylar. Stature and sitting height were measured (Seca 206, roll-up) to the closest 0.1 cm, with stadiometer placed vertically on a flat wall, and the subject standing erect with his head at the Frankfurt plane. Sitting height was measured with the subject sitting upright on a base plate and weight was measured on a portable scale (model 707, Seca) to the nearest 0.1 kg. Skinfolds were taken using the Slimguide skinfold calliper (CH, Plymouth Mich, USA) to the nearest 0.5 mm (Ackland et al., 2009), and the girths were performed with a flexible metallic tape measure (Lufkin W606PM, Mexico), with a precision of 1 mm (Mielgo-Ayuso et al., 2017; Noor Hafizah et al., 2019; Torres-Unda et al., 2013). Skinfolds were taken two times and the mean value was recorded for the calculations (Stewart & Sutton, 2012). BMI was calculated as body mass/height2, body mass was expressed in kilograms (kg) and height in meters (m). Withers equation was used to estimate percentage of body fat (BF) (Withers et al., 1987). Somatotype was determined according to the Heath and Carter somatotyping method (Carter et al., 1990).The LMI is calculated as M/S, where M is the subject's body mass in kilograms, S is the sum of skinfolds in millimetres (Duthie et al., 2006; Slater et al., 2006).

Statistical analysis

The statistical software IBM Statistical Package for the Social Sciences (SPSS) v.23.0 (SPSS, Chicago, IL, USA) was used to analyse all statistical data. Mean values and standard deviations were expressed for all variables. The Shapiro Wilk test was used to assess normal distribution of the variables and log transformations (log10) were performed where normal distribution was violated. The normality of distribution was verified following the Shapiro Wilk test, which confirmed that all data were normally distributed and hence parametric statistical tests were performed. One-way analysis of variance (ANOVA) was used to test for differences in the anthropometrical variables among weight categories. Partial eta squared (η2) were used to calculate the effect sizes for ANOVA. Subsequent comparisons on weight categories were performed using the post hoc Tukey test. An independent t-test was used to compare the sitting height/stature ratio between national and international groups. The level of significance was set at $p \leq 0.05$.

Results

The anthropometric characteristics and body composition of taekwondo athletes based on weight category and competition level are presented in table 1 and 2, respectively.

Insert Table 1 near here

One-way ANOVA identified significant differences (p<0.05) amongst individual weight categories for height, sum of 8 skinfolds, BMI, %BF and somatotype (Table 1). The post-hoc Tukey tests indicated that athletes in the heavier weight categories were taller and had greater skinfold thickness and %BF than the lighter weight groups (p<0.05; table 1). Post-hoc Tukey tests also indicated that lighter weight categories (<54, <58, <63 <68kg), with respect to somatotype components values, displayed greater ectomorphic (p<0.05) and lower mesomorphic and ectomorphic values than the heavy weight categories (<74, <80, and >87 kg) (Figure 1). No significant difference was found in lean mass index (LMI) between the weight categories (p>0.05) (Table 1).

Insert Figure 1 near here

When taekwondo athletes were analyzed based on the competition level (Table 2), international level athletes had significantly lower sitting height/stature ratio than national athletes (p<0.05).

Insert Table 2 near here

Discussion

The main findings of this study demonstrate that taekwondo athletes' anthropometric characteristics display marked variation between weight divisions. Most notably, athletes competing in lighter weight divisions tended to be smaller, exhibit lower %BF, lower BMI and displayed greater ectomorphy, with lower mesomorph and endomorph, somatotype components when compared with athletes competing in heavier weight divisions. A further key finding, was the discovery of differences in sitting height/stature ratio between taekwondo athletes levels of success, which were lower in international level athletes compared with national players. These novel findings have implications for talent identification programmes and the development of specialised preparatory strategies for athletes competing in different taekwondo weight divisions.

Previous research has documented that 'ectomorphic mesomorph' is the typical somatotype in male taekwondo competitors (Olds, 2000; Taaffe & Pieter, 1990); reflecting a predominance of musculoskeletal tissue, moderate-high relative body linearity, and a lower degree of fatness. For the first time, our data demonstrate that this archetypal somatotype may not be generalisable between taekwondo athletes in different WT weight divisions. This was realised through the detection of differences in the numerical somatotype profiles between lighter and heavier weight divisions, and via differences in the overall somatotype categories across the weight division spectrum. Indeed, athletes in the lightest weight divisions (e.g. <54 and <58kg) displayed significantly higher ectomorphy, and lower mesomorphy when compared with athletes in the heavier weight divisions (e.g. <74, <80, >87kg). Athletes in the heavy >87kg weight division also displayed significantly lower ectomorphy compared with the (<63, <68 and <80kg) weight division athletes. These differences serve to adjust the overall conventional somatotype categories of the weight divisions previously reported as 'ectomorphic mesomorph' (Olds, 2000; Taaffe & Pieter, 1990). Athletes in the (<54 and <58kg) weight divisions may be categorised as 'mesomorphic ectomorph' reflecting a dominance of ectomorphy and relative body linearity. In contrast, athletes in the (<63kg) division satisfy the 'mesomorph-ectomorph' category displaying more equal proportions of mesomorphy and ectomorphy (musculoskeletal tissue and relative body linearity). Athletes competing in the (<68, <74 and <80kg) divisions characterise a 'ectomorphic mesomorph’ somatotype, indicating an ascendency of muscular-skeletal tissue, with lower relative body linearity, Whereas the heavy (>87kg) division display ‘mesomorphy’ somatotype reflecting a predominance of muscular-skeletal tissue. Variation in these somatotypes between weight divisions might well be a function of differences in the physical and metabolic demands experienced during combat (Bridge et al., 2011). For instance, heavy weight competitors have been shown to perform greater proportions of fighting activity than lighter weight divisions (Bridge et al., 2011), where a predominance of muscular-skeletal tissue might be more conducive to executing such actions. It might also be a function of variation in the requirements to ‘make the weight’ for selected weight divisions, which does not feature in heavy weights preparations (da Silva Santos et al., 2016). Other combats sports have also documented variation in the somatotypes between athletes weight divisions, but such differences appear specific to the nature of the combat sports (Franchini et al., 2014; Noh et al., 2014).

Differences in the %BF were also observed between athletes competing in different weight divisions. The lighter (<54 and <58kg) weight divisions displayed lower %BF and skin-fold thickness than athletes competing in the heavier (<80 and >87kg) weight divisions. Similar trends have been observed across weight divisions in other combat sports (Franchini et al., 2014).The differences in %BF observed in the present study could represent a reduced requirement to ‘make the weight’ for competition and/or efforts to maximise the power-to-weight ratio in some taekwondo weight divisions (Bridge et al., 2014; Langan-Evans et al., 2011). Whilst there was a complementary trend for greater LMI in the heavier weight divisions compared with lighter divisions, this difference did not reach statistical significance. These differences in body composition should be considered by scientific practitioners who are responsible for developing taekwondo athletes muscular strength qualities, and designing strategies to ‘make the weight’ for competition.

Differences in taekwondo athlete’s height were also evident between the weight divisions. Athletes in the lighter (<54, <58 and <63kg) weight divisions were smaller in stature when compared with the heavier (<80 and >87kg) divisions. The BMI was also lower in the lighter (<54, <58 and <63 kg) divisions when compared with the heavier (<74, <80 and >87kg) divisions. The heavy (>87 kg) division also displayed greater BMI than both the (<74 and <80kg) divisions. These differences might be expected given the increase in height and body mass observed across the lighter to heavier weight categories. A similar trend has been observed in these variables across weight divisions in other combat sports, albeit they do not appear generalisable to taekwondo (Franchini et al., 2014; Noh et al., 2014).The data in the current study might therefore better support talent identification programmes in taekwondo.

It is presumed that stature and/or longer lower extremities may be conducive to achieving success in striking sports such as taekwondo, but existing evidence remains inconclusive (Kazemi et al., 2013; Marković et al., 2005; Sadowski, Gierczuk, Miller, & Cieslinski, 2012; Sadowski, Gierczuk, Miller, Cieśliński, et al., 2012). For the first time, we evaluated and compared the sitting height/stature ratio between national and international taekwondo athletes to discern potential differences in the stature of the head and trunk, and the length of the legs (Malina et al., 2004) between levels of success. This ratio was lower for international taekwondo players when compared with national players. This indicates that international level athletes characterise longer lower extremities than their less successful national counterparts. From practical standpoint, longer lower limbs might offer a ‘reach’ advantage for executing techniques from distance. Conversely, a shorter trunk/head component might reduce the target size for striking/scoring. This measure might therefore hold potential as valuable composite of talent identification programmes within the sport. Further research is clearly warranted into additional makers of success within the sport.

There are some limitations that should be considered with the interpretation of the current study findings. These findings represent data obtained from male national and international competitors during competition. It remains unclear whether these data are generalisable to other taekwondo populations, including females, youth competitors and different standards of competitors. Due to difficulties in recruiting sufficient numbers of players, data from the (<87kg) weight division were excluded from the current study. Further research is clearly needed in these areas to advance our understanding of these anthropometric characteristics and to permit the development of specialised preparatory strategies for different populations within the sport. Finally, the TEM of skin-fold measurements was always below 7.5% for each skinfold region. Whilst this level of precision may be acceptable (Perini et al., 2005), we acknowledge that lower TEM for each skinfold region would increase measurement sensitivity, and may permit detection of more subtle differences in skinfold measurements between specific weight divisions. This should be acknowledged in future studies.

Conclusion

This study demonstrates that taekwondo athletes competing in different weight categories display unique anthropometrical characteristics. This suggests that coaches and practitioners should avoid using anthropometric reference values based upon mean group data to prepare athletes for competition. This study provides specialised reference values that can be used to tailor conditioning and ‘weight making’ preparations for athletes competing in specific taekwondo weight divisions. A further key discovery was the identification of longer lower extremities in international level athletes when compared with their less successful national counterparts. This finding, in concert to the observed differences in anthropometric variables between the weight divisions, might also serve as a valuable composite of talent identification programmes within the sport.

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References

Ackland, T. R., Elliott, B., & Bloomfield, J. (2009). *Applied anatomy and biomechanics in sport*. Human Kinetics.

Bridge, C. A., da Silva Santos, J. F., Chaabene, H., Pieter, W., & Franchini, E. J. S. M. (2014). Physical and physiological profiles of taekwondo athletes. *44*(6), 713-733.

Bridge, C. A., Jones, M. A., & Drust, B. (2011). The activity profile in international taekwondo competition is modulated by weight category. *International journal of sports physiology and performance*, *6*(3), 344-357.

Campos, F. A. D., Bertuzzi, R., Dourado, A. C., Santos, V. G. F., & Franchini, E. J. E. j. o. a. p. (2012). Energy demands in taekwondo athletes during combat simulation. *112*(4), 1221-1228.

Carter, J. L., Carter, J. L., & Heath, B. H. (1990). *Somatotyping: development and applications* (Vol. 5). Cambridge university press.

Čular, D., Krstulović, S., Katić, R., Primorac, D., & Vučić, D. (2013). Predictors of fitness status on success in Taekwondo. *Collegium antropologicum*, *37*(4), 1267-1274.

da Silva Santos, J. F., Takito, M. Y., Artioli, G. G., & Franchini, E. (2016). Weight loss practices in Taekwondo athletes of different competitive levels. *Journal of exercise rehabilitation*, *12*(3), 202.

Duncan, M., Woodfield, L., & Al-Nakeeb, Y. (2006). Anthropometric and physiological characteristics of junior elite volleyball players. *British Journal of Sports Medicine*, *40*(7), 649-651.

Duthie, G., Pyne, D., Hopkins, W., Livingstone, S., & Hooper, S. (2006). Anthropometry profiles of elite rugby players: quantifying changes in lean mass. *British Journal of Sports Medicine*, *40*(3), 202-207.

Franchini, E., Sterkowicz-Przybycien, K., & Yuri Takito, M. (2014). Anthropometrical Profile of Judo Athletes: Comparative Analysis Between Weight Categories. *International Journal of Morphology*, *32*(1).

Janiszewska, K., & Przybyłowicz, K. E. (2020). Pre-Competition Weight Loss Models in Taekwondo: Identification, Characteristics and Risk of Dehydration. *Nutrients*, *12*(9), 2793.

Kazemi, M., De Ciantis, M. G., & Rahman, A. (2013). A profile of the youth Olympic taekwondo athlete. *The Journal of the Canadian Chiropractic Association*, *57*(4), 293.

Kazemi, M., Waalen, J., Morgan, C., White, A. R. J. J. o. s. s., & medicine. (2006). A profile of Olympic taekwondo competitors. *5*(CSSI), 114.

Langan-Evans, C., Close, G. L., & Morton, J. P. (2011). Making weight in combat sports. *Strength & Conditioning Journal*, *33*(6), 25-39.

Malina, R. M., Bouchard, C., & Bar-Or, O. (2004). *Growth, maturation, and physical activity*. Human kinetics.

Marković, G., Mišigoj-Duraković, M., & Trninić, S. J. C. a. (2005). Fitness profile of elite Croatian female taekwondo athletes. *29*(1), 93-99.

Mielgo-Ayuso, J., Zourdos, M. C., Urdampilleta, A., Calleja-González, J., Seco, J., & Córdova, A. (2017). Relationship of long-term macronutrients intake on anabolic-catabolic hormones in female elite volleyball players. *Nutricion hospitalaria*, *34*(5), 1155-1162.

Nikolaidis, P. T., Chtourou, H., Torres-Luque, G., Tasiopoulos, I. G., Heller, J., & Padulo, J. J. J. o. h. k. (2015). Effect of a six-week preparation period on acute

physiological responses to a simulated combat in young national-level taekwondo athletes. *47*(1), 115-125.
Noh, J.-W., Kim, J.-H., Kim, M.-Y., Lee, J.-U., Lee, L.-K., Park, B.-S., Yang, S.-M., Jeon, H.-J., Lee, W.-D., & Kwak, T.-Y. (2014). Somatotype analysis of elite boxing athletes compared with nonathletes for sports physiotherapy. *Journal of physical therapy science*, *26*(8), 1231-1235.
Noor Hafizah, Y., Ang, L. C., Yap, F., Nurul Najwa, W., Cheah, W. L., Ruzita, A. T., Jumuddin, F. A., Koh, D., Lee, J. A. C., & Essau, C. A. (2019). Validity and reliability of a food frequency questionnaire (FFQ) to assess dietary intake of preschool children. *International journal of environmental research and public health*, *16*(23), 4722.
Olds, T. S. (2000). *Anthropometric characteristics of adult male Korean taekwondo players* KAHPERD].
Perini, T. A., Oliveira, G. L. d., Ornellas, J. d. S., & Oliveira, F. P. d. J. R. B. d. M. d. E. (2005). Technical error of measurement in anthropometry. *11*(1), 81-85.
Sadowski, J., Gierczuk, D., Miller, J., & Cieslinski, I. (2012). Success factors in elite WTF taekwondo competitors. *Archives of Budo*, *8*(3), 141-146.
Sadowski, J., Gierczuk, D., Miller, J., Cieśliński, I., & Buszta, M. J. J. C. S. M. A. (2012). Success factors in male WTF taekwondo juniors. *1*, 47-51.
Slater, G., Duthie, G., Pyne, D., & Hopkins, W. (2006). Validation of a skinfold based index for tracking proportional changes in lean mass. *British Journal of Sports Medicine*, *40*(3), 208-213.
Stewart, A. D., & Sutton, L. (2012). *Body composition in sport, exercise and health*. Routledge.
Taaffe, D., & Pieter, W. (1990). Physical and physiological characteristics of elite taekwondo athletes. Commonwealth and international conference proceedings,
Torres-Unda, J., Zarrazquin, I., Gil, J., Ruiz, F., Irazusta, A., Kortajarena, M., Seco, J., & Irazusta, J. (2013). Anthropometric, physiological and maturational characteristics in selected elite and non-elite male adolescent basketball players. *Journal of sports sciences*, *31*(2), 196-203.
Withers, R., Craig, N., Bourdon, P., & Norton, K. (1987). Relative body fat and anthropometric prediction of body density of male athletes. *European journal of applied physiology and occupational physiology*, *56*(2), 191-200.

Table 1: Descriptive anthropometric characteristics for male taekwondo players according to weight category (means± SD)

Measure (n)	Weight <54kg(8)	Weight <58kg(8)	Weight <63kg (8)	Weight <68kg (14)	Weight <74kg (9)	Weight <80kg (7)	Weight >87kg (5)	p value	η2
Age (years)	20.20 ± 2.45	19.14 ± 2.21	21.19 ± 2.92	22.42 ± 4.28	22.83 ± 3.02	21.24 ± 2.58	27.18 ± 4.09	Ns	
Body Mass (kg)	56.4 ± 2.4	60.1 ± 3.6	64.9 ± 3.3	71.0 ± 1.9	77.0 ± 2.8	82.5 ± 4.4	91.3 ± 2.9	P=0.000	
Height (cm)	174.8 ± 6.31[a]	178.2 ± 7.2[b]	178.5 ± 4.5[b]	181.9 ± 5.4	183.6 ± 2.8	187.7 ± 3.7	187.9 ± 4.71	P=0.000	0.43
8 skinfold (mm)	65.4 ± 6.6[b]	67.2 ± 6.9[b]	70.4 ± 7.6[e]	72.4 ± 6.9	79.6 ± 9.5	87.1 ± 16	88.9 ± 16	P=0.000	0.45
LMI (kg/m^2)	0.86 ± 0.1	0.89 ± 0.1	0.92 ± 0.1	0.98 ± 0.1	0.98 ± 0.1	0.97 ± 0.2	1.05 ± 0.2	p=0.101	0.17
BMI (kg/m^2)	18.4 ± 1.4[c]	18.9 ± 1.7[c]	20.3 ± 1.5[a]	21.4 ± 1.3[b]	22.8 ± 0.7[d]	23.3 ± 0.8[d]	25.9 ± 1.3	P=0.000	0.75
%BF	10.4 ± 1.0[b]	10.6 ± 0.9[b]	10.9 ± 1.1[e]	11.2 ± 0.8	12.1 ± 1.3	12.9 ± 1.9	13.2 ± 1.9	P=0.000	0.38
Endomorph	1.2 ± 0.3[f]	1.3 ± 0.4[g]	1.5 ± 0.3	1.6 ± 0.3	1.9 ± 0.5	2.1 ± 0.5	1.8 ± 0	p=0.001	0.35
Mesomorph	3.2 ± 1.2[h]	2.9 ± 0.9[c]	4.2 ± 1.3	4.4 ± 0.8	4.8 ± 0.8	4.6 ± 0.7	5.9 ± 0.8	P=0.000	0.44
Ectomorph	4.8 ± 1.1[a]	4.8 ± 1.3[a]	3.9 ± 1.1[d]	3.6 ± 1[d]	3.0 ± 0.4	3.0 ± 0.4[d]	2.0 ± 0.7	P=0.000	0.46

[a] Significantly different (P<0.05) from weights <74, <80, >87kg. [b] Significantly different (P<0.05) from weight <80, >87kg. [c] Significantly different (P<0.05) from weights < 68, <74, <80, >87kg. [d] Significantly different (P<0.05) from weight >87kg. [e] Significantly different (P<0.05) from weight <80kg. [f] Significantly different (P<0.05) from weights <74, <80kg. [g] Significantly different (P<0.05) from weight <80kg. [h] Significantly different (P<0.05) from weights <74, >87kg. η2= Size Effect

Table 2: Sitting height to stature ratio between groups of success

Group (n)	International (17)	National (41)	P value
Stature (cm)	183.04±6.76	180.9±6.4	
Sitting Height (cm)	94.59±4.03	95.91±3.26	
Sitting Height/ Stature Ratio	0.51±0.01	0.53±0.01	P=0.001

FIGURES

Figure 1: Somatotype distribution of male taekwondo players according to weight category. Δ: Mean somatotype of each weight.