RESEARCH ARTICLE

INTERNATIONAL JOURNAL OF KINANTHROPOMETRY

DOI: 10.34256/ijk2218

Body Mass Index, Fat Mass, Muscle Mass, and Somatotype of Young Adult Male Non-Elite Judokas According to Body Weight Categories in Merida, Mexico

Sudip Datta Banik [1, *]

[1] Department of Human Ecology, Cinvestav del IPN, Merida, Yucatan, Mexico
* Corresponding authors email: dattabanik@cinvestav.mx
DOI: https://doi.org/10.34256/ijk2218
Received: 11-04-2022; Revised: 19-06-2022; Accepted: 20-06-2022; Published: 30-06-2022

Resumen

Objetivo: Evaluar y comparar las características antropométricas, la masa grasa, la masa muscular y el somatotipo de adultos jóvenes judokas masculinos, no de élite y de diferentes categorías de peso corporal, en la ciudad de Mérida, Yucatán, México**. Métodos**: Se realizó un estudio transversal en 2019; se seleccionó a 21 judokas, adultos jóvenes varones que tenían entre 20 y 24 años, y que no eran de élite. Estaban ubicados en tres categorías de peso (≤73 kg, ≤81 kg y ≤90 kg). Se registraron mediciones antropométricas de estatura, peso, perímetros, pliegues cutáneos y diámetros. Los parámetros derivados fueron el índice de masa corporal (IMC), el índice de estatura y peso, grasa corporal (%) y masa muscular (kg y %). Se estimaron valores *Phantom Z-score* (Zp) de parámetros antropométricos y Somatotipo. **Resultados**: La media de edad de los judokas fue de 22.43 años. Las medias de las características antropométricas de los atletas que estaban en las categorías de mayor peso fueron más elevadas que las de otros de categorías de menor peso. Los judokas tuvieron somatotipo mesomorfo endomórfico (3.4-5.7-1.6); se encontró que su musculatura relativa (mesomorfia) aumentaba en las categorías de mayor peso: 2.8-5.1-2.4 (≤73 kg), 3.5-5.5-1.6 (≤81 kg) y 3.6-6.7-0.9 (≤90 kg). El IMC tuvo una correlación positiva con la endomorfia y la mesomorfia, una correlación negativa con la masa muscular (%) y la ectomorfia. Los valores de Zp del diámetro de fémur y del perímetro de la pierna estuvieron entre (±0.5). **Conclusiones**: El predominio del componente muscular y la grasa corporal relativamente menor fueron las principales características del físico de los judokas participantes. Se encontró que el somatotipo es un indicador más confiable que el IMC para distinguir entre la grasa corporal relativa y la masa magra.

Palabras Clave: Judo, Grasa Corporal, Musculatura, Enodmorfia, Mesomorfia, Ectomorfia.

Abstract

Aim: To evaluate and compare anthropometric characteristics, body fat mass, muscle mass, and somatotype of young adult non-elite male judokas of different body weight categories in Merida, Mexico. **Methods:** A cross-sectional study in 2019 selected 21 young adult non-elite male judoists aged 20 to 24 years. They were in three weight categories (≤73 kg, ≤81 kg, and ≤90 kg). Anthropometric measurements of height, weight, circumferences, skinfolds, and breadths were recorded. Derived parameters were body mass index (BMI), height-to-weight ratio, body fat (%), and muscle mass (kg and %). Phantom Z-score values (Zp) of anthropometric parameters and Somatotype were estimated. **Results:** Mean value of age of the judokas was 22.43 years. Athletes in the higher weight categories had elevated mean values of anthropometric characteristics in comparison with peers of lower weight categories. The judokas had endomorphic mesomorph somatotype (3.4-5.7-1.6); relative muscularity of the judosits was found to increase in the higher weight categories: 2.8-5.1-2.4 (≤73 kg), 3.5-5.5-1.6 (≤81 kg), and 3.6-6.7-0.9 (≤90 kg). BMI had positive correlation with endomorphy and mesomorphy and negative correlation with muscle mass (%) and ectomorphy. The Zp values of femur breadth and calf circumference were in between (±0.5). **Conclusions:** Predominance of muscle component and relatively lower body fat was the principal characteristics of physique of the participant judokas. Somatotype was found to be a more reliable indicator than BMI to distinguish between relative body fat and lean mass.

Keywords: Judo, Body Fat, Muscularity, Enodmorphy, Mesomorphy, Ectomorphy.

Introduction

Judo, a martial art is a high-intensity, intermittent and grappling combat sport; athletes compete in different weight categories (Drid et al. 2015). Optimal body composition is a major concern for judo athletes; maximizing body lean mass and muscle strength with simultaneous reduction of body fat and body weight are the principal aims. Studies reported that elite judokas have low body fat and relatively high fat free mass; physique and physiological characteristics of judoists are associated with body weight, techniques, tactics, and levels of sport performance (Ceylan et al. 2018, Claessens et al. 1987, Franchini et al. 2011). Relatively higher muscularity (Endomorphic mesomorph somatotype) of judokas has been reported earlier (Lewandowska et al. 2011, Sterkowicz-Przybycień et al. 2012). Elite judoists have optimal morphological and physiological characteristics that include low body fat, higher lean mass (skeletal muscle mass, bones), circumferences (mid-upper arm, thigh, calf), and broader diameters (humerus, wrist, femur) in comparison with non-elite and amateur judokas (Buśko 2017, Claessens et al. 1987, Rodríguez 2013).

Anthropometric measurements and derived parameters are used to characterize physique and body types of athletes. Body mass index (BMI) is a widely used indicator to evaluate nutritional status; low BMI is an effective indicator to assess undernutrition or chronic energy deficiency (WHO 1995). However, it has limitation of use among individuals with high body weight due to either body fat or lean mass (Bogin and Varela-Silva 2012). Athletes with low body fat and high muscle mass generally have high BMI. On the other hand, people with high body fat also have elevated BMI. Short height and high BMI are general physical characteristics of Mexican population that is more evident in Yucatan (Bogin and Varela-Silva 2012, López-Alvarenga et al. 2003). High prevalence of BMI-based overweight and obesity (excess weight) in Mexican adults are reported. In 2016, prevalence of excess weight was remarkably high in adult men (69.4%) and women (72.7%) (Secretaria de Salud 2019).

Studies of physical and physiological characteristics of Mexican athletes are relatively less in comparison with the reports from other countries like Brazil, U.S.A, and several European nations. In Mexico, government sports institutes are found in the different states where training, exercise, and nutrition intervention programs are available (CONADE 2019). Athletes receive such facilities since their adolescence and they participate in the regional and national level competitions, and in the selection for international championships. In addition, several private clubs offer training, exercise, and nutrition intervention programs for the athletes of different events.

The aim of the present study was to evaluate and compare anthropometric characteristics, body fat mass, muscle mass, and somatotype of young adult non-elite male judokas of different body weight categories in Merida, Mexico. The present report will provide information on physical characteristics of young adult non-elite judo athletes from Merida that may help further research and development strategies for talent identification among young athletes in Mexico.

Methods and Participants

In a cross-sectional study during February-March 2019, young adult non-elite male judo athletes (n=21) of 20 to 24 years of age were selected from a university (*Universidad Modelo)* and different private sports training centers in Merida, Yucatan, Mexico. Protocol of research project was evaluated by the institutional ethics committee (see Acknowledgements). The sample was convenience type that was not representative of judokas from Yucatan. The participant athletes reported no chronic diseases at least in the three months prior to the study.

The athletes were grouped in three weight categories: lightweight (≤73 kg), half-middleweight (≤81 kg), and middleweight (≤90 kg), according to the rules of the International Judo Federation for adult males (IJF 2018). Recording of somatometric measurements followed the protocol of International Society for the Advancement of Kinanthropometry (ISAK) (Esparza-Ros et al. 2019). The measurements were taken by the author (trained researcher and a certified anthropometrist ISAK level III); recording time was in the morning between 7 and 9 A.M., before physical exercise. Somatometric measurements included height, weight, circumferences (relaxed and flexed mid-upper arm, mid-thigh, calf), skinfolds (biceps, triceps, subscapular, iliac crest, supraspinale, thigh, calf), and breadths (humerus, femur).

Height (cm, to nearest 1 mm) was measured using a standard stadiometer with platform (Seca model no. 225, Hamburg, Germany) and body weight (kg, to nearest 50 gm) was recorded using an electronic scale (Seca, Hamburg, Germany, model no. 881). A standard sliding caliper (CESCORF ®, Brazil) was used to measure breadths; circumferences were measured using standard inelastic tape (Lufkin)- both to the nearest 1 mm. Skinfold thickness nearest 0.1 mm was measured using a Harpenden skinfold caliper. Intra-observer technical error of

measurement for skinfolds (<5%) and other anthropometric parameters (<1%) were within acceptable limits; intra-class correlation coefficients at 95% confidence interval levels were >0.85.

Body mass index (BMI) was calculated; overweight and obesity were evaluated (WHO 1995). Another derived variable was height-to-weight ratio (HWR). Body fat (%) was estimated using standard equation (Siri 1956); formula was used to calculate density (Durnin and Womersley 1974). Skeletal muscle mass (kg and %) was estimated based on standard formula (Lee et al. 2000) that has been validated by a previous study in Mexico and showed best agreement with the results obtained using dual-energy X-ray absorptiometry (DXA) (González-Mendoza et al. 2019). Somatotype rating was done using standard references (Carter and Heath 1990). Relative body size and body proportions of the participant athletes were evaluated using Phantom Z-score values (Zp scores) (Ross and Marfell-Jones 1991).

Microsoft Excel ® and SPSS (Statistical Package for Social Sciences) (Version 15.00, Chicago IL, USA) were used for data analysis and somatoplot. Anthropometric data followed the principles of normal distributions (Shapiro-Wilk test, $p>0.05$). Descriptive statistics of mean and standard deviation, Student's t-test values were calculated. One-way Analysis of Variance (ANOVA) was used to find significant differences of mean values of three independent (unrelated) groups (weight categories). Pearson's correlation coefficients were used to find association between anthropometric characteristics and somatotype. All analyses were run using a 5% significance level ($\alpha = 0.05$).

Results

The young adult judokas had mean age 22.43±1.81 years (mean value ± standard deviation); age of the athletes of different body weight categories (≤73 kg, ≤81 kg, and ≤90 kg) was not different ($p>0.05$) (Table 1).

Mean values of anthropometric characteristics of athletes (n=21) including height, skinfolds, humerus breadth, and body fat had no significant differences ($p>0.05$) among judokas of three weight categories. However, body weight, circumferences, femur breadth, BMI, HWR, and muscle mass (kg) showed significant differences of mean values among judokas of three weight categories ($p<0.05$); highest mean values were observed among judokas of ≥81 kg body weight category except HWR showing lowest value among these judoists in comparison with the peers of lightweight and half-middleweight categories.

Somatotype of the athletes (n=21) was endomorphic mesomorph (3.36-5.74-1.59); mean values showed significant differences ($p<0.05$) among weight categories: ≤73 kg (balanced mesomorph 2.82-5.11-2.36), ≤81 kg (endomorphic mesomorph 3.53-5.47-1.62), and ≤90 kg (endomorphic mesomorph 3.56-6.69-0.91) (Table 1, Figure 1).

In the sample, endomorphic mesomorph somatotype was most frequent (85.71%). Frequencies of somatotype were different in three weight categories: ≤73 kg (endomorphic mesomorph 66.7%, balanced mesomorph 33.3%), ≤81 kg (endomorphic mesomorph 87.5%, mesomorph endomorph 12.5%), and ≤90 kg (endomorphic mesomorph 100%) (Table 2, Figure 1). Percentages of BMI-based overweight (42.86%) and overweight (9.52%) in the sample were notable. Athletes of ≤73 kg had normal BMI; among other weight categories, percentages of overweight (≤81 kg 50%, ≤90 kg 71.43%) and obesity (≤90 kg 28.57%) were different. No judoka in the ≤81 kg category was obese and all athletes in ≤90 kg category were excess weight (either overweight or obese) (Table 2).

Interrelationships of BMI-based nutritional status (normal, overweight, and obesity), body fat (%) and somatotype (endomorphy, mesomorphy, ectomorphy) were tested by one-way analysis of variance (ANOVA) and Pearson correlation analysis. Mean values of body fat (%) in three levels of BMI were not significantly different ($F= 2.26$, $p=0.13$); correlation between BMI and body fat (%) was not significant ($r=0.42$, $p=0.06$). Mean values of muscle mass (%) showed significant difference at BMI levels ($F= 3.59$, $p=0.05$); BMI and muscle mass (%) had negative correlation ($r= -0.57$, $p=0.01$). Mean values of endomorphy at levels of BMI were not different ($p>0.05$) but BMI and endomorphy was correlated ($r=0.44$, $p=0.05$). BMI showed significant interrelationship ($p<0.05$) with mesomorphy (rise of mean values at elevated levels of BMI and positive correlation) and ecotomorphy (reduced mean values at elevated levels of BMI and negative correlation) (Table 3).

Relative body size and proportionality of judokas were tested using Phantom Z-scores. The Z-scores (Zp) of anthropometric parameters (body weight, MUAC relaxed and flexed, humerus breadth) were higher (positive); Zp of calf circumference (-0.02) and femur breadth (-0.20) were close to 0.5, and Z-scores of skinfolds (triceps, subscapular, supraspinale, calf) were lower (negative) (Figure 2).

Table 1. Descriptive statistics of age, anthropometric characteristics, and somatotype of male judokas (n=21).

Variables	All (n=21)	66 ≤ 73 kg (n=6)	≤ 81 kg (n=8)	≤ 90 kg (n=7)	ANOVA	
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	F	p-value
Age (years)	22.43 (1.81)	23.17 (1.61)	22.42 (2.04)	21.80 (1.70)	0.91	0.42
Body weight (kg)	78.23 (7.54)	69.23 (2.16)	77.48 (2.85)	86.81 (2.88)	69.58	**<0.0001**
Height (cm)	175.30 (4.24)	173.37 (2.42)	175.40 (4.88)	176.86 (4.56)	1.11	0.35
MUAC (cm) (relaxed)	33.87 (2.31)	32.47 (1.39)	33.21 (2.24)	35.81 (1.85)	5.76	**0.01**
MUAC (cm (flexed)	35.96 (2.58)	34.30 (1.73)	35.21 (2.31)	38.23 (2.0)	6.74	**0.01**
Mid-thigh circumference (cm)	56.0 (3.8)	52.27 (1.74)	55.71 (3.36)	59.39 (2.08)	12.34	**<0.0001**
Calf circumference (cm)	36.26 (2.20)	34.72 (0.64)	35.58 (1.97)	38.37 (1.75)	9.34	**<0.0001**
Biceps skinfold (mm)	5.29 (1.36)	5.50 (1.84)	4.92 (1.01)	5.54 (1.36)	0.45	0.64
Triceps skinfold (mm)	8.98 (2.17)	8.00 (1.67)	9.63 (2.62)	9.07 (1.97)	0.97	0.40
Subscapular skinfold (mm)	12.61 (2.76)	11.47 (2.32)	13.25 (3.54)	12.86 (2.12)	0.74	0.49
Iliac crest skinfold (mm)	14.15 (2.80)	11.90 (0.97)	14.58 (2.20)	15.59 (3.48)	3.75	**0.04**
Supraspinale skinfold (mm)	12.44 (3.67)	9.83 (1.33)	12.73 (2.47)	14.36 (5.01)	2.99	0.08
Thigh skinfold (mm)	12.2 (5.1)	11.50 (3.74)	11.60 (3.96)	13.57 (7.33)	0.34	0.72
Calf skinfold (mm)	8.34 (2.43)	6.67 (1.33)	9.73 (2.19)	8.19 (2.70)	3.38	0.06
Humerus breadth (cm)	7.08 (0.57)	6.90 (0.51)	7.18 (0.69)	7.20 (0.56)	0.63	0.54
Femur breadth (cm)	9.71 (0.66)	9.41 (0.58)	9.55 (0.68)	10.19 (0.50)	3.54	**0.05**
Body mass index (kg/m^2)	25.50 (2.56)	22.97 (0.44)	25.23 (1.59)	27.99 (2.26)	15.01	**<0.0001**
Height-to-weight ratio	40.91 (1.36)	42.32 (0.33)	40.92 (0.83)	39.69 (1.25)	13.68	**<0.0001**
Body fat (%)	15.64 (2.67)	13.65 (1.95)	16.33 (2.45)	16.55 (2.85)	2.74	0.09
MM (kg) (Lee et al., 2000)	36.6 (3.6)	33.60 (1.18)	35.26 (2.48)	40.82 (1.96)	23.73	**<0.0001**
MM (%) (Lee et al., 2000)	46.9 (3.1)	48.71 (2.49)	45.52 (2.87)	46.84 (3.23	2.06	0.16
Endomorphy	3.36 (0.66)	2.82 (0.42)	3.53 (0.62)	3.56 (0.75)	2.17	0.14
Mesomorphy	5.74 (1.0)	5.11 (0.65)	5.47 (0.71)	6.69 (0.89)	8.78	**<0.0001**
Ectomorphy	1.59 (0.84)	2.36 (0.24)	1.62 (0.79)	0.91 (0.68)	8.20	**<0.0001**

MUAC: Mid-upper arm circumference; MM: Muscle mass; SD: Standard deviation; ANOVA: One-way analysis of variance

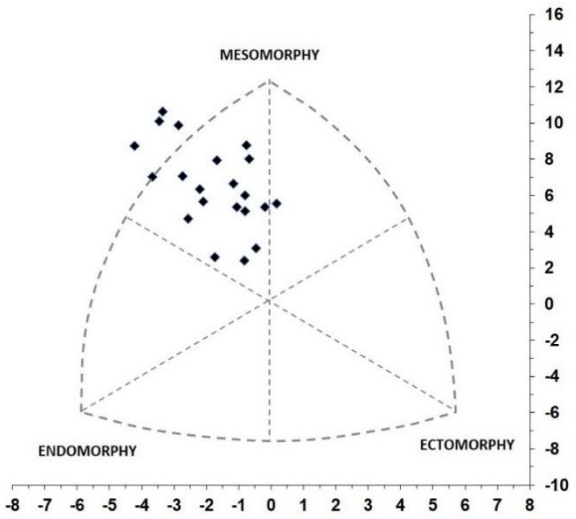

Figure 1A. Somatotype of all particpants (n=21)

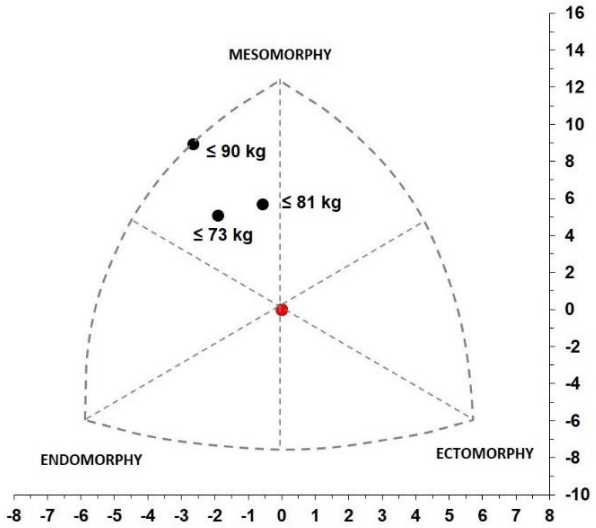

Figure 1B. Mean values of somatotype in body weight categories

Figure 1. Somatotype of adult male judokas (n=21)

Table 2. Somatotype and BMI-based nutritional status of male judokas (n=21) at body weight categories.

Somatotype and nutritional status	All (n=21)	66 ≤ 73 kg (n=6)	≤ 81 kg (n=8)	≤ 90 kg (n=7)
Endomorphic mesomorph (%)	85.71	66.70	87.50	100.0
Mesomorph endomorph (%)	4.76	0.0	12.50	0.0
Balanced mesomorph (%)	9.53	33.30	0.0	0.0
BMI-based overweight (%)	42.86	0.0	50.0	71.43
BMI-based obesity (%)	9.52	0.0	0.0	28.57

BMI: Body mass index

Table 3. Interrelationships of BMI-based nutritional status with body fat (%), and somatptype in male judokas (n=21).

BMI-based nutritional status	Body fat (%)	Muscle mass (%) (Lee et al., 2000)	Endomorphy	Mesomorphy	Ectomorphy
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Normal (n=10)	14.45 (2.40)	48.30 (2.34)	3.07 (0.52)	5.20 (0.71)	2.31 (0.39)
Overweight (n=9)	16.54 (2.67)	46.10 (2.96)	3.57 (0.71)	6.10 (1.05)	1.12 (0.41)
Obesity (n=2)	17.54 (2.37)	43.17 (3.72)	3.91 (0.59)	6.85 (0.38)	0.12 (0.03)
F (ANOVA)	2.26	3.59	2.49	4.38	38.58
p-value	0.13	0.05	0.11	**0.03**	**<0.0001**
r	0.42	-0.57	0.44	0.54	-0.96
p-value	0.06	**0.01**	0.05	**0.01**	**<0.0001**

BMI: Body mass index; SD: Standard deviation; ANOVA: One-way analysis of variance; r = Pearson Correlation coefficient

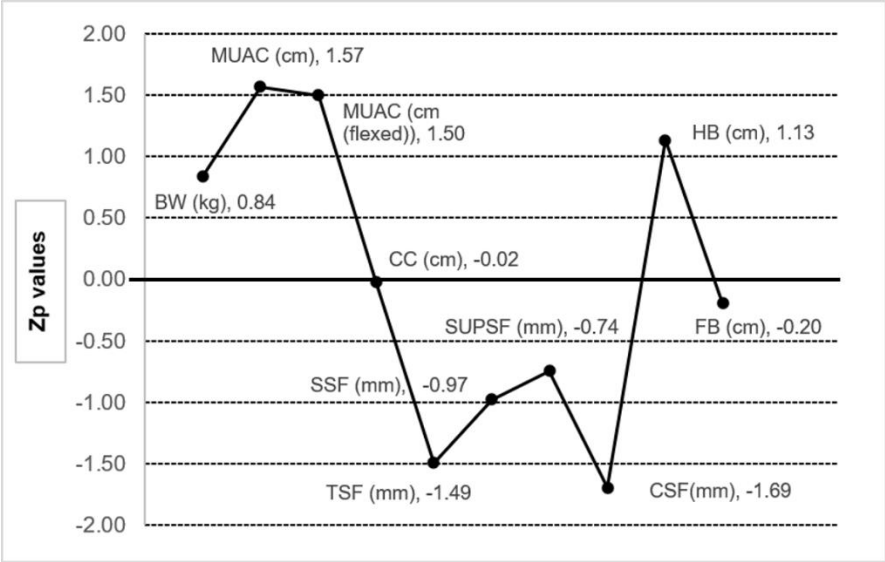

Figure 2. Relative body size of adult male judokas (n=21), with reference to Phantom z-score. (BW: Body weight; CC: Calf circumference; CSF: Calf skinfold; FB: Femur breadth; HB: humerus breadth; MUAC (flexed): Mid-upper arm circumference (flexed); MUAC: Mid-upper arm circumference (relaxed); SUPSF: Supraspinale skinfold; SSF: Subscapular skinfold; TSF: Triceps skinfold)

Discussion

Consistent rise of mean values of anthropometric characteristics of the participant judokas was observed in higher body weight categories (≤73 kg, ≤81 kg, and ≤90 kg). Therefore, it has been revealed that morphological characteristics were significantly different in three weight categories and body robusticity and muscularity increased with such levels that comply with the required physical characteristics of judokas. BMI was not found to be a reliable indicator that could not clearly distinguish between body fatness and lean mass as reported earlier (Bogin and Varela-Silva 2012).

Young adult judoists had endomorphic mesomorph somatotype; notable proportions of athletes had balanced mesomorph and mesomorph endomorph somatotypes, in the weight categories ≤73 kg (33.3%) and ≤81 kg (12.5%), respectively. In the somatoplot, body types according to the weight category were observed to be increasing as usual, ≤90 kg athletes on the top and ≤73 kg in the lowest position with ≤81 kg in the middle; three groups of athletes were in the same area (endomorphic mesomorph) (Table 2, Figure 1B). Therefore, blend of body fat mass and muscle mass was evident in the somatotype of the participant judokas with predominance of muscle component. The participant judoists were non-elite athletes according to their records despite having background of judo practice since adolescence.

In the present study, mean values of body fat (%), endomorphy, and mesomorphy consistently increased with levels of BMI (normal, overweight, obesity) with significant differences. On contrary, mean values of muscle mass (%) and ectomorphy decreased with the rise of BMI. Correlation coefficients were positive between BMI and body fat (%), endomorphy and mesomorphy; negative between BMI, muscle mass % and ectomorphy. It seems that somatotype could classify body types with higher component of relative body fat (endomorphy), muscularity (mesomorphy), and leanness (ecomorphy). It was evident that somatotype acted as a better tool to distinguish between relative body fatness and lean mass in comparison with BMI.

Body fat (%) of the young adult male judokas in the present study (15.64%) was relatively higher in comparison with the results obtained in the previous studies among male judokas from different countries. It has been reported earlier that non-elite judoists had relatively higher percentage body fat in comparison with elite athletes from same country save for a few exceptions. Judo athletes from Brazil had body fat 11.5% (Branco et al. 2013) and 13.4% (Marinho et al. 2016). Non-elite judoists from France was 12.2% body fat (Almansba et al. 2007). Elite judokas had comparatively lower body fat; studies representing different countries were France (11.1%) (Almansba et al. 2007), Poland (14.7% in ≤73 kg category, and 15.96% in ≤90kg category) (Almansba et al. 2007), Spain (7.8%) (Casals et al. 2017), Turkey (13.6%) (Ceylan et al. 2018), Iran 13.4% (Shariat et al. 2017), and

Colombia 15.2% (Monterrosa Quintero et al. 2019). The judokas in the present study had almost similar percentage body fat reported among elite judoists from Poland (Almansba et al. 2007) and Colombia (Monterrosa Quintero et al. 2019).

Somatotype of male judo athletes in the present study was enodomorphic mesomorph that matched with the somatotype of judokas reported earlier from different countries. Balanced mesomorph and ectomorphic mesomorph somatotypes were also reported from some other studies in different weight categories. Therefore, dominance of relative muscularity in the physique of judoists was evident. Elite judokas from different European countries had somatotypes: 3.5-5.9-1.8 in Poland (Lewandowska et al. 2011) and 3.29-5.23-2.88 in Serbia (Milosevic et al. 2017). Another study from Serbia reported somatotypes of non-elite judokas in different weight categories: 2.08-4.02-3.09 (–73 kg), 2.23-4.89-2.49 (–81 kg), and 2.33-5.50-1.93 (–90 kg) (Roklicer et al. 2020). A study from Montenegro, among young judokas (21.8±3.9 years of age) also reported somatotype in weight categories: 2.17-4.56-3.03 (–73 kg), 2.16-6.41-2.32 (–81 kg), and 2.29-6.24-1.82 (–90 kg) (Drapsin et al. 2020). Muscularity was observed to increase among judokas of higher body weight category. The present study conformed to the results of previous studies (Drapsin et al. 2020, Roklicer et al. 2020). The pattern of elevated relative muscularity was reported in a review of somatotype of world top judoists: 2.3-5.6-1.9 (<71 kg), 3.0-6.0-1.7 (71-86 kg), and 4.1-6.2-1.3 (>86 kg) (Claessens et al. 1987). Somatotype of elite male judokas from Iran was 4.0-4.8-2.6 (Shariat et al. 2017). Reports on somatotype of judokas in Latin American countries represented Brazil 2.9-6.4-1.9 (Marinho et al. 2016), Colombia 3.5-6.24-1.5 (elite judokas) (Monterrosa Quintero et al. 2019), and Cuba 4.57-6.16-1.5 (elite athletes) (Rodríguez 2013). In general, relatively lower percentage body fat, increased fat-free mass, and maximal strength and muscle endurance are the relevant physical conditions for mixed aerobic and anaerobic exercise by the judo athletes (Franchini et al. 2011). The non-elite male judokas in the present study showed similar endomorphic mesomorph somatotype (3.36-5.74-1.59) as reported by most of the previous studies across the world; muscularity of the judoists was also found to increase in the higher weight categories: 2.82-5.11-2.36 (≤73 kg), 3.53-5.47-1.62 (≤81 kg), and 3.56-6.69-0.91 (≤90 kg). Increase of endomorphy with weight category among judokas of the present study also matched with the findings that have been reported earlier (Claessens et al. 1987, Lewandowska et al. 2011, Roklicer et al. 2020).

Limitations

It is worthy to mention limitations of the present study. First, the sample was not representative and relatively smaller. The study design was cross-sectional in nature and did not select male judokas of other weight categories. The participant judokas in the present study were reasonably tall (175.30 cm) if we consider height of Mexican adults and particularly in Yucatan (Azcorra and Dickinson 2020, López-Alvarenga et al. 2003). There was no significant difference of mean height of judokas in three weight categories and due to that reason, HWR of judokas was lower in the increasingly higher weight categories (lightweight, half-middleweight, and middleweight). Studies reported taller and heavier judo athletes in higher weight categories (Franchini et al. 2011, 2014). However, combination of height with higher muscularity may give advantage to the jodukas; this idea will be explored in future studies where height of judokas in different weight categories will have significant difference, along with their body proportion (relative leg length, arm span ratio with height) and body composition characteristics (body fat mass and muscle mass).

Conclusions

The present study contributes important information on the physical characteristics of young adult male judokas from Yucatan, Mexico that are not commonly reported from this part of the world. Judoists of higher weight categories were taller, had relatively higher mean values of somatometric dimensions (circumferences, breadths, BMI, and muscle mass). Somatotype of the participant athletes (endomorphic mesomorph), predominant muscularity evaluated by mesomorphy and muscle mass, and relatively lower body fatness are the principal findings of the present study that matched with the previous reports from different countries. Somatotype was found to be a more reliable indicator to distinguish between body fatness and leanness in comparison with BMI.

References

Almansba, R., Franchini, E., Sterkowicz, S., (2007). An *Uchi komi* with load, a physiological approach of new special judo test proposal, *Science & Sports,* 22(5): 216–23. https://doi.org/10.1016/j.scispo.2007.06.006

Azcorra, H., Dickinson, F., (2020). Culture, Environment and Health in the Yucatán Peninsula. *Springer Cham*. https://doi.org/10.1007/978-3-030-27001-8

Bogin, B., Varela-Silva, M.I., (2012). The Body Mass Index: the good, the bad, and the horrid, *Bulletin de la Société Suisse d'Anthropologie,* 18(2): 5-11.

Branco, B.H.M., Massuca, L.M., Andreato, L.V., Marinho, B.F., Miarka, B., Monteiro, L., Franchini, E., (2013). Association between the rating perceived exertion, heart rate and blood lactate in successive judo fights (Randori), *Asian Journal of Sports Medicine,* 4: 125–130. https://doi.org/10.5812/asjsm.34494

Buśko, K., (2017). Comparison of muscle strength in male combat sport athletes, *Polish Journal of Sport and Tourism,* 23(4): 186-189. https://doi.org/10.1515/pjst-2016-0024

Carter, J.E.L., Heath, B.H., (1990). Somatotyping - Development and Applications, *Cambridge University Press,* United Kingdom

Casals, C., Huertas, J.R., Franchini, E., Sterkowicz-Przybycien, K., Sterkowicz, S., Gutierrez-Garcia, C., Escobar-Molina, R., (2017). Special judo fitness test level and anthropometric profile of elite Spanish judo athletes. *Journal of Strength and Conditioning Research,* (31)5: 1229-1235. https://doi.org/10.1519/JSC.0000000000001261

Ceylan, B., Gurses, V.V., Akgul, M.S., Baydil, B., Franchini, E., (2018). Anthropometric profile, wingate performance and special judo fitness levels of Turkish Olympic judo athletes, *Ido Movement for Culture. Journal of Martial Arts Anthropology,* 18(3): 15-20. https://doi.org/10.14589/ido.18.3.3

Claessens, A., Beunen, G., Wellens, R., Geldof, G., (1987). Somatotype and body structure of world top judoists, *Journal of Sports Medicine and Physical Fitness,* 27: 105–113. https://pubmed.ncbi.nlm.nih.gov/3599963/

CONADE (2020). Reglamento General de Participación de los Nacionales CONADE y Nacionales CONADE del Deporte Adaptado 2020. *Comisión Nacional de Cultura Física y Deporte,* Mexico

Drapsin, M., Bojanic, D., Ljubojevic, M., Sadri, F., Jaksic, D., Trivic, T., Drid, P., (2020). Somatotype profiles of male and female Montenegrin judokas, *International Journal of Morphology,* 38(5): 1244-1249. https://doi.org/10.4067/S0717-95022020000501244

Drid, P., Casals, C., Mekic, A., Radjo, I., Stojanovic, M., Ostojic, S.M., (2015). Fitness and anthropometric profiles of international vs. national judo medalists in half-heavyweight category, *Journal of Strength and Conditioning Research,* 29(8): 2115-2121. https://doi.org/10.1519/JSC.0000000000000861

Durnin, J.V.G.A., Womersley, J., (1974). Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 Years, *British Journal of Nutrition,* 32(1): 77-97. https://doi.org/10.1079/BJN19740060

Esparza-Ros, F., Vaquero-Cristóbal, R., Marfell-Jones, M., (2019). International Standards for Anthropometric Assessment, *International Society for the Advancement of Kinanthropometry*, Wellington, New Zealand.

Franchini, E., Del Vecchio, F.B., Matsushigue, K.A., Artioli, G.G. (2011). Physiological profiles of elite judo athletes, *Sports Medicine,* 41(2): 147-66. https://doi.org/10.2165/11538580-000000000-00000

Franchini, E., Sterkowicz-Przybycien K., Takito M.Y., (2014). Anthropometrical profile of judo athletes: Comparative analysis between weight categories, *International Journal of Morphology,* 32(1): 36-42. https://doi.org/10.4067/S0717-95022014000100007

González-Mendoza, R.G., Gaytán-González, A., Jiménez-Alvarado, J.A., Villegas-Balcázar, M., Jáuregui-Ulloa, E.E., Torres-Naranjo, F., López-Taylor, J.R., (2019). Accuracy of anthropometric equations to estimate DXA-derived skeletal muscle mass in professional male soccer players, *Journal of Sports Medicine (Hindawi Publishing Corporation),* 2019: 4387636. https://doi.org/10.1155/2019/4387636

IJF., (2018). Sports and Organizing Rules. *International Judo Federation*. Switzerland.

Lee, R.C., Wang, Z., Heo, M., Ross, R., Janssen, I., Heymsfield, S.B., (2000). Total-body skeletal muscle mass: development and cross-validation of anthropometric prediction models, *American Journal of Clinical Nutrition,* 72(3): 796-803. https://doi.org/10.1093/ajcn/72.3.796

Lewandowska, J., Buśko, K., Pastuszak, A., Boguszewska, K., (2011). Somatotype variables related to muscle torque and power in judoists, *Journal of Human Kinetics,* 30(2011): 21-28. https://doi.org/10.2478/v10078-011-0069-y

López-Alvarenga, J.C., Montesinos-Cabrera, R.A., Velázquez-Alva, C., González-Barranco, J., (2003). Short stature is related to high body fat composition despite body mass index in a Mexican population, *Archives of Medical Research,* 34(2):137-40. https://doi.org/10.1016/S0188-4409(03)00002-X.

Marinho B., Follmer B., Esteves J.V., Andreato L.V. (2016). Body composition, somatotype, and physical fitness of mixed martial arts athletes, *Sport Sciences for Health,* 12: 157-165. https://doi.org/10.1007/s11332-016-0270-4

Milosevic N., Mekic A., Stankovic N., Purenovic-Ivanovic T.P, (2016). Somatotype of top Serbian judokas, *Homo Sporticus,* 2: 24-27.

Monterrosa Quintero, A., Orssatto, L.B.R., Pulgarín, R.D., Follmer, B., (2019). Physical Performance, Body Composition and Somatotype in Colombian Judo Athletes. *Ido Movement for Culture, Journal of Martial Arts Anthropology,* 19(2): 56-63. https://doi.org/10.14589/ido.19.2.8

Rodríguez, G.A., (2013). Judokas anthropometric profile of elite and youth in combat mode. *Revista Iberoamericana de Ciencias de la Actividad Física y el Deporte (Riccafd),* 2(2): 16-27. https://doi.org/10.24310/riccafd.2013.v2i2.6198

Roklicer, R., Atanasov, D., Sadri, F., Jahić, D., Bojanić, D., Ljubojević, M., Trivic, T., Drid, P., (2020). Somatotype of male and female judokas according to weight categories, *Biomedical Human Kinetics,* 12(1): 34-40. https://doi.org/10.2478/bhk-2020-0005

Ross, W.D., Marfell-Jones, M.J., (1991). Kinanthropometry. In: J.D. MacDougall, H.A. Wenger, H.J. Green, (Eds.), *Physiological Testing of the High-performance Athlete,* Human Kinetics Books, Champaign

Secretaria de Salud. (2019). Prevención y Control de la Obesidad y Riesgo Cardiovascular, Programa Sectorial de Salud 2013-2018. *Government of Mexico,* Mexico City.

Shariat A., Shaw B.S., Kargarfard M., Shaw I., Lam E.T.C., (2017). Kinanthropometric attributes of elite male judo, karate and taekwondo athletes, *Revista Brasileira de Medicina do Esporte,* 23(4): 260-263. https://doi.org/10.1590/1517-869220172304175654

Siri, W.E., (1956). Body composition from fluid spaces and density, *University of California Radiation Laboratory*, California.

Sterkowicz-Przybycień, K., Błach, W., Żarów, R., (2012). Somatotype components in judoists, Journal of Combat Sports and Martial Arts, 2(2): 73-78.

WHO. (1995). Committee Physical Status: The Use and Interpretation of Anthropometry, WHO Technical Report Series, 854.

Funding

The study received institutional financial assistance for fieldwork. However, no fund is available for publication.

Acknowledgements

The work was an extension of a research project of Ms. Mariana Margarita Torres Arroyo for her master's thesis and approval of institutional bioethics committee had folio number 047/2017. The protocol of research project was also connected to a doctoral thesis of Ms. Ana María del Mar Concha Viera. Approval of the authorities of the *Universidad Modelo* and of the private training centers were taken before commencement of the study. Informed Consent Statement was obtained from each participant. The author is thankful to Ms. Alejandra Itzel Nudel Ontiveros for her partial assistance in data collection and to Mr. Lindsay Edwards for the revision of English language of the manuscript.

Conflicts of Interest

The Authors declares no potential conflicts of interest in connection with this research.

About the License