Anthropometric profile and estimation of competition weight in elite judokas of both genders

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Summary

Introduction: The aim of the research is to define the anthropometric profile of judokas by gender and weight categories and to estimate the most suitable competition weight according to their physical constitution using regression equations.
Methods: An cross-sectional retrospective anthropometric study was carried out on three hundred and eighteen judokas when their weight was no more than 5% over the limit stipulated for their category, 187 males and 131 females, in all seven weight categories; mean age was 22.5±3.4 years (18-37 years). The anthropometric profile included forty-two direct variables. Their body composition was assessed by estimating the percentage of fat, muscle mass and theoretical minimal weight (TMW) and somatotype. Multiple linear regression equations were developed with each type of variable (lengths, breadths, girths) and in combination as predictors of body weight.
Results: Significant differences ($p<0.05$) were established in the anthropometric profile between the male and female samples and between the different weight categories whithin each gender. Only 2.4% of the judokas were at their TMW at the moment of the study. In males, height and 4 breadths (A-P chest, biiliocristal, femur and bimalleolar) explained 86.8% of the weight variation and 98.3% when girths were added, with an SEE of 4.2 and 1.5 kg, respectively. Among women, height and 3 breadths (A-P chest, biacromial and femur) gave 87.3% and, with girths, 97.9%, with an SEE of 3.3 and 1.3 kg, respectively.
Conclusions: In competition, judokas do not reduce the percentage of fat to the minimum and will lose weight at the expense of lean component. The regression equations developed may be useful to advise the most suitable weight category according to the anthropometric characteristics.

Key words:
Judo. Weight loss. Minimal weight. Anthropometry. Regression analysis.

Perfil antropométrico y estimación del peso de competición en judocas de elite de ambos sexos

Resumen

Introducción: Definir el perfil antropométrico del judoca por sexos y categorías de peso y estimar el peso de competición más adecuado según la constitución física mediante ecuaciones de regresión.
Métodos: Se realizó un estudio retrospectivo del control antropométrico de trescientos dieciocho judocas cuando su peso no excedía al 5 % del estipulado para su categoría, incluyendo 187 varones y 131 mujeres, de las siete categorías de peso, edad media de 22,5±3,4 años (18-37 años). El perfil antropométrico incluyo cuarenta y dos variables directas. Se valoró la composición corporal, estimándose el porcentaje de grasa, la masa muscular y el peso mínimo teórico (PMT) y el somatotipo. Se desarrollaron las ecuaciones de regresión lineal múltiple con cada tipo de variable (longitudes, diámetros, perímetros) y en combinación como variables predictoras del peso corporal.
Resultados: Se establecieron diferencias significativas ($p<0,05$) en el perfil antropométrico entre las muestras masculina y femenina y dentro de cada sexo entre las diferentes categorías de peso. Sólo el 2,4% de los judocas se encontraba en el PMT en el momento del estudio. En varones, la talla y 4 diámetros (A-P de tórax, biiliocrestal, fémur y bimaleolar) explicaron el 86,8% de la variación del peso y añadiendo perímetros el 98,3%, con un Se de 4,2 y 1,5 kg respectivamente. En las mujeres, talla y 3 diámetros (A-P de tórax, biacromial and fémur) el 87,3% y con perímetros el 97,9 %, con un Se de 3,3 y 1,3 kg respectivamente.
Conclusiones: El judoca en competición no baja al porcentaje de grasa mínimo y perderá peso a expensas del componente magro. Las ecuaciones de regresión desarrolladas pueden servir para aconsejar según las características antropométricas la categoría de peso más adecuada.

Palabras clave:
Judo. Pérdida de peso. Peso mínimo. Antropometría. Análisis de regresión.

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Introduction

Weight categories have been established in combat sports in order to promote balanced competition for athletes of different sizes and to ensure the safety of participants. The athletes wish to lower their body weight as far as possible to compete in a lower weight category and thus have an advantage. Because of this, very serious health problems sometimes arise, as the fast weight loss methods to reach that minimum often use different techniques that produce dehydration and consequential hyperthermia.

In the United States, following three cases of deaths among wrestlers in 1977, the National College Athletics Association (NCAA)[1], began a programme involving professionals at all levels. The measures adopted include the establishment, at the start of the season, of the weight category in which each wrestler can compete according to their physique.

In judo, competitions are divided into seven weight categories, with differences in both functional capacity and body composition as well as in technical-tactical aspects between competitors in different categories[2-4]. Effective bout time is 4 minutes, with predominance of the oxidative system, although decisive actions will depend on the anaerobic system[5-7]. Their physical condition will require high values of maximum strength, aerobic and anaerobic capacity[3,8,9].

The body composition of judokas is of great importance not only to achieve those functional capacities but also to conform to the most suitable weight category. In judo competition is, the official weigh-in takes place the day before the bout, and random controls may be carried out subsequently, at which up to 5% more than the wait for the category is allowed[10]. In principle, this would give more margin for athletes to think about the possibility of compensating their dehydration and the loss of energy deposits and facilitate fast weight loss practices. In 2010, Artioli *et al.* proposed a regulation for judo similar to that of wrestling (NCAA) incorporating a hydration test at the official weigh-in prior to the bout[11].

The aim of our study was to define anthropometric profiles of judokas for each weight category, both males and females, and to develop regression equations in order to estimate body weight based on anthropometric variables in order to provide guidance about the most suitable weight category according to their physique.

Material and method

A retrospective study was conducted on the judokas attending for assessment between 1993 and 2016, including Caucasians over 18 years of age. For each judoka, the control at which his or her body weight was closest to the competition category weight was chosen. Subsequently, we excluded those with the body weight more than 5% above that of the category. The sample finally comprised 318 athletes, 187 males (V) and 131 females (M), with a mean age of 22.5 ±3.4 years (18 37 years), in training for 12.2±5.1 years for 5.4±0.8 days a week and 3.2±1 hours a day at the moment of the study. Their distribution by categories was as follows: males < 60 kg (V1, n=28), < 66 kg (V2, n=33), < 73 kg (V3, n=42), < 81 kg (V4, n=32), < 90 kg (V5, n=25), < 100 kg (V6, n=14), > 100 kg (V7, n=13); females: < 48 kg (M1, n=24), < 52 kg (M2, n=19), < 57 kg (M3, n=18), < 63 kg (M4, n=30), < 70 kg (M5, n=23), < 78 kg (M6, n=8), >78 kg (M7, n=9).

The protocol included 42 variables: general measurements (weight, height, sitting height and arm span), girths (head, neck, shoulders, chest, waist, hip, arm relaxed, arm flexed and tensed, forearm, wrist, thigh, mid-thigh, calf and ankle), bone breadths (biacromial, A-P chest depth and transverse chest, biiliocrestal, bitrochanteric, bi-styloid wrist, biepicondylar humerus, biepicondylar femur, bimalleolar ankle), lengths (upper arm, forearm, hand, thigh, tibial height, and foot) and skinfolds (pectoral, iliac crest, supraspinal, abdominal, subscapular, biceps, triceps, front thigh and medial calf).

The material used was: scales, Seca brand; stadiometer, measuring table for seated position, bone calibrator and body fat calliper, Holtain brand; large calliper with curved arms and anthropometer from GPM Siber Hegner Machinery Limited; and an anthropometry tape, Rosscraft brand. The anthropometrist, qualified to level III by the ISAK (International Society for the Advancement of Kinanthropometry), observed this society's standards[12], except for the variables of shoulders[13] and mid-thigh girth[14].

The body composition was assessed by means of: skinfold profile; sum of 8 skinfolds (all those in the protocol except for the pectoral skinfold); percentage of fat estimated using modified equations by Lohman[15] (males), Slaughter[16] (females) and Withers[17] (both samples), fat weight; lean or fat-free weight; muscle mass using Lee's equation[14] (% and kg/m^2); and muscular cross-sectional areas (CSA), arm, thigh and calf, using Heymesfield equations[18]. The theoretic minimal weight (TMW)[19] was estimated and set, in males, for a 7% fat percentage according to Lohman's equation and 14% in females using Slaughter's equation. The somatotype was calculated using the Heath-Carter method[20].

Prior to the study, athletes signed an informed consent form and the work was conducted in accordance with the ethical standards of the Helsinki Declaration.

In order to determine the difference between genders, the Mann-Whitney U test was applied. Comparison between weight categories was by ANOVA (Tukey HSD subsets). The correlation and linear regression (stepwise method) was analysed for each gender between the weight and the rest of the anthropometric variables, excluding athletes in the last category (>78 kg and >100 kg). Values were considered statistically significant with a $p \leq 0.05$. The software used was Excel and SPSS Statistics.

Results

Body composition and somatotype are shown in Tables 1 and 2. Male judokas have a lower value for the skinfold profile, sum of skinfolds, percentage of fat and fat weight; and a larger height, weight, lean and muscular component both in percentage terms and in kg/m^2 than the females ($p = 0.015$ in subscapular skinfold, $p = 0.002$ in pectoral skinfold and $p < 0.0001$ in the rest of the variables).

In the comparison by weight categories for both the male and the female samples, there are significant differences $p < 0.0001$ in body composition. In terms of skinfolds, the greatest differences between groups were established in the supraspinal and abdominal skinfolds of males; and the least difference was seen in the medial calf. In the case of the women, however, the differences established were smaller due to the greater range in each category, with those in M7 always showing higher values that significantly differentiated them from the rest (except with V6 in the whole profile and V5 in the values for the lower limbs). In terms of fat percentages, four sub-groups can be established among the males (V1-V4, V3-V5, V6, and V7) and three among the women (V1-V4, V4-V6, and V7). In terms of lean weight, there are as many subgroups defined as there are weight categories in both the male and female samples. And with respect to muscle weight kg/m^2, three subgroups existed in males (V1-V3, V3-V6, V7) and in females (V1-V5, V3-V6, V6-V7).

Muscle development at the level of the arm, thigh and calf (CSA) was greater in males ($p < 0.0001$) compared to females. By weight category, the CSA also gave significant differences ($p < 0.0001$) in each sample. The CSA values in males indicate that judokas in one category may have similar values to those of the category immediately below them. In women, however, there is more overlap between groups, with coincidences in more than two categories.

The mean somatotype for judokas was dominant mesomorphic located in balanced mesomorph in males and in endomorphic mesomorph in females. Males had a lower endomorphic component and a larger mesomorphic component than females ($p < 0.0001$), with similar levels of ectomorphism. By weight categories, the judoka somatotype is fundamentally different if the extreme categories are compared. In males, endomorphism was greater in V6 V7; mesomorphism was lower in V1 V3; and ectomorphism was less in V4 V7 and greater in V1 V2. Three categories were classified as balanced mesomorph (V1, V3 and V4), two as ectomorphic mesomorph (V2 and V5) and two as endomorphic mesomorph (V6 and V7). Among the females, endomorphism and mesomorphism were greater in V7; and ectomorphism lower in V6 V7. Endomorphic mesomorph occurred in five categories (V1, V4 V7) and balanced mesomorph in two (V2 and V3). The somatocharts (Figure 1) represent the mean somatotype and the somatotype for each weight category in both samples.

Table 3 shows the estimated TMW if the judokas had the theoretical minimum body fat percentage and maintained their current lean weight; and the difference in this value with its real weight, in absolute terms (kg) and as a percentage.

The correlation between the bodyweight and the rest of the direct variables was significant with $p<0.0001$, except for pectoral skinfold (0.05) and biceps (0.01) in the women. The greatest correlation in lengths was height (R♂= 0.840 and R♀= 0.847). In bone breadths, biepicondylar femur (R♂= 0.800 and R♀= 0.826). In girths, hip girth (R♂= 0.913 and R♀= 0.910). Lastly, in skinfolds, the coefficients are lower with the largest among males being abdominal (R♂= 0.590) and triceps among women (R♀= 0.470).

If we estimate bodyweight by simple regression exclusively on the basis of height (in cm), weight (kg) is found to be equal to:

Males: (height*1.230) - 141.250 (R^2=0.706, SEE=6.2 kg).

Females: (height*1.004) - 104.187 (R^2=0.718, SEE=4.8 kg).

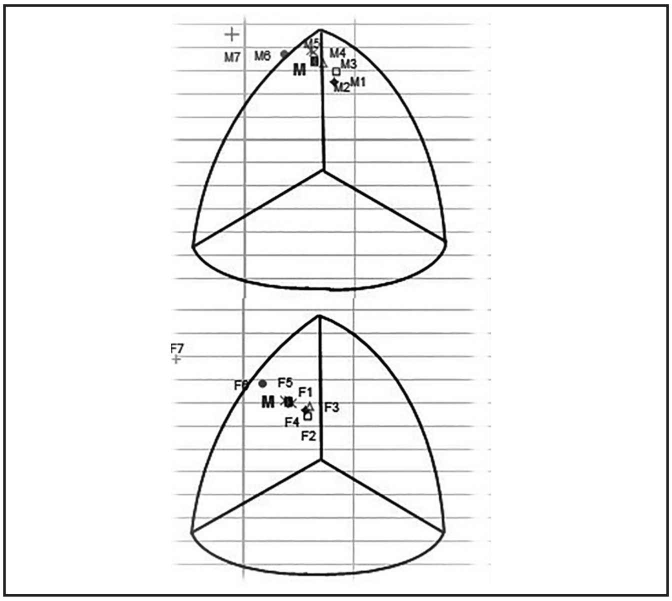
Tables 4 and 5 show the different multiple linear regression models, first independently with each type of variable (lengths, breadths, girths) and then combining them by selecting those with the lowest estimation

Table 1. Body composition and somatotype in the total male sample and by weight categories (m±SD).

	Total n =187	-60 kg n= 28	-66 kg n = 33	-73 kg n = 42	-81 kg n =32	-90 kg n =25	-100 kg n =14	+100 kg n =13
Weight (kg)	78.9±15.7	60.9±1.2	66.9±1.2	73.5±1.9	80.6±1.9	90.1±2	98.4±3	118.7±8.4
Height (cm)	177.6±8.6	166.5±4.2	172.5±5.6	175.2±3.5	178.8±3.6	185.4±3.6	188.7±4.6	191.9±4.3
Profile Skinfolds (mm)								
Chest	5.2±2.2	4.2±0.7	4.1±0.7	4.7±0.9	4.8±0.9	5.4±1.4	6.3±1.4	10.6±4.4
Iliac crest	10.3±6.1	7.4±2.2	7.1±1.9	8.7±2.4	9.3±2.8	10.6±3.1	15.4±5.9	26.5±8.9
Supraspinale	7.8±4.4	5.8±1.2	5.6±1.0	6.4±1	7±1.6	7.9±2.5	11.1±4	20±7.3
Abdominal	10.6±7.2	6.9±2.0	6.8±1.9	8.2±2.6	9.3±2.9	11.4±5.1	16.9±6.6	30.9±7.3
Subscapular	9.9±3.9	8.2±1.6	7.8±1.7	8.6±1.5	9.3±1.2	10.1±2.2	13.6±3.1	20±6.1
Biceps	3.7±1.3	3.2±0.5	3.1±0.4	3.4±0.5	3.6±0.4	3.9±0.6	3.8±0.5	7.2±2.8
Triceps	7.8±3.5	6.3±1.4	6.1±1.4	7±1.6	7.5±2	7.6±1.5	10.6±3.1	16.2±6.2
Front thigh	10.3±4.6	8.1±1.8	8.2±1.9	9.1±2.5	9.5±2.3	11.2±3	13.4±3.6	21.7±8.1
Medial calf	7.1±4.1	5.6±1.2	5.6±1.5	5.8±1.3	6.5±1.8	6.8±2.1	9.2±4	17.4±8.7
∑ 8 Skinfolds (mm)	67.5±32.3	51.6±9.8	50.3±9.2	57.2±10	61.9±12.2	69.7±16.8	93.8±22.3	160±44.5
% fat by E. Lohman	10.9±4.1	8.9±1.3	8.6±1.3	9.6±1.5	10.3±1.7	11.2±2.4	14.8±3.2	22.5±4.7
Minimum weight from the Lohman (kg)	75±11.6	59.6±1.4	65.7±1.5	71.4±2.1	77.8±2.4	86±2.8	90.2±4.4	98.7±6.1
% fat by E. Withers	10.1±4.7	7.9±1.3	7.7±1.3	8.6±1.4	9.3±1.8	10.4±2.4	13.8±3.1	23.6±7
Fat weight by E. Withers (kg)	8.6±6.6	4.8±0.8	5.1±0.9	6.3±1.1	7.5±1.4	9.4±2.2	13.5±3.1	28.3±10
Lean weight by E. Withers (kg)	70.3±10.7	56.1±1.3	61.7±1.3	67.2±1.9	73.1±2.3	80.8±2.6	84.9±4	90.4±7.4
Muscle mass. % by E. Lee	46.6±3.3	49.6±2.0	48.4±2.1	47.5±2	46.5±1.9	45.3±1.7	43.3±2.4	39.8±4.4
Muscle mass. kg/m^2 by E. Lee	11.5±1.0	10.9±0.7	10.9±0.9	11.4±0.8	11.7±0.6	11.9±0.7	12±0.9	12.8±1.6
Cross-sectional areas (cm^2)								
CSA Arm	67.8±13.5	53.1±5.5	57.2±6.6	65.3±7	71.1±7.7	78.7±6.1	81.2±10	90.9±15.2
CSA Thigh	205.1±33.4	171.2±15.0	182.6±16.7	196.2±16.7	209.8±14	225.8±19.4	238.6±23.4	276.4±33
CSA Calf	103.7±16.0	86.7±8.3	93.6±8.2	99±8	108.1±8.1	114.6±8	119±10.7	132.6±21.8
Somatotype								
Endomorphy	2.4±1.0	2±0.5	1.8±0.5	2.1±0.4	2.2±0.5	2.3±0.6	3.2±0.8	4.9±1.3
Mesomorphy	6.4±1.0	5.7±0.7	5.9±1.0	6.2±0.9	6.6±0.7	6.7±0.7	6.8±0.9	8±1.2
Ectomorrphy	1.9±0.9	2.4±0.7	2.5±1.0	2±0.6	1.7±0.5	1.7±0.6	1.4±0.6	0.5±0.4

Significant between-group differences, $p < 0.0001$.

Figure 1. Somatochart. M, sample mean. Distribution from seven weight categories: M1-M7 males and F1-F7 females.



error. In the male sample, height and 4 breadths (A-P chest, biiliocristal, femur and bimalleolar) explain 86.8% of the variation in weight and 98.3% when girths are added, with an SEE of 4.2 and 1.5 kg respectively. In the female sample, height and 3 breadths (A-P chest, biacromial and femur) explain 87.3% and 97.9% when girths are added, with an SEE of 3.3 and 1.3 kg respectively.

Discussion

The study has been conducted on a wide sample of male and female judokas representing the different weight categories, all members of high-level Spanish teams and while they were at competition weight. The sample included finalists from the Olympic Games, World and European Championships[21]. The anthropometric profile for the valuation of judokas by genders and weight categories is provided as a reference. There is sexual dimorphism and intra-category dimorphism in the anthropometric characteristics of judokas as has been mentioned by other authors. Furthermore, these differences are reflected both in the competition and in judo fitness tests[22-26].

As judo is a sport in which competitors are divided by weight categories, it is necessary to identify the most appropriate weight for each participant. In practice, the tendency is to choose the lowest possible bodyweight in order to maximize the advantages potentially provided by a greater physique and muscle mass. In judo, methods for fast weight loss are extremely prevalent[27-30] and may affect both health and performance[31-34]. In order to determine the athletes' weight category, use is often made of the theoretical minimal weight (TMW)

Table 2. Body composition and somatotype in the total female sample and by weight categories (m±SD).

	Total n =131	-48 kg n= 24	-52 kg n = 19	-57 kg n = 18	-63 kg n =30	-70 kg n =23	-78 kg n =8	+78 kg n =9
Weight (kg)	62.4±12.1	48.8±1.1	52.8±0.9	57.2±1.2	63±1.6	70.5±1	78.4±1.8	92.6±5.5
Height (cm)	164.3±7.7	154.1±3.4	158.6±4.3	162.9±3.6	166.3±3	171.7±5	173.8±5.1	172.5±3.4
Profile Skinfolds (mm)								
Chest	5.8±2.4	4.8±1.1	5±1.7	5.3±1.5	5.5±1.4	5.6±1.4	6±1	12.2±3.2
Iliac crest	12.2±6.0	9.2±2.6	9.3±3.4	9.4±3.2	12.3±3.6	12.5±4.4	14.9±4.6	28.3±5.4
Supraspinale	9.3±5.0	7.1±1.7	7.1±2.2	7.3±2.2	8.5±3	9.6±3.5	11.1±3.1	23.7±5.7
Abdominal	13.5±7.4	9.7±3.4	10.3±3.8	10.7±4.4	12.6±4.7	15.2±7.3	16.7±6.9	31±7.2
Subscapular	11.1±5.5	9.2±3.1	8.7±2	8.5±1.4	10.7±2.2	11.1±3.1	12.8±3.7	27.2±7.6
Biceps	5.0±2.2	4.2±1.3	4.5±1.3	4.4±1	4.9±1.2	4.4±1	6.2±2.7	10.2±4
Triceps	13.7±5.6	10.8±3.2	11.2±3.7	11.2±2.5	13.4±2.7	14.4±4	16.6±5.3	28.1±6.2
Front thigh	20.7±7.6	16.4±5.6	18.2±5.3	17.4±4	20.6±4.3	22.7±5.9	23±7.3	38±9.4
Medial calf	12.7±5.8	9.7±3.4	10.5±3.7	10.1±2.5	12.1±2.8	13.6±4.4	16.1±5.7	26.7±8.1
∑ 8 Skinfolds (mm)	98.2±39.9	76.2±17.7	79.8±22.4	79±14	95.2±15.8	103.4±22.8	117.3±33	213.3±40.6
% fat by E. Slaughter	21.8±6.6	18.6±3.5	18.5±4	18.5±2.7	21.8±2.8	22.5±4.3	25±5.3	39.9±7.1
Minimum weight from the Slaughter (kg)	56.1±7.5	46.2±2	50±2.4	54.2±2.2	57.3±2.3	63.5±3.5	68.3±3.8	64.5±6.1
% fat by E. Withers	18.7±4.8	15.9±3	16.1±3.6	16.2±2.3	18.8±2.2	19.7±3.6	21.8±4.3	31±3.2
Fat weight by E. Withers (kg)	12.1±5.7	7.8±1.5	8.5±2	9.2±1.3	11.9±1.5	13.9±2.6	17.1±3.6	28.8±4.4
Lean weight by E. Withers (kg)	50.3±7.3	41.1±1.6	44.3±1.8	47.9±1.7	51.2±1.8	56.6±2.6	61.3±2.4	63.8±2.9
Muscle mass % by E. Lee	40.9±3.6	44±2.4	41.8±2.9	42.8±1.9	41.1±1.9	39.2±2.5	37.9±2.5	33±2.4
Muscle mass kg/m^2 by E. Lee	9.3±0.7	9.1±0.7	8.8±0.5	9.2±0.6	9.4±0.8	9.4±0.7	9.8±0.4	10.3±0.7
Cross-sectional areas (cm^2)								
CSA Arm	46.4±9.1	38.5±4.3	38.9±6	45.1±5.7	47.5±7.8	51.4±7	58.3±5.9	58.6±7.3
CSA Thigh	156.5±25.1	135.2±13.9	136.1±10.8	152.0±14.1	158.6±17.1	163.4±14.5	193.1±9.1	208.3±19.7
CSA Calf	81.7±12.3	70.4±7.7	70.6±7.4	79.2±7.9	85.4±7.2	90.0±10.2	91.3±9.7	97.6±11.8
Somatotype[18]								
Endomorphy	3.5±1.3	3.0±0.7	2.9±0.9	2.9±0.6	3.4±0.7	3.5±0.9	4.0±1.1	7.0±1.2
Mesomorphy	5.2±1.1	4.8±0.7	4.5±0.7	4.9±0.9	5.2±0.8	5.2±0.9	5.8±1.1	7.8±1.2
Ectomorrphy	2.0±0.9	2.3±0.6	2.4±0.8	2.4±0.7	2.0±0.6	1.9±0.8	1.3±0.9	0.3±0.3

Significant between-group differences, $p < 0.0001$.

Table 3.Theoretical minimal weight (mean±SD).

Weight categories	n	TMW kg	Difference BW – TMW kg (%)	range (kg)
M 1 - 60 kg	28	59.6±1.4	1.2±0.9 (2)	-0.3 ; 3.4
M 2 - 66 kg	33	65.7±1.5	1.2±1.0 (1.8)	0.0 ; 3.7
M 3 - 73 kg	42	71.4±2.1	2.0±1.2 (2.8)	0.3 ; 6.2
M 4 - 81 kg	32	77.8±2.4	2.8±1.4 (3.5)	0.8 ; 5.9
M 5 - 90 kg	25	86.0±2.8	4.1±2.4 (4.5)	0.7 ; 8.9
M 6 -100 kg	14	90.2±4.4	8.3±3.4 (8.3)	2.8 ; 13.7
F 1 - 48 kg	24	46.2±2.0	2.6±2.0 (5.4)	-0.6 ; 6.6
F 2 - 52 kg	19	50.0±2.4	2.8±2.4 (5.3)	-1.0 ; 8.4
F 3 - 57 kg	18	54.2±2.2	3.0±1.8 (5.3)	0.1 ; 6.1
F 4 - 63 kg	30	57.3±2.3	5.7±2.1 (9.1)	1.1 ; 9.5
F 5 - 70 kg	23	63.5±3.5	7.0±3.5 (10.0)	-0.6 ; 12.1
F 6 - 78 kg	8	68.3±3.8	10.1±5.0 (12.9)	0.6 ; 17.1

M: males; F: females; TMW: theoretical minimal weight; BW: body weight.
The estimate of minimal weight through percent fat. In males, the modified Lohman equation (7%); and in females, the Slaughter equation (14%).

defined as the bodyweight at which the fat percentage is as close to the minimum possible without harmful effect on health[35]. This is calculated by performing a body composition study in which the fat-free component is assumed to remain stable compared to a fatty component that will be reduced to the minimum required. However, TMW is rarely achieved with the percentage of fat with which it was estimated as only some athletes in fact come down to those body fat ranges (5-7% in males; 12-14% in females)[19] therefore, after that weight is achieved, if we were to determine the body composition, we would verify that the lean component has also been diminished. In our sample, only one male (0.6%) obtained values of less than 7% of fat and only six women (4.9%) less than 14%. The most frequent percentage falls between 7 and 11% of fat among males and between 18 and 22% in females. For this reason, it is common in judo to be above the TMW, with this difference increasing as athletes move up through weight categories, and larger among the female sample.

Another way to determine weight was proposed by Tcheng and Tipton[36] in 1973 and was subsequently modified by Oppliger and Tipton[37]. These authors developed anthropometric equations to estimate TMW in wrestlers, relating their weight to height along with bone breadths ($R^2 = 0.852$, SD = 4.04 kg) or adding thigh girth ($R^2 = 0.953$, SEE = 2.36 kg). For our study on judokas, we have included additional anthropometric variables (forty-one compared to the fifteen of the previous authors), and have obtained lower estimation errors.

Bone structure as determined by height, lengths and bone breadths in both the trunk and the limbs after growth has finished in an adult athlete conforms the frame size and this does not change through training, therefore estimation equations based on this will give us an initial approach about judokas' competition weight, explaining around 87% of its variability. In men, the estimated weight is more related to the width of the pelvis and in women with the width of the shoulders. And in both genders with the depth of the thorax and the width of the knee.

The equations developed with inclusion of girths are the ones that determine the bodyweight of judokas with fewest errors. There is some discussion as to whether the girth is a measure that includes subcutaneous fat and this might be overvalued in the case of athletes with a greater adipose panicles, which might be lost in order to reduce weight.

Table 4. Multiple stepwise regressions to estimate body weight. Males.

Variables	Weight	R^2	SEE
L	-141.915 + (Tibial height 1.416) + (Sitting height 0.987) + (Foot length 2.268)	0.764	5.6
B	-130.229 + (A-p chest depth 1.846) + (Bimalleolar 5.736) + (Biiliocristal 1.444) + (Humerus 4.094) + (Biacromial 0.730) + (Femur 2.611)	0.844	4.6
G	-149.672 + (Hip 0.665) + (Chest 0.177) + (Calf 0.767) + (Wrist 1.281) + (Head 0.495) + (Waist 0.283) + (Shoulders 0.219) + (Armflexed and tensed 0.454)	0.949	2.6
H,B	-145.285 + (Height 0.512) + (A-P Chest 1.862) + (Biiliocristal 1.160) + (Bimalleolar 4.515) + (Femur 2.661)	0.868	4.2
H,G	-164.304 + (Height 0.493) + (Waist 0.345) + (Mild-Thigh 0.400) + (Forearm 0.787) + (Hip 0.213) + (Chest 0.180) + (thigh 0.264) + (Calf 0.276) + (Head 0.298)	0.983	1.5
H,B,G	-164.610 + (Height 0.479) + (G. waist 0.340) + (G. thigh 0.335) + (G. Forearm 0.748) + (G. Mid-thigh 0.370) + (G. Chest 0.177) + (G. Hip 0.149) + (G. Calf 0.287) + (G. Head 0.308) + (B. Bitrochanteric 0.223)	0.983	1.5

L: length; B: breadth; G: Girth; H: Height; R^2: coefficient of determination; SEE: standard error of estimate; p<0.0001.

Table 5. Multiple stepwise regressions to estimate body weight. Females.

Variables	Weight	R^2	SEE
L	-118.030 + (Height 0.156) + (Sitting height 0.796) + (Arm spam 0.306) + (Foot length 1.382)	0.764	4.5
B	-110.85 + (Femur 5.509) + (A-P chest depth 1.372) + (Biacromial 0.948) + (Bimalleolar 5.699) + (Biiliocristal 0.901)	0.856	3.5
G	-121.536 + (Hip 0.304) + (Calf 0.759) + (Shoulders 0.312) + (Waist 0.226) + (Wrist 1.603) + (Thigh 0.397) + (Head 0.567)	0.948	2.1
H,B	-116.688 + (Height 0.456) + (Femur 5.565) + (A-P chest 1.424) + (Biacromial 0.694)	0.873	3.3
H,G	-118.433 + (Height 0.455) + (Waist 0.448) + (Mild-Thigh 0.591) + (Hip 0.248) + (Forearm 0.785)	0.977	1.4
H,B,G	-118.313 + (Height 0.447) + (G. Mid-thigh 0.597) + (G. waist 0.398) + (G. Hip 0.219) + (G. Forearm 0.817) + (B. A-P chest 0.352) +	0.979	1.3

L: length; B: breadth; G: Girth; H: Height; R^2: coefficient of determination; SEE: standard error of estimate; p<0.0001.

However, when in good physical condition, the value of the skinfold in comparison to the total value of the girth is proportionally small. The problem lies in athletes who are still growing or those who have not yet achieved suitable muscle development and therefore their estimated weight would be undervalued with respect to what they would obtain after full development of their muscular and skeletal system.

After reviewing the percentiles of our general population[38], we have confirmed that the weights established in the respective categories 1 to 7 by the official organizations correspond to percentiles 10, 25, 50, 75-80, 90, 98 and > 98 in both samples. While the mean of the heights by categories would be in a somewhat lower range: percentiles 3 (V1), 20 (V2), 25-50 (V3), 50 (V4), 85 (V5), 90-97 (V6) and 98 (V7) in males and percentiles 3 (M1), 15-20 (M2), 25-50 (M3), 50-75 (M4), 85 (M5) and 90 (M6, M7 and M8) in females. Moreover, the weights in the different categories coincide with the independent subsets that can be established, while the heights in some of the categories overlap or, to put it another way, a judoka with a particular height may belong to one or another adjacent category, except those in V1 and M1.

The female sample presents a greater adipose panicle and greater variability, their higher weight categories are fundamentally due to having a larger fatty component, whereas the lean component increases in all categories for males. In both samples, the lean component is what classifies a sample into as many groups as there are weight categories established, confirming that this component is the determining factor, although the increase in lean weight is more marked in males than in females as we move up through the weight categories since, as mentioned above, the fatty component also increases markedly in female judokas in higher categories. The categories are also more clearly defined for males with regard to muscle mass compared to height than in females, where there is more overlap.

If general rules are adopted internationally and strictly enforced, then, on the one hand, there would be an end to techniques that are dangerous for health and, on the other hand, competition would be fairer. The safest method, as Artioli[20] proposes, would be to determine urine density by refractometer on the day of the competition together with the official weigh-in, thus confirming that the judokas is normohydrated at competition weight.

Conclusion

There is sexual dimorphism and intra-category dimorphism in the anthropometric characteristics of judokas. The anthropometric profile for the valuation of judokas by genders and weight categories is provided as a reference for the individualized assessment of athletes.

In competition, judokas do not come down to the minimum fat percentages and that their bodyweight estimated in this way will be undervalued, obliging them to lower it at the expense of the lean component. The regression equations proposed may be useful as tools for athletes to adapt to the most suitable weight category according to their anthropometric characteristics.

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Conflict of interest

The authors do not declare a conflict of interest.

References

1. Loenneke JP, Wilson JM, Barnes JT, Pujol TJ. Validity of the current NCAA minimum weight protocol: a brief review. *Ann Nutr Metab.* 2011;58:245–9.
2. Callister R, Callister RJ, Staron RS, Fleck SJ, Tesch P, Dudley GA. Physiological characteristics of elite judo athletes. *Int J Sport Med.* 1991;12:196–203.
3. Franchini E, Del Vecchio FB, Matsushigue KA, Artioli GG. Physiological profiles of elite judo athletes. *Sports Med.* 2011;41(2):147-66.
4. Franchini E, Sterkowicz-Przybycien K, Takito MY. Anthropometrical profile of judo athletes: comparative analysis between weight categories. *Int J Morphol.* 2014;32(1):36-42.
5. Amtmann J, Cotton A. Strength and Conditioning for Judo. *Strength Cond J.* 2005; 27(2):26–31.
6. Julio UF, Panissa VLG, Esteves JVDC, Cury RL, Agostinho MF, Franchini E. Energy System Contributions to Simulated Judo Matches. *Int J Sports Physiol Perform*. 2017;(5):676-83.
7. Sterkowicz-Przybycien K, Fukuda DH. Sex differences and the effects of modified combat regulations on endurance capacity in judo athletes: A meta-analytic approach. *J Hum Kinet.* 2016;51:113-20.
8. Azoury J. A descriptive study of Australian elite Judo players. *J Sci Med Sport.* 2002;5(4):36.
9. Ghrairi M, Hammouda O, Malliaropoulos N. Muscular strength profile in Tunisian male national judo team. 2014;4(2):149-53.
10. International Judo Federation (Sport Commission). Sport and Organization Rules of the International Judo Federation 2018. [Cited 2018 July 10]. Available from: https://www.ijf.org/ijf/documents/.
11. Artioli GG, Franchini E, Nicastro H, Sterkowicz S, Solis MY, Lancha AH Jr. The need of a weight management control program in judo: a proposal based on the successful case of wrestling. *J Int Soc Sports Nutr.* 2010;7:15.
12. Norton K, Whittingham N, Carter L, Kerr D, Gore C, Marfell-Jones M. Measurement Techniques in Anthropometry. In Norton K, Olds T. *Anthropometrica: a textbook of body measurement for sports and health courses*. Sydney, University of New South Wales Press; 1996. p. 25-75.
13. Lohman TG, Roche AF, Martorell R. *Anthropometric Standardization Reference Manual.* Champaign, IL: Human Kinetics Books; 1988. p. 42-43.
14. Lee RC, Wang Z, Heo M, Ross R, Janssen I, Heymsfield SB. Total-body skeletal muscle mass: development and cross-validation of anthropometric prediction models. *Am J Clin Nutr.* 2000;72(3):796-803.
15. Thorland WG, Tipton CM, Lohman TG, Bowers RW, Housh TJ, Johnson GO, et al. Midwest wrestling study: prediction of minimal weight for high school wrestlers. *Med Sci Sports Exerc.* 1991;23(9):1102-10.
16. Slaughter MH, Lohman TG, Boileau RA, Horswill CA, Stillman RJ, Van Loan MD, *et al.* Skinfold equations for estimation of body fatness in children and youth. *Hum Biol.* 1988;60(5):709-23.
17. Norton K. Anthropometric Estimation of Body Fat. In: In Norton K, Olds T. *Anthropometrica: a textbook of body measurement for sports and health courses.* Sydney, University of New South Wales Press; 1996. p. 172-198.
18. Heymsfield SB, McManus C, Smith J, Stevens V, Nixon DW. Anthropometric measurement of muscle mass: revised equations for calculating bone-free arm muscle area. *Am J Clin Nutr.* 1982;36(4):680-90.
19. Oppliger RA, Case HS, Horswill CA, Landry GL, Shelter AC. American College of Sports Medicine position stand. Weight loss in wrestlers. *Med Sci Sports Exerc.* 1996;28(10):135-8.
20. Carter JEL, Heath BH. *Somatotyping - Development and Applications*. Cambridge, Cambridge University Press; 1990. p. 374-5.
21. Gutiérrez C, Santos L, Montero-Carretero C, Escobar-Molina, R. Éxitos del judo español a nivel internacional: una perspectiva histórica. *Revista de Artes Marciales Asiáticas.* 2018;13(2s):3-8.
22. Casals C, Huertas JR, Franchini E, Sterkowicz-Przybycien K, Sterkowicz, S, Gutierrez-Garcıa C, *et al*. Special judo fitness test level and anthropometric profile of elite spanish judo athletes. *J Strength Cond Res.* 2017;31(5):1229-35.
23. Torres-Luque G, Hernández-García R, Escobar-Molina R, Garatachea N, Nikolaidis PT. Physical and Physiological Characteristics of Judo Athletes: An Update. *Sports (Basel).* 2016; 4:20.
24. Ceylan B, Gurses VV, Akgul MS, Baydi B, Franchini, E. Anthropometric Profile, Wingate Performance and Special Judo Fitness Levels of Turkish Olympic Judo Athletes. *J Martial Arts Anthrop*. 2018;18(3):15-20.

25. Martins FP, Pinto de Souza LSC, de Campos RP, Bromley SJ, Takito MY, Franchini E. Techniques utilised at 2017 Judo World Championship and their classification: comparisons between sexes, weight categories, winners and non-winners. *J Martial Arts Anthrop.* 2019;19(1): 58-65
26. Franchini E, de Moura C FD, Shiroma SA, Humberstone C, Julio UF. Pacing in judo: analysis of international-level competitions with different durations. *Int J Perform Anal Sport.* 2019;1–10.
27. Artioli GG, Gualano B, Franchini E, Scagliusi FB, Takesian M, Fuchs M, *et al.* Prevalence, magnitude, and methods of rapid weight loss among judo competitors. *Med Sci Sports Exerc*. 2010;42(3):436-42.
28. Malliaropoulos N, Rachid S, Korakakis V, Fraser SA, Bikos G, Maffulli N, *et al*. Prevalence, techniques and knowledge of rapid weight loss amongst adult british judo athletes: a questionnaire based study. *Muscles Ligaments Tendons J.* 2017;7(3):459–66.
29. Mazzoccante RP, Sousa IC, Mendes LCV, Mendes MCV, Asano RY. Comparação da prevalência de métodos de perda de peso pré-competição em judocas de diferentes categorias. *Rev Bras Ciênc Esporte.* 2016;38(3):297-302.
30. Reale R, Slater G, Burke LM. Weight Management Practices of Australian Olympic Combat Sport Athletes. *Int J Sports Physiol Perform*. 2018;13(4):459-66.
31. Koral J, Dosseville F. Combination of gradual and rapid weight loss: Effects on physical performance and psychological state of elite judo athletes. *J Sports Sci.* 2009;27(2):115-20.
32. Franchini E, Brito CJ, Artioli GG. Weight loss in combat sports: physiological, psychological and performance effects. *J Int Soc Sports Nutr.* 2012;9:52.
33. Fortes LS, Costa BDV, Paes PP, Cyrino ES, Vianna JM, Franchini E. Effect of rapid weight loss on physical performance in judo athletes: is rapid weight loss a help for judokas with weight problems? *Int J Perform Anal Sport*. 2017;17(5):763-73.
34. Morales J, Ubasart C, Solana-Tramunt M, Villarrasa-Sapiña I, González LM, Fukuda D, *et al.* Effects of Rapid Weight Loss on Balance and Reaction Time in Elite Judo Athletes *Int J Sports Physiol Perform.* 2018;13(10):1371-7.
35. Lohman TG. Advances in Body Composition Assessment. Champaign, IL: Human Kinetics Publishers;1992. p.109-118.
36. Tcheng TK, Tipton CM. Iowa Wrestling Study: anthropometric measurements and the prediction of a "minimal" body weight for high school wrestlers. *Med Sci Sports.* 1973;5(1):1-10.
37. Oppliger RA, Tipton CM. Iowa wrestling study: cross-validation of the Tcheng-Tipton minimal weight prediction formulas for high school wrestlers. *Med Sci Sports Exerc.* 1988;20(3):310-6.
38. Carrascosa A, Fernández JM, Fernández C, Ferrández A, López-Siguero JP, Sánchez E, et al. Estudio transversal español de crecimiento 2008. Parte II: valores de talla, peso e índice de masa corporal desde el nacimiento a la talla adulta. *An Pediatr.* 2008; 68(6):552-69.

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