ORIGINAL ARTICLE

The diversity of body composition, body proportions and strength abilities of female judokas in different weight categories

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

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Abstract

Background & Study Aim: Athletes who belong to the same weight category do not have to possess the identical body build and body composition, since body mass consists of a number of different components. The aim of the study was to find out weather female judokas in different weight categories varied regard to the contributions of particular body components, relative size characterizing musculature and skeletal massiveness and also strength abilities.

Material & Methods: The study material consisted of results of anthropological and body composition measurements of 50 female judo competitors, aged 16-20 years, included in the three weight divisions adopted in judo (lightweight, middleweight, heavyweight). The different anthropometric indices were calculated and the somatotypes according to Sheldon's typology as modified by Heath and Carter were determined. The body composition was also examined with the use of bioelectrical impedance analysis. The athletes' handgrip strength was also measured.

Results: The examined female judokas in the lightweight, middleweight and heavyweight categories differed from each other not only in terms of their body mass but also in a number of somatic features. The BIA showed that the heavyweight competitors had higher body fat mass and more massive body build than their counterparts from the two other weight categories. Also the SANOVA revealed significant differences between the somatotypes of judokas in various weight categories. The middleweight judokas had the greatest absolute handgrip strength despite the fact that they had medium content of muscle mass.

Conclusions: The analyzed weight categories of female judokas differed in body massiveness, fatness and musculature. It can be stated that the division of competitors into weight categories is fully justified in martial arts such as judo. The increase in body mass occurs mainly through the increase in fat mass, while muscle mass and skeletal robustness have little impact on excessive body mass. The handgrip strength in female judokas is not strictly depend on the contribution of muscle mass.

Key words: body composition • anthropometry • somatotypes • hand strength

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Body composition – contribution of particular tissues (eg. fat and muscle called body components) in body mass, often shows in kilograms or percentages.

Anthropometry - the technique that deals with the measurement of the size, weight, and proportions of the human or other primate body.

Somatotypes - particular categories of body build, determined on the basis of certain physical characteristics. The three basic body types are ectomorph (thin physique), endomorph (rounded physique), and mesomorph (athletic physique).

Hand strength - force exerted when gripping or grasping.

BIA – method of bioelectrical impedance analysis for body composition measurements; the body weight is shown as sum of fat and fat free components (extracellular mass, intracellular mass).

Introduction

Body build is a factor which greatly affects sports results. Proper body build proportions, specific somatotypes as well as body composition can determine the success of athletes in respective sports disciplines [1-4]. In some sports, especially strength sports, an increase in body mass, mainly in its muscle component, can also influence one's sports results. However, as noted by Burdukiewicz in a study of adolescents [5], an increase in body muscle mass is usually accompanied by an increase in body fat. This is particularly the case in contact sports where greater body mass can be an important advantage over the opponent. In martial arts such as judo, on the one hand, a greater body mass ensures better stability and improves the chances of defeating the opponent, but on the other hand, excessive body mass can be a heavy load decreasing a judoka's speed and agility. During matches, judo competitors use a vast array of techniques and combinations of techniques, depending on their individual predispositions and the opponent's demands [6, 7].

The introduction of weight divisions into combat sports enables greater control over the impact of athlete's body mass on sport results. However, athletes who belong to the same weight category do not have to possess the identical body build and body composition and therefore may display varied strength abilities. Body mass consists of a number of components, the most significant for athletes being muscle mass and body fat. Muscle mass allows generating power and executing movements, while body fat plays an important role in maintaining body equilibrium and constitutes an energy storage for muscles in conditions of depleted glucose. Also body hydration with the proper proportions of extracellular and intracellular water is of great significance to athletic performance. The introduction of weight divisions leads also to athletes taking various efforts aimed at body mass reduction before important competitions [8], often at the expense of body hydration [9]. Sudden energy restriction and water deficit disturb metabolic processes and, in consequence, decrease the athlete's performance and weaken muscles, entailing the risk of an injury [10]. Frequent fluctuations in body mass and body compositions are particularly dangerous for young female judokas, who have just entered their reproductive age, and may profoundly affect their biological condition and fertility.

Previous research studies have been concerned i.a. with comparative analyses of the body build of elite and non-elite judo competitors in age categories [11-13]. Works devoted to the body build of female and male athletes in various weight categories indicated that competitors of heavy categories are characterized by bigger body build than middle and light categories [14, 15].

The aim of the study was to find out weather female judokas in different weight categories varied regard to the contributions of particular body components, relative size characterizing musculature and skeletal massiveness, and also strength abilities. The athletes' body fat distribution were also examined. The results of the study provide important information to judo trainers that may help them reach decisions concerning reducing body mass by young female judokas.

Material and methods

The study material consisted of results of anthropological and body composition measurements of fifty female judo competitors who participated in the Polish Junior Judo Cup in Wrocław. They were selected to the study by following criteria:
- aged 16-20 years (post-adolescent phase of ontogenesis) (Figure 1),
- they trained judo at least 5 years,
- they agree to participate in the study (written informed consent).

The athletes' mean body height was 165.9 +/- 6.4 cm, and mean body mass 66.0 +/-14.9 kg. For the purpose of the study the subjects were divided into three conventional weight divisions according to the Polish Judo Association [16]: lightweight (N=17), middleweight (N=19) and heavyweight (N=14).

The measurements were taken with instruments manufactured by GPM. The judokas' body height (*B–v*) was measured with a Martin anthropometer (to the nearest 0.1 cm). The biepicondylar breadths of the humerus (*cl–cm*) and the femur (*epl–epm*) were measured with a breadth caliper (to the nearest 0.1 cm). Subcutaneous fatness was assessed at four sites (triceps, subscapular, supraspinale, medial calf) with a Holtain skinfold caliper (to the nearest 0.2 mm). The subjects' body mass was measured using a standard electronic weighing scale (to the nearest 0.1 kg). Tensed arm and calf girths were measured with an anthropometric tape (to the nearest 0.1 cm).

The Body Mass Index (BMI) and the following anthropometric indices were calculated to determine the judokas' body build, musculature, skeletal massiveness and fat distributions:

- humeral robustness index: (*cl-cm* / *B-v*) * 100,
- femoral robustness index: (*epl-epm* / *B-v*) * 100,
- arm girth index: (*tensed arm circumference* / *B-v*) * 100,
- calf girth index: (*calf circumference* / *B-v*) * 100,
- trunk fatness index: (*subscapular skinfold* + *supraspinale skinfold*) / B-v *100,
- limb fatness index: (*triceps skinfold* + *medial calf skinfold*) / B-v *100,
- index of subcutaneous fat distribution: (*triceps skinfold* + *medial calf skinfold*) / (*subscapular skinfold* + *supraspinale skinfold*) *100.

The collected anthropometric measurements allowed the somatotyping of subjects following Sheldon's typology as modified by Heath and Carter [17], based on the contribution of three build components: endomorphy (fatness), mesomorphy (musculo-skeletal robustness) and ectomorphy (slenderness). The levels of particular components were calculated on a point scale.

The body composition of female judokas was also examined with the use of bioelectrical impedance analysis (BIA). The measurements of resistance and reactance were carried out with a BIA Akern 101 Anniversary Sport Edition analyzer. The percentage contributions of particular body components: fat mass (FM), fat-free mass (FFM), total body water (TBW), extracellular water (ECW), intracellular water (ICW), muscle mass (MM) were calculated with the Bodygram 1.3.1. software package. All measurements were taken before the fight, in a supine position.

Also the athletes' handgrip strength of the right hand and the left hand as an important factor in martial arts was measured with a Takei handgrip dynamometer with an adjustable grip (to the nearest 0.5 kg). The relative strength index: *(right hand+ left hand) / body mass* was calculated for weight categories.

The distribution of analyzed variables was checked against normal distribution (Levene's test). To determine the significance of differences in body build proportions and levels of body components between particular weight categories parametric (ANOVA, Scheffe's post-hoc test) and non-parametric tests (Kruskal-Wallis test, Wilcoxon signed-rank test) were applied. The somatotypical differences were examined with the Somatotype Analysis of Variance (SANOVA). Pearson's coefficients of correlation between individual variable and body height were calculated. The significance level was set at $p \leq 0.05$. All statistical analyses were carried out with the use of Statistica 9.0. software package. The histograms were drawn with the use of Microsoft® Office Excel 2003, and the somatochart with the Somatotype Calculation and Analysis software by Sweet Technologies©.

The study was conducted according to the Helsinki Declaration and Committee for the Ethics of the University School of Physical Education in Wrocław accepted the performance of the research. Valid informed consents from all volunteers was collected.

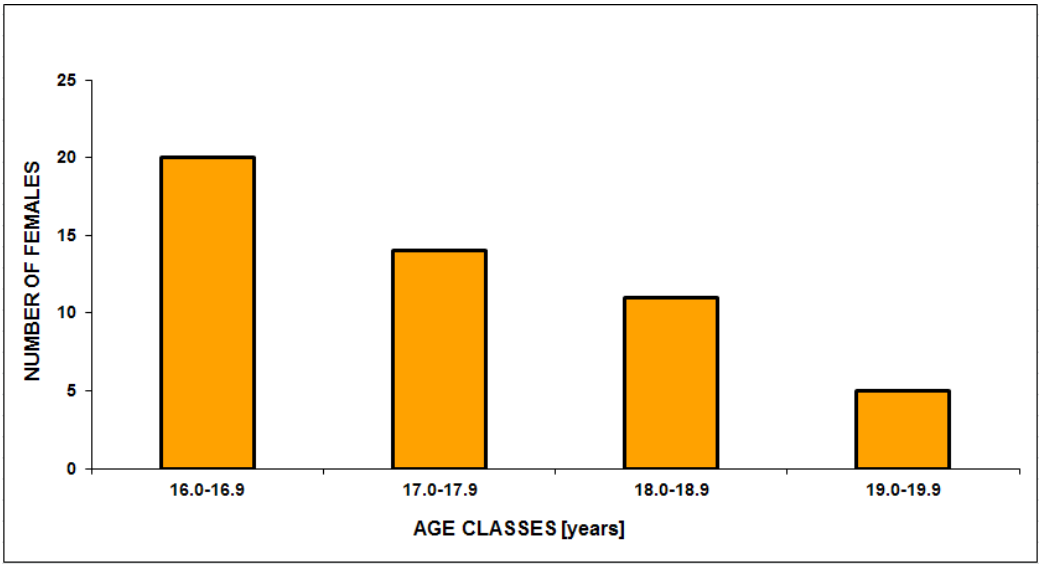

Figure 1. Age structure in studied female judokas.

Table 1. Body build characteristics of examined female judokas.

VARIABLE		MEAN (SD) WEIGHT CATEGORIES [kg]			ANOVA or Kruskal-Wallis test results	
		Light 44.0 – 57.0 (N=17)	Middle 57.1 – 70.0 (N=19)	Heavy > 70.0 (N=14)	F(*) / H(**)	p
Body mass [kg]		52.2 (4.8)	64.0 (3.8)	85.6 (10.8)	43.4 (**)	0.0000
Body height [cm]		161.5 (5.8)	167.1 (4.4)	169.6 (6.7)	8.9 (*)	0.0005
BMI [kg/m^2]		20.1 (1.4)	23.0 (1.5)	29.8 (3.1)	38.7 (**)	0.0000
cl-cm [cm]		5.9 (0.2)	6.2 (0.3)	6.7 (0.3)	30.6 (*)	0.0000
epl-epm [cm]		8.8 (0.3)	9.4 (0.4)	10.6 (0.6)	35.8 (**)	0.0000
Humeral robustness index		3.7 (0.2)	3.7 (0.2)	3.9 (0.2)	11.5 (*)	0.0001
Femoral robustness index		5.4 (0.2)	5.6 (0.3)	6.3 (0.4)	28.6 (*)	0.0000
Tensed arm circumference [cm]		27.6 (1.9)	30.5 (1.6)	35.9 (1.9)	78.6 (*)	0.0000
Calf circumference (max) [cm]		33.4 (1.5)	36.7 (2.0)	40.6 (2.5)	47.9 (*)	0.0000
Arm girth index		17.1 (1.3)	18.2 (1.3)	21.2 (1.1)	42.2 (*)	0.0000
Calf girth index		20.7 (1.2)	21.9 (1.3)	23.9 (1.5)	22.2 (*)	0.0000
Triceps skinfold [mm]		7.7 (2.3)	8.6 (1.7)	13.9 (3.6)	23.4 (**)	0.0000
Subscapular skinfold [mm]		7.7 (2.3)	9.9 (1.7)	19.8 (5.2)	31.8 (**)	0.0000
Supraspinale skinfold [mm]		7.7 (2.7)	11.4 (4.2)	21.5 (6.9)	28.5 (**)	0.0000
Medial calf skinfold [mm]		6.9 (2.2)	8.5 (2.0)	14.6 (4.1)	26.3 (**)	0.0000
Trunk fatness index		9.6 (3.2)	12.8 (3.4)	24.4 (6.9)	42.8 (*)	0.0000
Limb fatness index		9.1 (2.3)	10.3 (1.8)	16.9 (4.1)	34.5 (*)	0.0000
Index of subcutaneous fat distribution		96.8 (17.0)	83.4 (16.9)	72.3 (17.8)	7.9 (*)	0.0010
Handgrip strength (right + left)		57.9 (7.6)	66.7 (7.6)	59.2 (12.3)	7.8 (**)	0.0205
Relative strength index		1.1 (0.1)	1.04 (0.1)	0.7 (0.2)	32.3 (*)	0.0000
Body composition (BIA)	FM [%]	18.3 (4.7)	24.2 (4.0)	34.2 (6.4)	38.8 (*)	0.0000
	FFM [%]	81.7 (4.7)	75.8 (4.0)	65.8 (6.4)	38.8 (*)	0.0000
	TBW [%]	59.8 (3.4)	55.4 (2.9)	47.4 (4.6)	45.8 (*)	0.0000
	ECW [%]	42.4 (2.6)	43.6 (2.3)	44.9 (2.5)	3.9 (*)	0.0280
	ICW [%]	57.6 (2.6)	56.4 (2.3)	55.1 (2.5)	3.9 (*)	0.0280
	MM [%]	57.3 (3.7)	51.9 (2.9)	43.7 (5.1)	45.8 (*)	0.0000
Somatotype components	Endomorphy	2.3 (0.8)	3.0 (0.7)	5.4 (1.2)	51.3 (*)	0.0000
	Mesomorphy	4.0 (0.9)	4.9 (1.0)	7.2 (1.1)	36.9 (*)	0.0000
	Ectomorphy	3.1 (0.8)	2.1 (0.8)	0.5 (0.6)	48.2 (*)	0.0000

(*) - value of F statistic (ANOVA) (**) - value of H statistic (Kruskal-Wallis test); p - level of significance; cl-cm – elbow width; epl-epm – knee width; FM – fat mass; FFM – fat free mass; TBW – total body water; ECW – extracellular water; ICW – intracellular water; MM – muscle mass

Results

The examined judokas in the three weight categories did not differ significantly in terms of their age (ANOVA; F = 1.38; p = 0.2615). Their mean age amounted to 17.5 +/- 1.4 years. The athletes in the three weight categories differed, however, in their mean body height and body mass (Table 1). The heaviest athletes were at the same time the tallest (Table 1). The body mass-height proportions as expressed by the BMI differed significantly between

particular weight categories (Table 1). The BMI of the examined judokas ranged from 17.9 kg/m^2 to 36.9 kg/m^2. The higher weight category, the more robust body build was noted in the female judokas. The athletes in the heaviest weight category were overweight, and many of them were obese (according to the WHO official classifications) [18].

Scheffe's post-hoc test results revealed statistically significant differences in body height between the athletes in the heaviest weight category and in the other categories, as well as significant body mass and BMI differences between all categories (Table 2).

The athletes from the heaviest weight category had the greatest biepicondylar breadths of the humerus (*cl-cm*) and the femur (*epl-epm*) as well as the largest arm and calf circumferences (Table 1). They also had the thickest subcutaneous fat tissue at all skinfold measurement sites (Table 1). The athletes in the middleweight and lightweight categories featured similar skinfold thickness (Table 3). Since all the measured somatic parameters were significantly correlated with body height (Pearson's r for body height between 0.3 – 0.6; $p<0.05$), the athletes' musculo-skelatal robustness was also assessed on the basis of anthropometric indices. The lightweight and middleweight judokas revealed no significant differences in their relative humeral and femoral robustness (Table 1); however, in the athletes with body mass under 70.0 kg the bone robustness indices were significantly higher (Table 2). Similar relationships were noted in trunk and limb fatness indices (Table 2) that were significantly higher in the heaviest judokas (Table 1). The obtained index of subcutaneous fat distribution showed that the female competitors in the lightweight category (< 57.1 kg) had similar trunk and limb fatness levels, whereas the heaviest athletes had a significantly higher level of trunk fatness than limb fatness (Table 1, Table 2). The arm girth and calf girth indices displayed a distinct rising trend along the increase of judokas' body mass (Table 1).

The measurement of the functional parameter of handgrip strength showed that the middleweight judokas had the greatest absolute handgrip strength (right + left hand); while the lightest and the heaviest judo competitors had similar handgrip strength levels (Table 1, Table 2). The handgrip strength values in relation to body mass were the highest in the lightest competitors, and the lowest in the heaviest competitors.

The bioelectrical impedance analysis of female judokas' body composition showed that the heavyweight competitors had significantly higher body fat mass than their counterparts from the two other weight categories. The percentage of fat in body mass was shown to increase with judokas' body mass (Table 1). The competitors in the heaviest weight category had twice as many percent of their body fat as the lightest competitors. An opposite trend was, however, observed in the percentage of fat-free mass and total body water in body mass (Table 1). The proportions of intracellular and extracellular water contents did not differ significantly among the examined judo competitors (Table 3); however, the results pointed to a decreasing percent of ICW and increasing percent of ECW in the heavier weight categories (Table 1).

The somatotypes of female judo competitors were determined according to W. Sheldon's typology as modified by Heath and Carter. The SANOVA revealed significant differences between the somatotypes of judokas in various weight categories ($F = 44.14$; $p = 0.0010$). The highest mesomorphy and endomorphy levels had the heaviest athletes, who also had the lowest ectomorphy level (Table 1). The lightest competitors had the lowest endomorphy and the highest ectomorphy (Table 1). The mesomorphy levels in the lightweight and middleweight categories were similar (Table 3). The distribution of somatotypes on the somatochart indicated that the lightest and the heaviest judokas differed significantly from each other, whereas the middleweight competitors had the most scattered results on the somatochart (Figure 2).

Discussion

The examined female judokas in the lightweight, middleweight and heavyweight categories differed from each other not only in terms of their body mass but also in a number of somatic components. Such differences had been indicated in some earlier research [14, 15, 19, 20]. The heaviest judo competitors were at the same time the tallest, with the most robust skeleton, largest arm and calf circumference and thickest skinfolds. Therefore they featured the greatest body robustness as expressed by their mean BMI values (29.8 +/- 3.1). The obtained BMI values also point to the highest percentage of overweight and obese women among the heaviest competitors, according to the WHO standards [18]. This was also noted by Franchini et al. [7] and Jagiełło et al. [14]. The WHO BMI ranges concern differences in the risk of incidence of cardiovascular diseases, which increases with higher BMI values since excessive body mass can greatly overload the circulatory system and the heart [21, 22]. Excessive body fat may lead to risky adiposity levels in the blood vessels. The BMI does

Table 2. Results of post-hoc tests for anthropometric features and handgrip strength of examined female judokas (table contains level of significance *p* values).

VARIABLE	WEIGHT DIVISIONS	LIGHT	MIDDLE	HEAVY
Body mass [kg]	LIGHT		0.0006	0.0000
	MIDDLE	0.0006		0.0039
	HEAVY	0.0000	0.0039	
Body height [cm]	LIGHT		0.0149	0.0009
	MIDDLE	0.0149		0.4596
	HEAVY	0.0009	0.4596	
BMI [kg/m^2]	LIGHT		0.0040	0.0000
	MIDDLE	0.0040		0.0026
	HEAVY	0.0000	0.0026	
cl-cm [cm]	LIGHT		0.0202	0.0000
	MIDDLE	0.0202		0.0000
	HEAVY	0.0000	0.0000	
epl-epm [cm]	LIGHT		0.0117	0.0000
	MIDDLE	0.0117		0.0022
	HEAVY	0.0000	0.0022	
Humeral robustness index	LIGHT		0.7937	0.0002
	MIDDLE	0.7937		0.0012
	HEAVY	0.0002	0.0012	
Femoral robustness index	LIGHT		0.2134	0.0000
	MIDDLE	0.2134		0.0000
	HEAVY	0.0000	0.0000	
Tensed arm circumference [cm]	LIGHT		0.0001	0.0000
	MIDDLE	0.0001		0.0000
	HEAVY	0.0000	0.0000	
Calf circumference (max) [cm]	LIGHT		0.0000	0.0000
	MIDDLE	0.0000		0.0000
	HEAVY	0.0000	0.0000	
Arm girth index	LIGHT		0.0271	0.0000
	MIDDLE	0.0271		0.0000
	HEAVY	0.0000	0.0000	
Calf girth index	LIGHT		0.0332	0.0000
	MIDDLE	0.0332		0.0018
	HEAVY	0.0000	0.0018	
Trunk fatness index	LIGHT		0.0866	0.0000
	MIDDLE	0.0866		0.0000
	HEAVY	0.0000	0.0000	
Limb fatness index	LIGHT		0.0392	0.0000
	MIDDLE	0.0392		0.0000
	HEAVY	0.0000	0.0000	

VARIABLE	WEIGHT DIVISIONS	LIGHT	MIDDLE	HEAVY
Index of subcutaneous fat distribution	LIGHT		0.0604	0.0030
	MIDDLE	0.0604		0.3769
	HEAVY	0.0030	0.3769	
Handgrip strength (right + left)	LIGHT		0.0242	0.9257
	MIDDLE	0.0242		0.0919
	HEAVY	0.9257	0.0919	
Relative strength index	LIGHT		0.3158	0.0000
	MIDDLE	0.3158		0.0000
	HEAVY	0.0000	0.0000	

cl-cm – elbow width; epl-epm – knee width

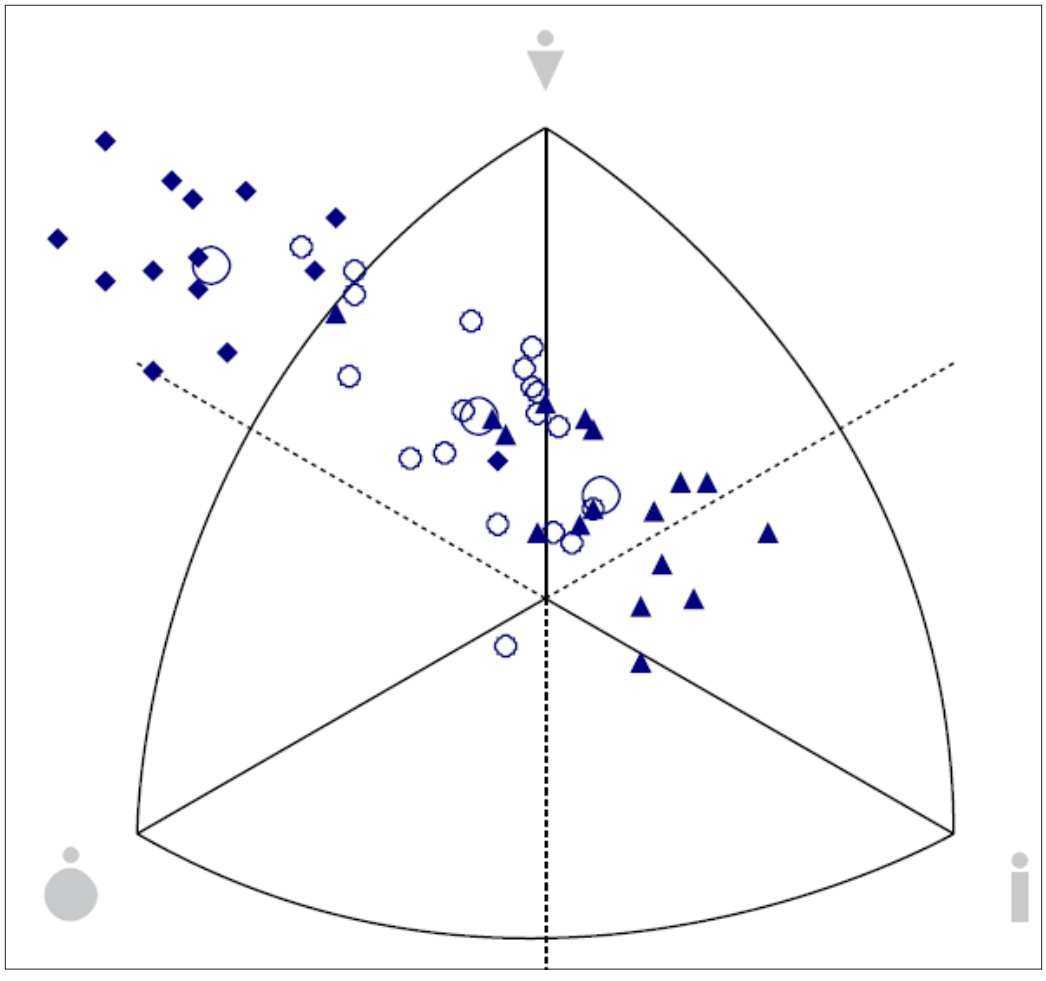

Figure 2. Distribution of examined female judokas on the somatochart.

Weight divisions: ▲ 44.0 – 57.0 kg; ○ 57.1 – 70.0 kg; ♦ > 70 kg

Table 3. Results of post-hoc tests for body compositions features and body components of examined female judokas (table contains level of significance *p* values).

VARIABLE	WEIGHT DIVISIONS	LIGHT	MIDDLE	HEAVY
Subscapular skinfold [mm]	LIGHT		0.0499	0.0000
	MIDDLE	0.0499		0.0014
	HEAVY	0.0000	0.0014	
Triceps skinfold [mm]	LIGHT		1.0000	0.0000
	MIDDLE	1.0000		0.0003
	HEAVY	0.0000	0.0003	
Supraspinale skinfold [mm]	LIGHT		0.0790	0.0000
	MIDDLE	0.0790		0.0024
	HEAVY	0.0000	0.0024	
Medial calf skinfold [mm]	LIGHT		0.4224	0.0000
	MIDDLE	0.4224		0.0005
	HEAVY	0.0000	0.0005	
Endomorphy	LIGHT		0.0396	0.0000
	MIDDLE	0.0396		0.0000
	HEAVY	0.0000	0.0000	
Mesomorphy	LIGHT		0.0532	0.0000
	MIDDLE	0.0532		0.0000
	HEAVY	0.0000	0.0000	
Ectomorphy	LIGHT		0.0006	0.0000
	MIDDLE	0.0006	0.0000	0.0000
	HEAVY	0.0000		
FFM [%]	LIGHT		0.0020	0.0000
	MIDDLE	0.0020		0.0000
	HEAVY	0.0000	0.0000	
FM [%]	LIGHT		0.0020	0.0000
	MIDDLE	0.0020		0.0000
	HEAVY	0.0000	0.0000	
TBW [%]	LIGHT		0.0014	0.0000
	MIDDLE	0.0014		0.0000
	HEAVY	0.0000	0.0000	
ECW [%]	LIGHT		0.4631	0.0263
	MIDDLE	0.4631		0.2542
	HEAVY	0.0263	0.2542	
ICW [%]	LIGHT		0.4631	0.0263
	MIDDLE	0.4631		0.2542
	HEAVY	0.0263	0.2542	
MM [%]	LIGHT		0.0008	0.0000
	MIDDLE	0.0008		0.0000
	HEAVY	0.0000	0.0000	

FM – fat mass; FFM – fat free mass; TBW – total body water; ECW – extracellular water; ICW – intracellular water; MM – muscle mass.

not make distinctions between reasons for excessively robust body build such as higher body fat, muscle mass or bone mass. However, the measurements of tissue components (skinfold thickness, BIA) showed that the body fat level was excessive in the heaviest judokas. Previous studies also pointed to the negative impact of body fatness on the motor performance of judo competitors [11, 13, 23].

The massiveness of body build of female judokas was primarily affected by fat mass, while muscle mass and bone mass had a less significant influence. The body fat level in the examined female judokas determined with skinfold thickness, BIA and Heath-Carter somatotyping was the highest in the competitors in the heavyweight category. The skinfolds of the lightest judokas were two- or three-times thinner than in their counterparts in the heavyweight category. Similar conclusions were drawn by Pieter et al. [20] in their study of Filipino female judokas. Also the indices of trunk and limb fatness were significantly lower in the lightweight and middleweight competitors. The percent of fat mass in body mass assessed with BIA was twice as high in heavyweight competitors as compared with their lightweight counterparts. In the former the mean FM values (34.2 +/- 6.4) indicated a high percentage of overweight women. The rising trend in the percentage of body fat in higher weight categories was also observed by Jagiełło et al. [14] and Thomas et al. [19]. The same tendency was observed among other combat sports i.a. male wrestlers [15]. The body fat level assessed by Sterkowicz [24] with the use of anthropometric method in a group of Polish female judokas (regardless of weight categories) was 23.27 +/- 3.67%, which corresponds to the fatness level in the middleweight judo competitors in the present study.

The index of subcutaneous fat distribution values showed that subcutaneous fat was most evenly distributed in lightweight female judo competitors (value close to 100). The middleweight competitors had a slightly higher level of trunk fatness (fat distribution index of 83.4), while the heavyweight judokas reached the fat distribution index of 72.3. Sterkowicz [24] also observed an even distribution of subcutaneous fat in Polish female judo practitioners; however, they were not divided into weight categories.

Skeletal massiveness measured with the humeral and femoral robustness indices had only a slight impact on the body mass increase in heavyweight female judo competitors. The humeral and femoral indices were similar in lightweight and middleweight categories, and only slightly higher among the heavyweight judokas. Franchini et al. [11] stated that greater breadths of the humerus and femur in judo practitioners indicated a higher level of adaptation of the skeleton to judo training. Such skeletal build allows judokas to practice under heavier training loads.

The lightweight female judokas had more fat-free mass (80%) than their middleweight (75%) and heavyweight (65%) counterparts. Similar trends were noted in the percentage of muscle mass (MM) and total body water (TBW). The lightweight competitors had, on the average, 14% more muscle mass than the heavyweight judokas, and 5% more than middleweight competitors. The TBW in judo competitors in the lightweight category amounted to almost 60%, whereas in heavyweight judokas did not exceed even 50%. This is a consequence of excessive body fat since fat tissue is less hydrated than the other body components. No significant differences were found between the judokas in three weight categories in terms of percentage of extracellular water and intracellular water. However, the observed tendencies point to a decrease in the ICW percentage and increase in the ECW percentage with the growing female judokas' body mass.

The Heath-Carter somatotyping revealed some other differences in body build of female judo practitioners. The heavyweight judokas featured the highest levels of endomorphy (fatness) and mesomorphy (musculoskelatal robustness). In consequence, they also displayed the lowest level of ectomorphy (slenderness). The female judokas in the lightweight category had the highest ectomorphy and the lowest endormorphy and mesomorphy. The somatochart distribution revealed very significant differences between lightweight and heavyweight judokas, while their middleweight counterparts had the most diversified somatotypes as illustrated by the wide scatter of results. The levels of body components of middleweight athletes are similar to those of Sterkowicz [24] in a somatotype study of elite Polish female judokas, regardless of weight divisions (4.04 – 4.89 – 1.55). The difference between Sterkowicz's results and the results of the present study concerns a slightly lower contribution of endomorphy to the somatotype of middleweight female judokas in the latter (3.0 – 4.9 – 1.2). On the other hand Franchini [7] attained a somatotype with a higher fat level for elite Spanish junior judo female competitors (4.9 – 4.6 – 1.2). The slightly different body build profiles obtained with the aid BIA and somatotyping are due to different methods of assessment of body composition (percent share in BIA and body height ratio in Sheldon's somatotyping).

The present research does not fully support the opinion that large body mass, in particular muscle mass, is associated with greater strength abilities. The highest level of absolute handgrip strength was noted in middleweight judo competitors, who also had medium percentage share of muscle mass. No significant differences were found between the lightweight and heavyweight judokas in their handgrip strength results. The handgrip strength index (relative to body mass) showed the highest relative handgrip strength among the lightweight competitors, who had the highest percentage contribution of muscle mass. Sanchez et al. [25] found that handgrip strength was significantly correlated with the sports results of female judokas; however, they noted no differences in handgrip strength between competitors' weight categories. Franchini et al. [26] and Nazar Ali et al. [27] found the greatest absolute maximal strength in male and female judo practitioners with the longest circumferences (including arm girth); however, the maximal strength to body mass index revealed no significant differences.

Conclusions

The body mass of female judo competitors is a factor that significantly differentiates body build proportions and body composition. The analyzed weight categories of female judokas differed in body height, BMI and other anthropometric indices, body composition and somatotype. It can be stated that the division of competitors into weight categories is fully justified in martial arts such as judo. In heavyweight competitors, the increase in body mass occurs mainly through the increase in fat mass, while muscle mass and skeletal robustness have little impact on excessive body mass. Large body mass is not associated with a greater percentage of muscle mass or increased strength parameters.

Competing Interests

Authors declare that we do not have any financial or personal relationships with other people or organisations that could inappropriately influence the paper.

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