



Changes in Anthropometric Traits and Body Composition Over a Four-Year Period in Elite Female Judoka Athletes

by

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The aim of the study was to determine changes in the structure and composition of the body in elite female athletes over a four-year period. The study involved 12 female judo athletes with 34 somatic variables evaluated. Anthropometric evaluation was performed twice, first, when the athletes were members of the national junior team (aged 16.64 ± 1.26 years), and second, after four years, when they were members of the national senior team (aged 20.78 ± 1.27 years). The measurements were taken in accordance with the recommendations of the IBP (International Biological Program) with a set of anthropometric instruments (GPM Swiss) while following the Martin-Saller technique. The average body mass, height, BMI, fat free mass (in kg) and body fat content significantly increased, while the percentage of fat free mass significantly decreased. All of the analyzed body circumferences also increased. Increases were recorded in the width of the upper limbs and they were the width of both hands and both elbows. There was also a statistically significant increase in the value of endomorphic and mesomorphic components, while the ectomorphic component value was similar. Body composition and a substantial number of somatic features of female judokas as seniors were not yet set at the junior stage. The predominant type of the body build was the endo-mesomorphic type and changes that occurred in the sample took place mainly in accordance with this tendency.

Key words: judo, female, somatic features, biological development.

Introduction

Establishing the relationships between age, the somatotype and adaptive changes under the influence of physical training is a complex issue. Furthermore, it is difficult to separate the effects of training from the effects of development and adolescence experience. On the one hand, the anthropometric somatotype consists of individuals' characteristics insensitive to training; on the other, physical activity and exercise are factors that significantly affect some variables of growth and development of particular tissues, especially bones, muscles and body fat (Malina, 2002).

Athletes tend to be less obese and more muscular than people who do not train competitively. Also, athletes practicing different sport disciplines, such as long-distance running, swimming and gymnastics have different body composition and functional capacity (MacDougall et al., 1991; Sterkowicz et al., 2011). Additionally, the tests of athletes practicing the same sport (e.g., judo) have shown that there are differences in body structure and composition between groups at different skill levels (Hazir, 2010; Kubo et al., 2006; Sterkowicz-Przybycień and Almansba, 2011; Tsolakis and Vagenas, 2010; Gołaś et al., 2017; Maszczyk et al., 2018) and weight category

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(Franchini et al., 2014). Some of these differences could be further impacted by practices needed to change weight category while transitioning between age groups (e.g., from juniors to seniors) or to build on certain technical and tactical strengths with respect to the national and international competition.

Previous research has demonstrated that the profile of the male judokas' somatotype is mesomorphic, whereas in female judokas, the endomorphic component predominates. A tendency to maximize muscle mass and minimize body fat was also indicated (Franchini et al., 2011a). Moreover, it appears that morphological, physiological and technique-related variables in competitive judo are intercorrelated, which may mean that improving any of these variables stimulates the improvement of the other ones (Franchini et al., 2005).

Franchini et al. (2011b) made a comparative analysis of anthropometric profiles of Spanish elite judokas (46 women and 41 men) from cadets through juniors to seniors. According to the study, cadets had a smaller flexed arm circumference and humerus bone epicondyle breadth compared to juniors and seniors, as well as lower values of absolute muscle mass than seniors. The authors also confirmed the differences between endo- and mesomorphic components in the age groups. They concluded that in judo anthropometric profiles may change, reflecting adaptations in judokas even at an early age. Nevertheless, little is still known about the differences between the age groups and weight and dimorphic categories of athletes training judo (Franchini et al., 2011a). Similarly, Little (1991) stated that despite the fact that competitions in judo begin at an early age, there are few studies comparing different age groups and the current literature on these issues continues to be scarce.

Previous cross-sectional studies of different age groups of judokas defined the differences between these groups, but as they did not follow the same participants, changes that occurred over the years of training could not be determined longitudinally. Previous, cross-sectional studies attempted to specify the differences in anthropometric features between particular age groups of female judokas. However, since the studies did not follow the same individuals, the differences that were

observed over the years of judo training were not determined longitudinally. It is still not clear which anthropometric characteristics attain their full development in female judokas as juniors, and which features may not be completely developed until they become seniors. Such information could be particularly useful for talent identification, choosing a target weight category or finding judo techniques that suit individual athletes best (Franchini et al., 2011b).

Clearly, there are few studies in judo comparing different age categories and discussing the relative importance of anthropometric factors in this sport discipline. Thus, the aim of this study was to determine whether such anthropometric changes occurred and the nature of changes in the structure and composition of elite female athletes assessed as juniors, and later as seniors.

Methods

Participants

The study involved 12 female judo athletes whose anthropometric features were assessed first when they were members of the national junior team at the age of 16.64 ± 1.26 years (mean \pm s) (1st Assessment), and again, after four years, when the same individuals (age 20.78 ± 1.27 years) were members of the national senior team (2nd Assessment). Three athletes as juniors and then seniors competed at the national level (medal winners of Polish Championships), three others performed at the international level (medal winners of European Championships) as juniors, and as seniors – national level (medal winners of Polish Championships). The remaining six athletes competed at the international level both as juniors (medal winners of European Championships) and seniors (medal winners of World's Cup). They all were post menarche before the 1st Assessment. The data on the number of athletes representing different weight categories are presented in Table 1.

In the four-year period between the two anthropometric assessments the athletes followed the national team judo training programme. During the first two years they performed on average six afternoon training sessions per week, and in the next two years - ten sessions per week, both in the morning and afternoon hours. Table 2 presents a sample of a weekly microcycle the study participants used during the preparatory

period. Additionally, during each of these years they took part in two or three judo national team training camps. Over the period under study none of the participants suffered any injury that would exclude them from training for longer than ten days.

All participants as well as their parents gave written consent after they had been informed about the purpose of the study and the procedures involved. The study was approved by the local Ethics Committee and the Bioethical Committee of the Regional Medical Society according to the Helsinki Declaration.

Measures

All anthropometric measurements were taken in accordance with the recommendations of the IBP (International Biological Program 1962-1975) with a set of anthropometric instruments (GPM Swiss) while following the Martin-Saller technique (1957-59). Body mass was determined using a 410 Tanita TBF MA scale. The following measurements were performed: (a) on the right and left sides of the body: width of the elbow (cubitale mediale [cm] - cubitale laterale [cl]); width of the knee (epicondylion medialis [epm] - epicondylion lateralis [ep]); width of the hand (metacarpale radiale [mr] - metacarpale ulnare [mu]); width of the foot (metatarsale tibiale [mtt] - metatarsale fibulare [mtf]); and (b) single measurements: body height (basis [B] - vertex [v]); shoulder width (acromion [a] - acromion [a]); width of the chest (thoracolaterale [thl] - thoracolaterale [thl]); width of the pelvis (iliocristale [ic] - iliocristale [ic]); and depth of the chest (xiphoidale [xi] - thoracospinale [ths]). In addition, the circumference of the chest (at rest, while inhaling and exhaling), the waist and the hips, and the circumference of both arms (bent arm), forearms, thighs and lower legs were measured. The skinfold measurements were taken only on the right side of the body: on the arm (triceps), under the shoulder blade (subscapular), chest, abdomen, hip (supraspinale), calf and knee (fossa poplitea). An average value of two measurements was registered, provided that the difference between them did not exceed 10% (Carter, 2002).

On the basis of body mass and height, the height-to-weight index BMI (weight [kg]/height [m²]) was calculated. Body components were assessed through the body density indexes that

were calculated according to the formulas proposed by Piechaczek (1975). Specifically, the thickness of three skinfolds was used: on the arm (triceps), under the shoulder blade (subscapular), on the abdomen to calculate the density of the body, and then fat mass and fat-free mass in kg and as a percentage in relation to body mass.

Piechaczek formulas:

$$D \text{ (density)} = 1.127900 - 0.000210 \log x_5 - 0.000164 \log x_1 - 0.000064 \log x_2$$

x_1 - skinfold under the shoulder blade (subscapular); x_2 - skinfold on the arm (triceps); x_5 - skinfolds on the abdomen

$$\text{Body fat [\%]} F = 100\% \left(\frac{4.201}{D} - 3.813 \right)$$

$$\text{Body fat [kg]} F = \frac{\text{Body weight [kg]} F [\%]}{100\%}$$

$$\text{Fat-free mass [kg]} = \text{Body weight [kg]} - \text{Fat [kg]}$$

$$\text{Fat-free mass [\%]} = 100\% - \text{Fat [\%]}$$

Individual somatotype profiles of study participants were prepared using the method of Heath-Carter, following the instruction manual of the Heath-Carter somatotype rating form (2002).

Design and Procedure

Both assessments took place at the Olympic Training Centre during the national teams' training camps.

The body mass and height as well as the thickness of skinfolds were determined after an overnight fast between 7.00 and 8.00 am. Other measurements were taken after breakfast, in the morning between 8.00 and 11.00 am. The study was conducted under the same conditions, in the same room, at the same temperature of 21°C, with the same instruments and by the same two experienced researchers from the Department of Anatomy and Anthropology of the supporting university. Prior to both evaluation sessions, the test-retest reliability of measurements was verified (two independent measurements on 20 volunteers) (Pederson and Gore, 1996). The test-retest was performed twice, before the 1st Assessment on a group of a regional team of female judokas and before the 2nd Assessment on a group of female athletes from a local academic sports club. Correlations between the first and the second measurements in the test-retest were

determined using the Pearson correlation coefficient and were, respectively, for body mass 0.98 and 0.98, for skinfolds 0.97 and 0.98, for body height 0.99 and 0.99, for width measurements 0.99 and 0.99, and circumferences 0.99 and 0.98. To illustrate how important the deviation was between the measurements relative to the average result, the technical error of measurements (TEM) (Pederson and Gore, 1996) was used, which values for the two time points were, respectively, 0.49% and 0.49% for body mass, 4.50% and 4.20% for skinfolds, 0.29% and 0.26% for body height, 0.49% and 0.46% for width measurements, and 0.45% and 0.61% for circumferences. The test-retest was performed within one day under the same conditions, before noon.

Statistical analysis

The statistical calculations were made using the Statistica 13.3 package. Numerical characteristics, such as means and standard deviations were used to describe the groups. For a normal distribution, the significance of differences was tested using t-tests for dependent samples with $\alpha = 0.05$ as the level of significance. For other than normal distribution, the Wilcoxon test for dependent sample was used.

Results

Body mass and height, fat mass and fat-free mass content

Significant statistical differences were obtained in body mass, height and BMI. There was a statistically significant increase in fat free

mass and fat in kilograms (Table 3). However, percentages of fat free mass in relation to fat decreased.

Widths and circumferences of the body

In three width measurements carried out, shoulder width and chest width were similar, however, pelvis width increased by 2.5 mm, which was a statistically significant change. All of

the analysed body circumferences increased, and these differences were statistically significant (Table 4).

Circumferences of the upper and lower limbs

An increase in both the right and the left side of the body in the circumferences of the upper and lower limbs was statistically significant, with the exception of the right thigh (Table 4).

Widths of the upper and lower limbs

Statistically significant increases were recorded only in the width of the upper limbs and they were the width of both hands and both elbows. There were no statistically significant differences in the measurement of the width of lower limbs (the width of the foot and knee) (Table 4).

Skinfolds

There was an increase in the value of all the seven skinfolds measured. In four cases (shoulder, chest, abdomen and hip), the differences were statistically significant (Table 4).

Table 1

Number of participants in each judo weight category.

Weight categories	1 st Assessment (junior level)	2 nd Assessment (senior level)
52 kg	3	3 (2)
57 kg	1	0
63 kg	3	3 (2)
70 kg	3 (2)	1 (1)
78 kg	1	4 (3)
>78	1	1

↗ Number in parentheses represents the number of athletes whose weight exceeded the weight category limit

Table 2*Weekly training schedule during the preparatory period for female judo players.*

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
am 11:00-12:00	Rest	Training B	Training D		Training B	Training E	Rest
pm 17:30-19:00	Training A	Training C	Training E	Training A	Training C	Training D	

*Rest: Wellness;**Training A: Judo training for practice (technique and tactics);**Training B: Interval training consisting of sprint running (4 x 50 m, 4 x 100 m, 2 x 200 m and jogging, rest between each repetition was 1 min, 3 min, and 3 min, respectively, and 10 min rest intervals between sets);**Training C: Power training; Training D: Distance running for 30 min;**Training E: Judo training for practice (randori – combat training 4 min x 10, 2 min rest intervals between sets)***Table 3***Body mass and height, BMI and values of body fat content and fat free mass (mean \pm s; t or z; p) in female judokas as juniors and seniors.*

Variable	1 st Assessment (junior level)	2 nd Assessment (senior level)	t/z	p
Body mass (kg)*	63.43 \pm 12.28	70.73 \pm 16.50	-3.61	0.0041
Body height (mm)*	1655.42 \pm 82.35	1669.17 \pm 83.82	2.55(z)	0.0108
BMI *	23.34 \pm 3.03	24.99 \pm 4.34	-2.98	0.0125
Body fat (%)*	20.28 \pm 3.60	23.57 \pm 4.23	-5.47	0.0002
Body fat (kg)*	13.10 \pm 4.21	17.12 \pm 6.78	-3.91	0.0024
Fat free mass (%)*	79.72 \pm 3.60	76.43 \pm 4.23	5.47	0.0002
Fat free mass (kg)*	50.33 \pm 7.92	53.61 \pm 10.21	-2.99	0.0124

**statistically significant differences at $p < 0.05$; z – for the Wilcoxon test*

Table 4

Anthropometric characteristics of female judokas as juniors and seniors (mean \pm s; t or z; p).

Anthropometric variable	1 st Assessment (junior level)	2 nd Assessment (senior level)	t/z	p
<i>Body width and circumferences</i>				
Shoulder width (mm)	370.33 \pm 15.24	373.33 \pm 16.99	-0.95	0.3632
Chest width (mm)	268.25 \pm 15.03	269.92 \pm 15.20	-0.52	0.6106
Pelvis width (mm)*	251.66 \pm 19.32	254.16 \pm 19.19	-4.72	0.0006
Chest circumference at rest (cm)*	81.83 \pm 7.15	84.03 \pm 6.98	-3.35	0.0064
Chest circumference at inhale (cm)*	86.33 \pm 6.61	88.52 \pm 6.61	-4.66	0.0007
Chest circumference at exhale (cm)*	79.25 \pm 7.16	81.66 \pm 8.01	2.25(z)	0.0244
Chest depth (cm)*	168.92 \pm 28.51	179.67 \pm 27.87	2.74(z)	0.0060
Waist circumference (cm)*	72.83 \pm 7.74	77.08 \pm 9.25	-4.29	0.0013
Hip circumference (cm)*	96.58 \pm 6.97	102.08 \pm 9.88	-4.18	0.0015
<i>Values of upper and lower limbs' circumferences</i>				
Arm circumference R (cm)*	29.17 \pm 2.63	31.41 \pm 4.45	-3.14	0.0094
Arm circumference L (cm)*	29.17 \pm 2.94	31.56 \pm 4.75	2.86(z)	0.0042
Forearm circumference R (cm)*	25.42 \pm 1.84	26.48 \pm 2.58	-2.83	0.0163
Forearm circumference L (cm)*	24.96 \pm 1.94	26.38 \pm 2.59	-4.89	0.0005
Thigh circumference R (cm)	60.38 \pm 6.01	63.62 \pm 8.43	-1.78	0.1021
Thigh circumference L (cm)*	59.13 \pm 5.12	62.38 \pm 7.21	-2.71	0.0204
Lower leg circumference R (cm)*	36.13 \pm 3.11	38.13 \pm 4.23	-3.77	0.0031
Lower leg circumference L (cm)*	36.79 \pm 2.78	38.10 \pm 3.96	-2.64	0.0230
<i>Width measurements of upper and lower limbs</i>				
Hand width R (mm)*	77.42 \pm 5.00	79.83 \pm 4.47	-4.99	0.0004
Hand width L (mm)*	76.7 \pm 4.45	78.58 \pm 3.99	-3.63	0.0040
Elbow width R (mm)*	64.08 \pm 3.75	68.08 \pm 4.60	-4.34	0.0012
Elbow width L (mm)*	63.33 \pm 4.19	67.25 \pm 4.22	-4.88	0.0005
Foot width R (mm)	94.58 \pm 7.29	96.25 \pm 8.01	-1.77	0.1039
Foot width L (mm)	95.42 \pm 8.87	97.17 \pm 7.65	-1.95	0.0770
Knee width R (mm)	99.08 \pm 7.05	99.25 \pm 5.94	-0.13	0.9004
Knee width L (mm)	98.75 \pm 6.54	99.17 \pm 5.91	-0.38	0.7079
<i>Values of skinfolds</i>				
Arm fold (mm)	7.42 \pm 0.98	10.37 \pm 4.46	1.86(z)	0.0619
Shoulder blade fold (mm)*	10.85 \pm 4.93	14.54 \pm 6.58	2.93(z)	0.0033
Chest fold (mm)*	8.40 \pm 3.54	9.68 \pm 4.57	-2.39	0.0360
Abdomen fold (mm)*	12.15 \pm 4.65	17.72 \pm 9.83	-2.80	0.0171
Hip fold (mm)*	10.18 \pm 4.64	17.43 \pm 9.11	-3.63	0.0039
Calf fold (mm)	5.65 \pm 2.33	7.48 \pm 4.63	-2.05	0.0653
Knee fold (mm)	7.38 \pm 2.13	10.89 \pm 6.38	-2.13	0.0565

*statistically significant differences at $p < 0.05$; z – for the Wilcoxon test; R - right, L - left

Table 5
Body build components (mean ± s, t, p) in female judokas as juniors and seniors.

Measure	1 st Assessment (juniors)	2 nd Assessment (seniors)	t	p
Endomorpha*	2.9 ± 1.04	4.2 ± 1.65	-4.15	0.0016
Mesomorpha*	4.8 ± 1.31	5.6 ± 1.51	-3.21	0.0084
Ectomorpha	1.9 ± 1.01	1.5 ± 1.18	1.96	0.0754

* statistically significant differences at $p < 0.05$; z – for Wilcoxon test

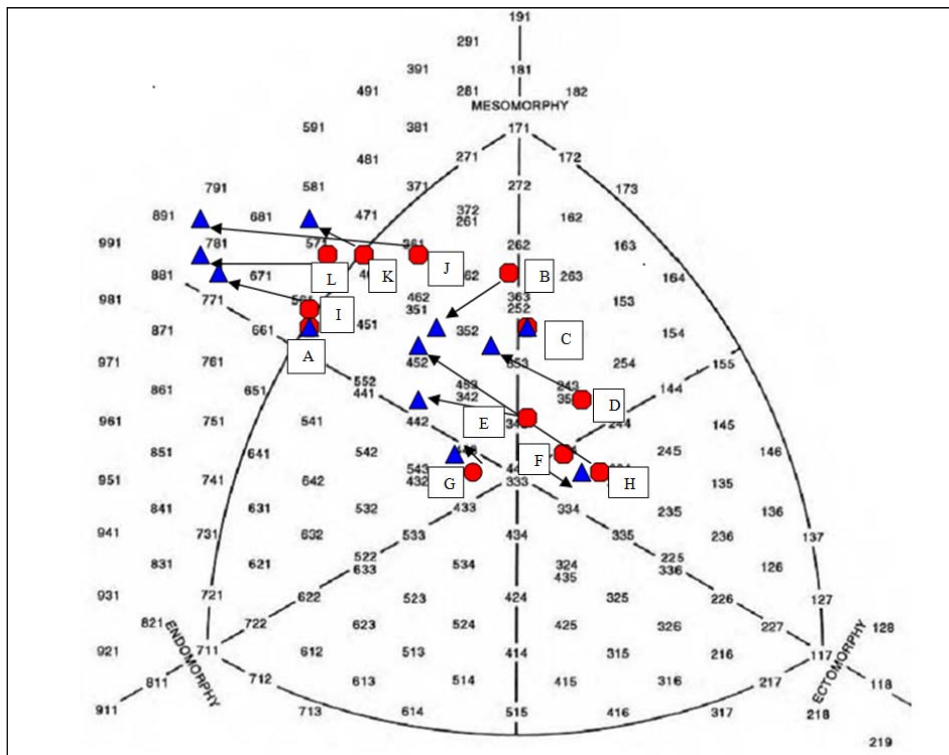


Figure 1

Changes between junior (●) and senior levels (▲) in individual somatotypes of studied female judo athletes.

Figure 1. Legend

- A ● 52 kg → ▲ 52 kg
- B ● 63 kg → ▲ 63 kg
- C ● 52 kg → ▲ 52 kg
- D ● 52 kg → ▲ 52 kg
- E ● 63 kg → ▲ 63 kg
- F ● 57 kg → ▲ 63 kg
- H ● 63 kg → ▲ 70 kg
- G ● 78 kg → ▲ 78 kg
- I ● +78 kg → ▲ +78 kg
- J ● 70 kg → ▲ 78 kg
- K ● 70 kg → ▲ 78 kg
- L ● 70 kg → ▲ 78 kg

Body build components

There was a statistically significant increase in the value of endomorphic and mesomorphic components. The ectomorphic component value was similar (Table 5).

As juniors, five female athletes were identified as endo-mesomorphic types, three were balanced mesomorphs, two had a meso-ectomorphic build, one had a central build and one showed an ecto-mesomorphic profile. As seniors, seven athletes did not change their build despite changes in the values of components used for calculating the body build. Four athletes were assessed as endo-mesomorphs, two as balanced mesomorphs, and one as a meso-ectomorph. The remaining athletes shifted towards endo-mesomorphs (3) and meso-endomorphs (2) (Figure 1).

Discussion

To the best of our knowledge, this is the first study to document changes in body structure that occurred between the junior and senior level of competition in the same group of elite female judo athletes. The observations made in the study will be particularly useful for talent identification and development in female competitive judo, specifically, for choosing a target weight category, and selecting optimal to the one's body type judo techniques.

In the studied sample, over the four years, several statistically significant differences were observed in a number of somatic features and body composition. The results revealed that, over the four-year transition period from junior to senior category, the average body mass, height, BMI, fat-free mass (in kg) and fat mass in female judokas significantly increased, but the percentage of fat-free mass significantly decreased. Bearing in mind the facts that judokas (both women and men) aim to maximize muscle mass and minimize the percentage of body fat (Franchini et al., 2011a) and that elite athletes tend to have lower body fat content compared to non-elite ones (Callister et al., 1991; Kubo et al., 2006), such change should be considered a disadvantage. The values of body fat content of seniors we studied (23.57%) were higher than for the Canadians (15.2%) and slightly higher than for the Brazilians (22.0%) (as cited in Franchini et al., 2011). Also Callister et al. (1991) presented lower values (15.2%) for elite female judo athletes.

However, their study did not examine athletes from three top weight categories; and for women from the categories of 56 kg and 61 kg they reported values close to 20%.

Individual analysis of the studied athletes indicated that five of them shifted, within four years, to a higher weight category. An average weight gain for the study participants was approximately 6 kg. However, the athletes of lower weight classes kept a similar body mass as juniors and seniors. Weight gain resulting in a change of weight category was most significant for the athletes of higher weight categories, with the largest increase from 92.3 to 111.2 kg (18.9 kg) observed for the heaviest athlete in the sample. It is worth adding that in terms of individual changes, body height increased by 1 cm in 11 athletes and by 9.1 cm in one athlete, with a body mass increase of 6.2 kg. It seems reasonable then to continue the observation of this group of participants in order to determine the ultimate values in the senior category.

All the measured circumferences of body and the limbs, and the width of the pelvis, increased in size by statistically significant values. There were no such increases in the width of the shoulder or the chest. The increase in the circumferences seems natural, considering both training and the weight gain in the group of study participants (body fat and fat free mass in kg). Interesting results were obtained in measurements of the width of the limbs. We found that statistically significant differences between junior and senior level dealt with the measurement of the upper limbs (hands and elbows width), but there was no such difference in the width of the lower limbs (feet and knees). On the one hand, lower limbs are strongly engaged in judo, since, as shown previously, a judo bout takes place primarily in a standing position and more points are earned in this position than in the groundwork (Adam et al., 2011; Adam et al., 2014) and on the other hand, the upper limbs are significantly involved during the bout as the athlete grips the opponent judoka, which provides the basis for the execution of throwing techniques (Bonitch-Góngora et al., 2012). Perhaps this unanticipated finding entails an early adaptation of lower limbs and the changes in the later years of training are not that substantial (Franchini et al., 2011b). Clearly, our

findings open the question of how the nature of training in judo contributes to the time dynamics in changes in widths of the upper and lower limbs (i.e., earlier vs. later in the career). The answer to this question would require longitudinal studies and should involve a young group of athletes (preferably just starting judo practice) at the initial assessment.

The measurements of skinfolds showed an increase of all the seven folds, and four folds manifested statistically significant differences. These unfavourable changes in the proportion of fat free mass and body fat content in the examined athletes might have been the result of the diet they had applied. Our consideration here would be also the athletes' and coaches' decisions on which category to enter the competition at the senior level. These decisions could potentially affect both dietary and training practices. Specifically, it should be noted that at the time of the 2nd Assessment, at the senior level, participants were still relatively young and it is very likely that in the nearest future they would aim to reduce the body fat content to replace it with muscle tissue in order to improve their performance (Franchini et al., 2011a). We should, however, take into account the fact that for five athletes, together with the change of the age group, they also changed their weight category to a higher one. Also, a change in their lifestyle must be noted: the sample were high school students at the time of the 1st Assessment and college students at the time of the 2nd Assessment. Some of them also changed their residence (change of the city, club) due to pursuing university education. These circumstances certainly influenced their diet and the specificity of training. Further analysis of the subjects would show whether these changes were only temporary. Therefore, future studies might include self-reported data (e.g., brief surveys or interviews with athletes, coaches, or both) to better understand the context of such transitions (especially surrounding the adolescence years) and further inform about the nature and dynamics of the observed anthropomorphic profiles.

There was a statistically significant increase in the endo- and mesomorphic components between the first and the second assessment. Franchini et al. (2011b) also found

higher values of the mesomorphic component for Spanish judo seniors than for juniors. Contrary to our study, the values of the endomorphic component for Spanish seniors were lower than for juniors. When comparing the results of these studies, two issues should be taken into account. First, Franchini et al. (2011b) studied different athletes (i.e., not the same sample examined longitudinally) and described their current condition, and the endomorphic component for Spanish and our seniors was similar and reached 3.8 ± 0.5 and 4.2 ± 1.65 , respectively. Second, the results we obtained from the present sample are a consequence of a previously identified increase in body fat mass and fat free mass.

Although Franchini et al. (2011a) cite the results for the mesomorphic component of their previous research of the Brazilian university team (1996) 5.0 ± 1.1 , for the Brazilian team (1999) 5.1 ± 0.9 and for the Spanish athletes 4.8 ± 0.3 (Franchini et al., 2011) and for the Polish female judo athletes 4.89 ± 1.21 (Sterkowicz-Przybycień and Almansba, 2011), the values of the mesomorphic component for our seniors (5.6 ± 1.5) are higher than those found in the literature. Firstly, the group we studied was highly selected and some of the judokas represented a high international sports level, and perhaps it is the type of their body build that gives them an advantage over their opponents. As the results of men's world top judokas show (Claessens et al., 1987), individual profiles of body build of such athletes often go beyond the somatogram, as it was observed for weightlifters (Keogh et al., 2007). Secondly, as Sterkowicz-Przybycień et al. (2012) indicate, despite the fact that women's judo is an Olympic sport since the 1988 Olympic Games in Seoul, data concerning somatotypes are scarce and it remains to be seen how our data can be more decisively interpreted.

Finally, based on a comparison of the somatograms of lighter and heavier female athletes, it can be concluded that the typology of lighter judokas focuses from the centre towards mesomorpha. However, heavier participants shifted in the second study towards endomorpha. It can also be seen that extreme endo-mesomorphic types included only athletes from 78 kg and plus 78 kg. This confirms suggestions made by other researchers (Claessens et al., 1987) about a general determination of the body build

of judokas, and yet with some specificity that is retained for particular weight categories. In this context, Callister et al. (1991) draw attention to the need to achieve a compromise between losing weight to meet competition limit and maximizing physiological capacities and performance. Taken together, it seems that the search for distinctive features in martial arts, not only of body build, should be done for each weight category separately.

Conclusion and practical implications

The results of this study showed that body composition and a number of somatic features of female judokas as seniors were not yet set at the junior stage. It is very likely that some changes that are important with regard to the skill level (especially the proportions of muscle mass to body fat content) occur only during the following years of training in the senior age category. These findings are important for coaches and can be used in applying, for example, proper training methods in seniors.

Another important observation is that the predominant type of body build is the endo-

mesomorphic type and changes that occurred in the sample took place mainly in accordance with this tendency. These results can help select proper techniques in juniors.

Greater differences obtained in the measurement of hand and elbow widths than of feet and knees widths, and a statistically significant increase in the width of the pelvis, may be due to the specific nature of judo training and explaining this issue would require future research that would involve younger age groups and utilize longitudinal designs along with both the anthropometric and contextual data. Thus, coaches should give special attention to morphological diversity of female judokas, which, on the one hand, could be a result of selection, and on the other hand, could be an outcome of adaptation to specific training loads (Jagięło et al., 2007). The information on how any specific training in judo influences body build will enable to improve judo athletes' performance in the future.

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