



THE DIFFERENCES IN FAT ACCUMULATION AND DISTRIBUTION IN FEMALE STUDENTS ACCORDING TO THEIR LEVEL OF ACTIVITY

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ABSTRACT

Purpose. The appropriate percentage of body fat is essential for women's health and biological condition. Both accumulation of fat and distribution pattern of adipose tissue are connected with health risk, which justifies the investigation and permanent monitoring of their diversity in different sub-populations. The aim of the study was to evaluate the percentage of body fat and its distribution in female students representing different physical activity levels. **Methods.** Fat proportion was estimated with use of classic anthropometric method and bioelectrical impedance analysis (BIA). The distribution of subcutaneous fat was calculated including waist and hip circumferences, and extremities and trunk skinfolds. The participants' level of physical activity was determined according to the IPAQ questionnaire. **Results.** Analysis showed that female students with medium level of physical activity had $26.5 \pm 5.1\%$ of total body fat estimated by BIA, whereas in the most active females almost 3% lower total body fat values were common. The bioelectrical impedance analysis indicated about 8% higher body fat content than classic anthropometry. Examined skinfolds revealed a tendency to decrease with increasing physical activity. The distribution pattern of subcutaneous fat varied according to level of activity. **Conclusions.** The study showed that estimation of fat content in young women differed depending on the applied method and the level of physical activity. We emphasize the need to select adequate reference data for measurement methods and consider the level of physical activity during fat percentage assessment. Another conclusion is that the high level of physical activity is connected with masculinization of subcutaneous fat pattern, both in extremities/trunk fat proportion and waist/hip proportion.

Key words: adiposity, BMI, WHR, skinfolds, body composition, female, physical activity

Introduction

Adiposity is conditioned by polygenic inheritance that causes high susceptibility to external factors among which diet and physical activity seem to be crucial. Maintaining an appropriate amount of body fat as well as distribution of fat tissue is important for one's good health and fitness [1–4]. During medical examination excessive fatness is diagnosed mainly on the base of body mass index (BMI), whereas a previous study showed that diagnostic values of the index varies in different subpopulations [5]. It is worth to noticed that frequencies of adiposity assessment connected with medical examination is not adapted to the dynamics of real changes in body composition. Moreover, the development of modern imaging techniques, allowing evaluation of visceral fat, diverted scientist's attention from subcutaneous fatness. However, some studies report the connection between the pattern of subcutaneous adiposity and health risk, which justifies the investigation of factors related to distribution of subcutaneous fat [1, 6]. The connection between adipose tissue, biological condition and physical

activity is multifarious and based on many various mechanisms [7].

The study of Kruschitz et al. [8] proved there are differences in subcutaneous fat patterns between young athletes and non-athletes. The abovementioned findings suggest that compared to BMI levels, subcutaneous fat patterns are a more accurate way of discriminating between young athletes and non-athletes. In women, the upper back and arms compartment were the best sites to discriminate between athletes and non-athletes [8]. Subcutaneous fat topography was also proven to be associated with decreased aerobic capacity [9].

The purpose of the study was to prove that higher level of physical activity is connected not only with decreased total body fat and subcutaneous fat, but also with a different subcutaneous fat distribution expressed by the extremity to trunk skinfold ratio. We assumed that highly active women are characterized by stronger reduction in subcutaneous fat in the extremities compared to the trunk, which can be explained by greater activity of the extremities than the trunk during sport exercises as well as by the fact that trunk fatness constitutes fat storage that secures fertility in women. The second aim of the study was to check the diagnostic value of widely used indexes BMI and WHR in a group of women with different level of physical activity.

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Material and methods

Participants

The survey contains results from cross-sectional anthropological measurements as well as a questionnaire study conducted among first-year female students ($N = 255$) of the University School of Physical Education in Wrocław, Poland (Faculty of Physical Education $N = 176$; Faculty of Sport $N = 45$), and the Medical University in Wrocław (Faculty of Health Sciences – studies in nursing $N = 34$). All the students who gave their informed consent were included in the study. The questionnaire study enabled the authors to excluded females which were on slimming or other special diets. Mean age of the examined women was 20.0 ± 1.0 years. All students underwent medical examination before they participated in the study and were recognized as healthy. The study was approved by the appropriate Ethics Committee. Females were informed of the benefits and risks of the investigation and were given an explanation of their own data.

Measurements and procedure

The anthropometric measurements were performed using the Martin-Saller method [10]. Body height ($B-v$) was measured with an anthropometer and circumferences with an anthropometric tape (to the nearest 0.1 cm; Siber Hegner Machinery Ltd., UK), skinfold thickness with a Tanner/Whitehouse skinfold caliper (Holtain, UK, with 0.2 mm graduation). Body mass was measured with an electronic weighing scale (to the nearest 0.1 kg). Body fat estimation was performed with a BIA-101 Anniversary Sport Edition analyzer (Akern, Italy) in the standard conditions recommended by the producer. Tissue analysis was performed using the Bodygram 1.3.1. software package with the Akern analyzer.

The results of anthropometric measurements enabled the authors to assess body composition using the classic anthropometric method. Fat mass (FM) and fat free mass (FFM) proportions were estimated on the basis of Slaughter–Lohman–Boileau regression equation for body fat in females as follows [11]:

$$\text{Fat (\%)} = 1.33^* (\text{triceps skinfold} + \text{subscapular skinfold}) - 0.013^* (\text{triceps skinfold} + \text{subscapular skinfold})^2 - 2.5$$

The massiveness of body build and type of fat distribution around the waist and hip were estimated, according to WHO recommendations, on the basis of Body Mass Index (BMI) and Waist-Hip Ratio (WHR) [12, 13]. The distribution of subcutaneous fat between the extremities and trunk was also estimated on the base of subcutaneous fat distribution index. Values below 100 mean predominance of trunk fatness, and the smaller the val-

ues of this index, the larger the difference between subcutaneous adiposity of trunk and extremities.

$$\text{Subcutaneous fat distribution index} = \frac{(\text{triceps skinfold} + \text{calf skinfold})}{(\text{subscapular skinfold} + \text{suprailiac skinfold})} \cdot 100$$

The participants' level of physical activity was determined using a shorter form of the International Physical Activity Questionnaire (IPAQ, Polish version) [14]. According to the protocol, participants were previously divided into groups with different level of physical activity (minimally active, HEPA active = health enhancing physical activity) [14, 15]. With regard to the high percentage of women involved in competitive sport and a wide range of MET-min/week that characterized the examined group of female students, we decided to divide HEPA active women into: medium active group (1500–3000 MET-min/week; $N = 76$) and highly active group (more than 3000 MET-min/week; $N = 90$). Minimally active group consisted of 49 females.

Statistical analysis

Means and standard deviations (SD) of the measured characteristics in the three groups of women were calculated. The compatibility of distribution of the analyzed data with normal distributions was checked with the Shapiro–Wilk test. Levene's test was used to check the homogeneity of variances. In order to investigate the differences between groups of women with various levels of physical activity, parametric statistical tests (ANOVA, post-hoc Scheffe test) and nonparametric tests (Kruskal–Wallis test, nonparametric test for multiple comparisons) were used. Statistical significance was set at $p < 0.05$. Statistical analyses were carried out with the StatSoft® Statistica 12 software. The obtained results were presented in charts using Microsoft® Office Excel 2003.

Results

The analyzed groups of women characterized by various levels of physical activity did not differ in age (ANOVA; $F = 1.57$; $p = 0.2096$), body height (ANOVA; $F = 1.18$; $p = 0.3102$), BMI and WHR (Table 1). The women's average body height ($B-v$) amounted to 168.1 ± 6.5 cm, the mean BMI was 21.5 ± 2.3 kg/m². The majority of women (87%) had normal body weight according to BMI categories (WHO). The mean WHR was 0.735 ± 0.058 , which is a correct value for young women.

Although the groups of women did not vary significantly in body mass (ANOVA; $F = 1.11$; $p = 0.3312$), the average body mass tends to increase as the level of activity increases: 59.3 kg in minimally active, 59.7 kg in medium active and 61.2 kg in highly active.

Table 1. Body Mass Index and Waist-Hip Ratio in groups of women with various levels of physical activity

Index	Mean \pm SD			ANOVA	
	minimally active	medium active	highly active	F	<i>p</i>
BMI (kg/m ²)	21.6 \pm 2.5	21.7 \pm 2.2	21.6 \pm 2.5	0.05	0.9551
WHR	0.73 \pm 0.05	0.73 \pm 0.04	0.74 \pm 0.07	1.19	0.3062

Table 2. The thickness of skinfolds and body composition in groups of women with various levels of physical activity

Skinfolds (mm)	Mean \pm SD			F*/H**	<i>p</i>
	minimally active	medium active	highly active		
Subscapular	11.9 \pm 3.7	10.8 \pm 3.0	9.3 \pm 2.4	6.20*	0.0024
Triceps	11.6 \pm 3.5	9.9 \pm 3.9	8.2 \pm 2.9	26.25**	0.0000
Abdomen	15.3 \pm 4.4	13.5 \pm 4.8	11.4 \pm 4.1	4.39*	0.0135
Suprailiac	12.0 \pm 4.6	11.9 \pm 4.9	10.2 \pm 3.5	8.61**	0.0135
Calf	10.0 \pm 3.5	8.4 \pm 3.0	7.1 \pm 2.6	14.88*	0.0000
Body composition (skinfolds thickness)					
FFM (%)	80.9 \pm 4.4	81.4 \pm 4.9	83.5 \pm 3.9	7.26*	0.0009
FM (%)	19.1 \pm 4.4	18.6 \pm 4.9	16.5 \pm 3.9	7.26*	0.0009
Body composition (BIA)					
FFM (%)	72.6 \pm 5.3	73.3 \pm 5.0	75.3 \pm 5.2	5.61*	0.0042
FM (%)	27.4 \pm 5.3	26.7 \pm 5.0	24.7 \pm 5.2	5.61*	0.0042

* ANOVA, ** Kruskal–Wallis test

Women declaring the highest physical activity level were characterized by the lowest subcutaneous fatness. They had the slimmest subscapular skinfold, triceps skinfold, suprailiac and abdomen skinfolds and calf skinfold (Table 2). All the examined skinfolds revealed a tendency to decrease as physical activity increases (Table 2). The differences in subcutaneous fatness between women declaring a medium physical activity and women declaring the highest activity level amounted to 2–4 mm. Detailed post-hoc test results are presented in Table 3.

Subcutaneous fat distribution index (SFDI) revealed a wide range of variability of fat distribution between the trunk and the extremities (Figure 1; min = 36.2; max = 195.2). In the majority of examined female students, the subcutaneous fat tissue of the extremities was lower than the subcutaneous fat tissue of the trunk, which is showed by SFDI values < 100 (Figure 1). In minimally active, medium active and highly active group this index differs significantly (Figure 2; Kruskal–Wallis test $H = 17.825$; $p = 0.0001$). The differences were most visible in minimally active women, while the highly active women displayed similar fat pattern as medium active group (Figure 2). HEPA active groups (medium and high level of activity) had on the average about 20% slimmer skinfolds in the extremities than in their trunk, whereas minimally active women mostly had similar skinfolds in the trunk and the extremities (SFDI = 95.7).

The average body fat content according to BIA in all examined women amounted to 26.1% \pm 5.2%. Body fat (FM), estimated both on the basis of regression equations and BIA, also decreased as the level of physical activity increased (Table 2). Women who were the least active had 2.6% more fat mass than the vigorously active women when using classic anthropometry, and 2.7% more when using BIA (Table 2). Women characterized by the highest level of physical activity were most muscular, i.e. they had more fat free mass than the others. Detailed post-hoc test results are presented in Table 3. Individual values of fat content estimated with BIA were higher than values estimated with classic anthropometry. The differences between these two methods were similar in all groups of women (8.3% in the group of the most active women, 8.1% in the less active, and 8.2% in the least active women).

Discussion

The multiplicity of body fat estimation methods with their varied reference values often causes confusion. Although there is a proven moderate concordance between results obtained with different methods, concrete results obtained with the use of these methods vary [16–18]. Frisch claims, without referring to any particular measurement method, that more than

Table 3. Detailed results of the post-hoc test of significance of differences between groups of women. The numbers in the table are values of probability (*p*)

Variables		Physical activity		
		minimally	medium	highly
Subscapular skinfold* (mm)	minimally		0.9964	0.1386
	medium	0.9964		0.0448
	highly	0.1386	0.0448	
Triceps skinfold** (mm)	minimally		0.0000	0.0186
	medium	0.0000		0.0723
	highly	0.0186	0.0723	
Abdomen skinfold* (mm)	minimally		0.8889	0.0376
	medium	0.8889		0.0624
	highly	0.0376	0.0624	
Suprailiac skinfold** (mm)	minimally		0.0000	0.0133
	medium	0.0000		0.0263
	highly	0.0133	0.0263	
Calf skinfold* (mm)	minimally		0.2225	0.0006
	medium	0.2225		0.0006
	highly	0.0006	0.0006	
FFM (skinfolds)* (%)	minimally		0.7854	0.0042
	medium	0.7854		0.0120
	highly	0.0042	0.0120	
FM (skinfolds)* (%)	minimally		0.7854	0.0042
	medium	0.7854		0.0120
	highly	0.0042	0.0120	
FFM (BIA)* (%)	minimally		0.9038	0.0413
	medium	0.9038		0.0993
	highly	0.0413	0.0993	
FM (BIA)* (%)	minimally		0.9038	0.0413
	medium	0.9038		0.0993
	highly	0.0413	0.0993	

* Scheffe's test, ** Wilcoxon rank sum tests for multiple comparisons

26–28% of body fat may negatively influence the reproductive ability of young women [19]. Jeukendrup and Gleeson classified > 30% body fat content in women as overweight [20].

In the present study, according to bioelectrical impedance analysis, young women had an average of 26.1% ± 5.2% body fat. The fat content in women varied significantly depending on the level of their physical activity. Less active women had little more than 27% body fat, whereas the most active women had almost 3% less fat. Applying BIA in their study, Lukaski et al. [21] estimated body fat in American women at 25.1%, whereas it amounted to 26.05% in young Polish women examined by Major-Gołuch et al. [22]. The body fat content estimation in Polish women obtained with the use of DXA method was slightly higher (32.05%) [22]. In a South African study, healthy active women were shown to

have 29.5% of body fat with the use of the DXA method, but 28.4% with the use of the near infrared reactance method [16], whereas resistance-trained women from the same study had 10% less body fat and 5.5% less body fat, respectively [16]. Scientists from the Czech Republic showed that elite female players in five different sports games were characterized by 20–21% of fat mass in BIA 2000 M estimation [23], whereas in the study of Buško and Lipińska female volleyball players had about 29% body fat according to BIA with use of Tanita TBF-300 [24]. According to Lugito et al., female and male students with low-moderate activity had a higher risk of obesity compared to students with high activity [25]. Friedl et al. revealed a 2% decrease in body fat content after a few weeks of combat training in women [26], whereas Gutin et al. proved that the lower adipose tissue level was mainly connected with the frequency of vigor-

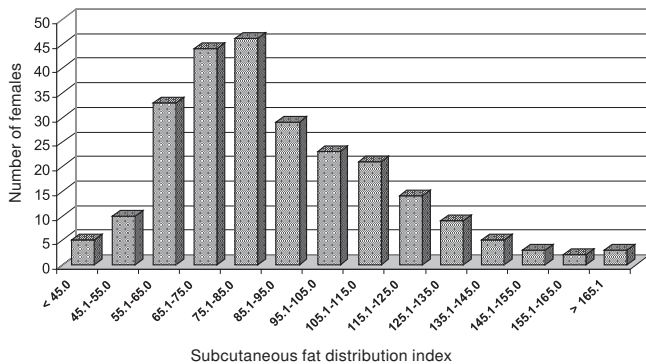


Figure 1. The distribution of subcutaneous fat distribution index between the extremities and the trunk in the examined female students

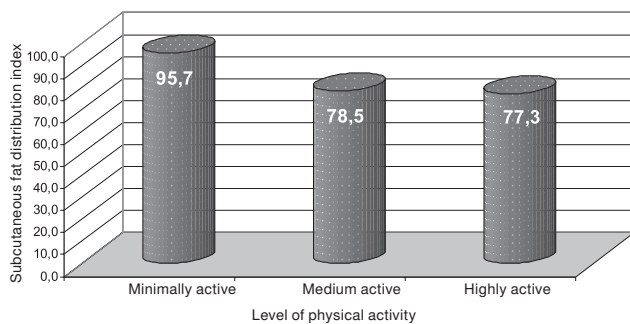


Figure 2. Subcutaneous fat distribution index in groups of women with various levels of physical activity (it reflects the relation between the extremities and trunk subcutaneous adiposity)

ous activity, but not with the intensity of moderate activity, which was also revealed in our study [27]. A similar suggestion was made by Ness et al., who claimed that physical activity of higher intensity may be more important for obesity prevention than the total amount of activity [28].

Fat content in women estimated in the present study on the basis of skinfolds thickness was lower by about 8% compared with the BIA results. The women under study who were the most physically active featured the thinnest skinfolds. The differences in skinfold thickness between the most and the least active women amounted to 2.0–4.0 mm and were the most visible in triceps, abdomen and calf skinfolds. According to Kruschitz et al., in women, the upper back (subscapular) and arms (triceps) skinfolds provided the strongest discrimination between athletes and non-athletes [8]. In another study the thickness of subscapular skinfold as well as total body fat also correlated negatively with the level of physical activity connected with sport or work [16, 29]. According to Washburn et al., students who declared higher physical activity than their counterparts had simultaneously significantly lower values of triceps skinfold thickness and resting heart rates [30]. However, on the basis of our previous study we concluded that athletes doing some sports were characterized by a higher

content of body fat, as compared with active but not trained women [31].

Despite the differences in body fat content between more active and less active female students, they did not differ significantly in the aspects of body massiveness (BMI) and shape (WHR). This proved that the mentioned indices are not appropriate tools to estimate fat content in this group of women. It was probably caused by some diversification of the aforementioned features in the studied group. The vast majority of subjects (90%) had normal weight according to WHO [12]. Fewer than 3% of women had WHR values outside the range of 0.7–0.8, which means that they had correct body fat distribution between the waist and hips for their sex and age [13]. The use of body weight and BMI as a diagnostic tool for overweight and obesity has been previously criticized, particularly in athletic populations [32]. Unlike in the female students in the present study, the increasing BMI values together with the decreasing level of physical activity were found in middle-aged adults [28, 33]. Choi et al. indicated a protective role of increased physical activity in women whose body weight increases during the midlife years [34].

The evaluation of fat distribution on the basis of the subcutaneous fat distribution index revealed that the subcutaneous fatness pattern in the trunk and the extremities strongly depends on the level of physical activity. We noticed that a high level of physical activity mainly reduces fat accumulation in the extremities, because trunk fatness constitutes fat storage that secures fertility in women. However, with regard to WHR, it is worth mentioning that there is a slight tendency toward increased android fatness in the most active women, which means that the very high level of physical activity promote the reduction in fat accumulation in the place specific for women, i.e. the hips. Trichopoulou et al. indicated earlier that WHR values strongly depended on the level of physical activity in males, but not in females, which was probably caused by the hormonal influence [35].

The subcutaneous fat distribution index revealed a wide range of variability of fat distribution between the trunk and the extremities. In the majority of examined female students the subcutaneous fat tissue of the extremities was lower than the subcutaneous fat tissue of the trunk. Values of SFDI less than 100 mean predominance of trunk fatness, and the smaller the values of this index, the larger the difference between subcutaneous adiposity of the trunk and the extremities. The mentioned tendency can be interpreted as masculinization of subcutaneous fat pattern [36]. In previous studies females were characterized by thicker extremities skinfolds comparing to males, whereas the thickness of trunk skinfolds were similar in both sexes [37].

In this study the pattern of subcutaneous fat distribution among trunk and extremities depends on the level of activity. The differences between trunk and extremities skinfolds were more visible in HEPA women (me-

dium and highly active). Their subcutaneous fat distribution index (about 77–78) was lower than in minimally active group (about 95), which made their fatness pattern masculinized [38]. As it was proven in our previous study, the subcutaneous fat distribution index is about 50–60 in male athletes [38].

Conclusions

The results of the present study showed that estimation of fat content differed depending on the applied method and the level of physical activity. Therefore we emphasize that during body fat content analysis one should pay attention to using appropriate reference values adequate to the applied method and measurement device. The fat content estimated by bioelectrical impedance analysis is about 8% higher than the body fat content estimated on the basis of anthropometric measurements of skinfolds. On the basis of BIA method we showed that female students from the University School of Physical Education and Medical University were characterized by average amount of $26.1\% \pm 5.2\%$ body fat, whereas in the most active females about 3% lower values of total body fat, comparing to minimally active group, were common. We also showed that the commonly used in medical practice indexes estimating fatness (BMI, WHR) are not appropriate tools for evaluation of fat tissue in this group of women. We also concluded that high level of physical activity is connected with masculinization of the subcutaneous fat pattern, both in extremities/trunk fat ratio and waist/hip ratio. Reduction in fat accumulation in the extremities is more visible because trunk fatness constitutes fat storage securing women's fertility.

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