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Agreement of measures between measured body adiposity and calculated indices of fatness in sedentary and active male and female students

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Abstract

Study aim: Our study was undertaken to analyze agreement between measured body fat and different indices of fatness in students of both sexes and with different physical activity.
Materials and methods: A total of 330 students not engaged in regular physical activity (150 males and 180 females) and 356 students (180 males and 176 females) engaged in regular physical activity due to their study program (5–7 h/week) were recruited. In all participants body adiposity was measured from skinfold thickness. In addition, calculated indices of fatness based on waist (WC) and hip circumference (HC), such as abdominal volume index (AVI), body adiposity index (BAI) and relative fat mass (RFM) were calculated.
Results: The analysis of Bland-Altman plots revealed that agreement between measured and calculated body fat was found for RFM and BAI in sedentary and active men and for BAI in sedentary women, but not for measured body fat and RFM in sedentary women and for RFM and BAI in active women.
Discussion: Our study showed that in young adult Poles of both sexes and with different physical activity, the calculated obesity rates should be used with caution, especially in women, as an indicator of total body fat.

Keywords: Males – Females – Physical activity – Indices of fatness – Bland-Altman plots

Introduction

All over the world it is well documented that excessive body fat stores adversely affect the health status with the special impact of visceral fat [31]. Body fat content and mainly the fat distribution or adiposity can therefore be considered as important indicators of health risk. Several studies have shown a linkage between the accumulation of body adipose tissue, adverse metabolic events and an elevated risk for cardiovascular disease also among young people [2, 41]. Therefore analysis of the various components of body composition, especially the fat content, has become an important research topic among health researchers and practitioners. Many methods of accurately determining body composition are known, such as magnetic resonance imaging, computed tomography, dual energy x-ray absorption, isotope measurements of body water, whole body plethysmography, bioelectric impedance analysis and underwater weighing. Despite the benefits of accuracy, their application in clinical practice is limited due to the cost and time involved. For this reason, studies often use indicators to easily calculate the approximate amount of body fat in men and women. Several indicators have been developed to assess body fat or obesity, including body mass index (BMI), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR), relative fat mass (RFM) and body adiposity index (BAI). The search for the most useful methods is currently the subject of numerous studies [6, 30].

Bland-Altman plots [3, 4, 13] showing the relationship between two different measurement methods are widely used in medical research. Additionally, Bland-Altman analysis is a simple and accurate way to quantify the agreement between two variables and can help clinicians compare a new measurement method with another method or with a reference standard. It has been applied to compare methods of blood pressure measurement, heart rate monitoring, artery-flow-mediated dilation and orthopedic surgery [11, 29, 34]. Additionally, it was also used to test

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agreement between different methods evaluating dietary habits [17, 18]. Sőgũt et al. [43] using Bland-Altman plots indicated that except for the waist-to-hip ratio, other indices of fatness such as abdominal volume index (AVI), body mass index (BMI), body roundness index (BRI), waist-to-height ratio (WHtR) were associated with body adiposity measured using bioelectrical impedance analysis (BIA). Similarly, Bland-Altman plots were used by Raschka et al. [39] to compare near infrared spectroscopy (NIRS), bioelectrical impedance analysis (BIA) and calipermetry in the measurement of body composition in male office workers. However, according to our best knowledge, in the Polish population the Bland-Altman method of anthropometric data agreements were used in children, adolescents and elderly persons with health problems but not in young adults [19, 24, 37, 40].

Purpose of the study

Thus, our study was undertaken to analyze agreement between measured body fat and relative fat mass (RFM) and body adiposity index (BAI) in students of both sexes and with different physical activity using Bland-Altman plots.

Materials and methods

Participants

The participants were recruited among students of both sexes on the basis of word-of-mouth and advertisements in student dormitories. All participants declared no health problems, no smoking and not taking supplements on a regular basis. A total of 356 active students (180 males and 176 females) were recruited from the Faculty of Physical Education. Their physical activity was briefly established from self-reported weekly hours of different activities according to the study program and equaled 5–7 h/week. They participated in different forms of physical activity according to their study program (swimming, games, martial arts and running). Students engaged in high performance sports were excluded from the study. A total of 330 sedentary students (150 males and 180 females) not engaged in any regular activity were recruited from other universities and colleges. Before the study all subjects provided their written consent for participation in all procedures. The project received a positive opinion on the compliance with the rules of ethics of the Senate Ethics Committee for Scientific Research of the Józef Piłsudski University of Physical Education in Warsaw. The study was conducted and financed as the DS-230 project included in the statutory activity in the Józef Piłsudski University of Physical Education in Warsaw.

Anthropometric measurements

In all students the weight was measured to the nearest 0.5 kg and the height to the nearest 0.5 cm using standard medical equipment. During the measurements, the study participants wore light underwear and were barefoot. In addition, waist (WC) and hip circumferences (HC) were measured in all participants. The WC was measured in the midway section between the lower edge of the ribs and the iliac crest with an accuracy of 0.1 cm using non-stretchable tape and values <102 cm were accepted as normal. The HC was measured to the nearest 0.1 cm at the largest circumference around the buttocks using non-stretchable tape. During both measurements students wore light clothes. All measurements were taken by a trained technician and were repeated twice but in the case of discrepancy were repeated for the third time.

Waist-to-hip ratio (WHR) was calculated by dividing waist circumference by hip circumference – both in centimeters [45]. Waist-to-height ratio WHtR was calculated by dividing waist circumference by height in centimeters [5]. Abdominal volume index (AVI) was calculated according to following formula [16]:

$$AVI = [2 \cdot WC^2 + 0.7 \cdot (HC - WC)^2]/1000.$$

Formula for body adiposity index [7] is:

$$BAI = [HC\ [cm]/height\ [m]^{1.5} - 18.$$

Relative fat mass (RFM) was calculated according to Woolcott and Bergman [46] and the following formula:

$$RFM = 64 - [20 \cdot (height/waist\ circumference\ 0 + 12 \cdot sex],$$

sex = 0 for males and 1 for females.

Additionally, in all participants the body fat percentage was determined from the sum of the thickness of four skinfolds (biceps, triceps, suprailiac and subscapular) measured using the Harpenden Skinfold Caliper (British Indicators, Burgess Hill, UK) and calculated according to the Durnin and Womersley formula [14]. All measurements were repeated twice but in the case of discrepancy were repeated for the third time and were done by a trained technician. Lean body mass (LBM) was calculated by subtracting fat weight from body weight.

Data analysis

All data were tested for normality using the Shapiro-Wilk test. Statistical significance of sex-related differences was tested using the Mann-Whitney test. Data are presented as mean ± SD. A P value ≤ 0.05 was considered significant. Quantification of the agreement between percentage of body fat and calculated indices of fatness was evaluated using the Bland-Altman procedure [3, 4, 8]. All calculations were carried out using Statistica v.12 (Statsoft, Illinois, USA).

Results

In sedentary students there were significant sex-related differences in average body mass (85.0 vs. 61.4), height (179.2 vs. 166.3) and LBM (66.6 vs. 43.5) in male vs. female sedentary subjects (P < 0.001. (Table 1). Despite a significantly lower percentage of body fat (21.4 in males vs. 26.6 in females) male participants were characterized by higher WC (78.3 vs. 72.4), HC (98.9 vs. 95.0), WHR (0.88 vs. 0.76) and WHtR (0.49 vs. 0.44) and AVI (15.3 vs. 11.0). In contrast, BAI and RFM in males were lower than in females (BAI 23.2 vs. 26.4, RFM 23.4 vs. 29.8).

The analysis of Bland-Altman plots in sedentary males revealed that agreement between measured and calculated body fat was noted for RFM and BAI (Bland-Altman index = 3,33% for RFM and 3,33% for BAI) (Fig. 1 and 2). Similarly, in sedentary women agreement between measured and calculated indices of body fat was observed for BAI (Bland-Altman index = 4,44% for BAI) (Fig. 4) but not for RFM (Bland-Altman index = 6,11% for RFM (Fig. 3).

In active students significant sex-related differences were observed between body mass (78.2 in males and 61.0 in females), height (181.7 vs. 168.1) and LBM (68.0 vs. 46.8, P < 0.001) (Table 2). Despite significantly lower measured adiposity (13.0 in males and 23.3 in females, P < 0.001) males were characterized by higher WC (80.0 vs. 71.1), HC (94.3 vs. 90.1), WHR (0.85 vs. 0.79), WHtR (0.44 in males and 0.42 in females, P<0.001) and higher AVI (13.1 vs. 11.0, P < 0.001). On the contrary, BAI and RFM in males were markedly lower than in females (BAI 20.6 vs. 23.4, P < 0.001) and RFM (18.6 vs. 28.7), P < 0.001). Analysis of agreement between measured and calculated indices of adiposity using Bland-Altman plots indicated that it was noted for RFM and BAI exclusively in active males (Bland-Altman index = 5% for RFM and 3,88% for BAI) (Fig. 5 and 6) but not in active women

Table 1. Characteristics of sedentary male and female students (mean ± SD)

Variables	Males (n = 150)	Females (n = 180)
Age [years]	23.4 ± 2.8 [a]	22.1 ± 1.9
Weight [kg]	85.0 ± 12.8 [a]	61.4 ± 11.8
Height [cm]	179.2 ± 4.8 [a]	166.3 ± 5.9
Fat [%]	21.4 ± 5.6 [a]	26.6 ± 7.2
Fat [kg]	18.2 ± 5.7 [a]	17.1 ± 7.6
LBM [kg]	66.6 ± 10,3 [a]	43.5 ± 4.9
WC [cm]^	87.3 ± 7.9 [a]	72.4 ± 9.1
HC [cm]	98.9 ± 7.2 [a]	95.0 ± 9.1
WHR	0.88 ± 0.05 [a]	0.76 ± 0.07
WHtR	0.49 ± 0.04 [a]	0.44 ± 0.06
AVI	15.3 ± 2.7 [a]	11.0 ± 2.8
BAI	23.2 ± 3.2 [a]	26.4 ± 4.4
RFM	23.4 ± 4.0 [a]	29.8 ± 5.3

Abbreviations: LBM – lean body mass; WC – waist circumference; HC – hip circu-mference; WHR – waist-to-hip ratio; WHtR – waist-to-height ratio; AVI – abdominal volume index; BAI – body adiposity index; RFM – relative fat mass; [a] P < 0.001 – significantly different vs. females.

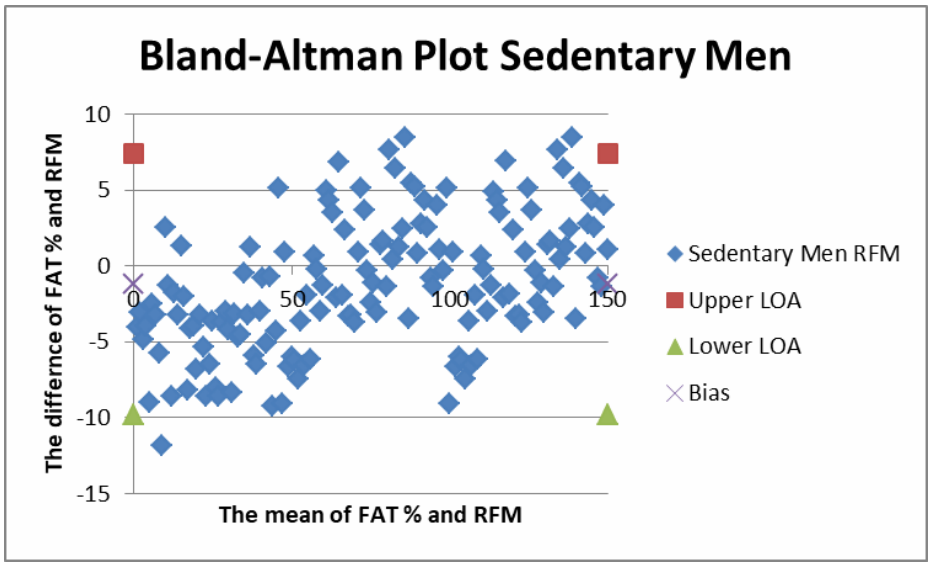


Figure 1. Bland-Altman Plot of agreement between FAT % and RFM in sedentary men

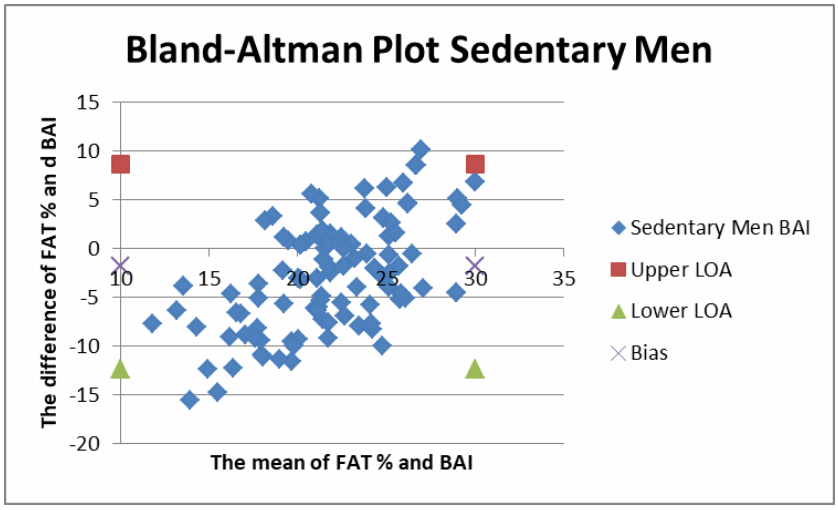


Figure 2. Bland-Altman Plot of agreement between FAT % and BAI in sedentary men

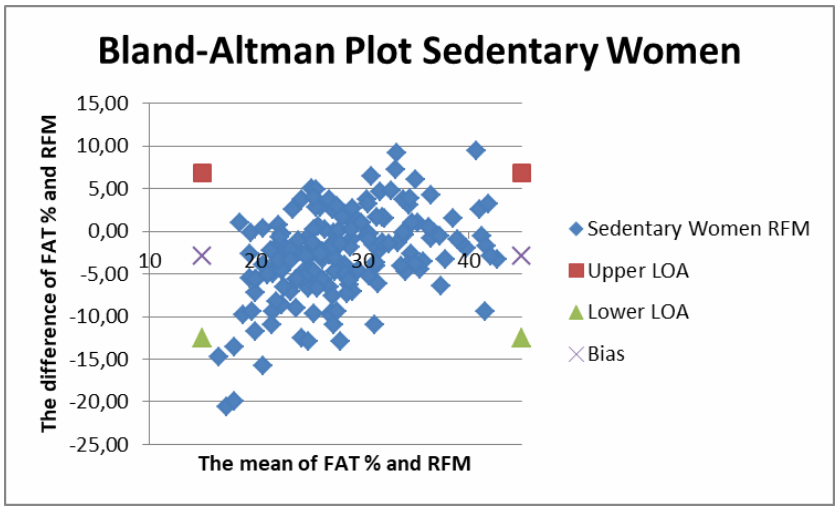


Figure 3. Bland-Altman Plot of agreement between FAT % and RFM in sedentary women

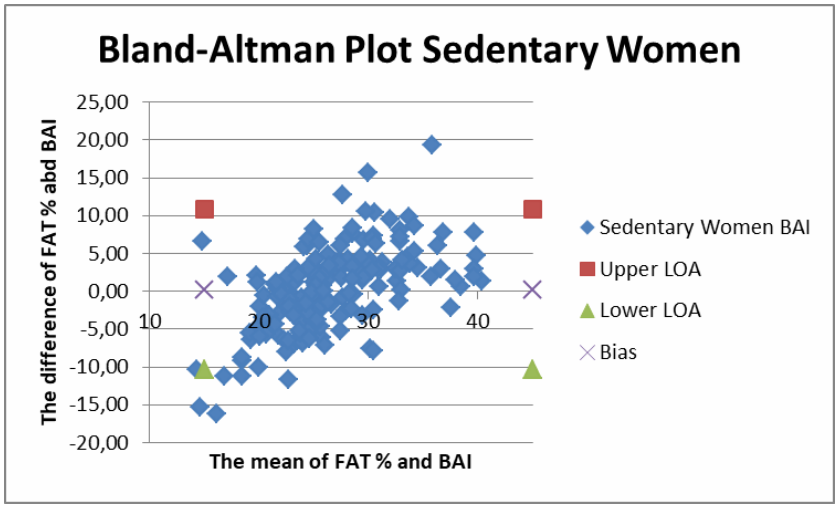


Figure 4. Bland-Altman Plot of agreement between FAT % and BAI in sedentary women

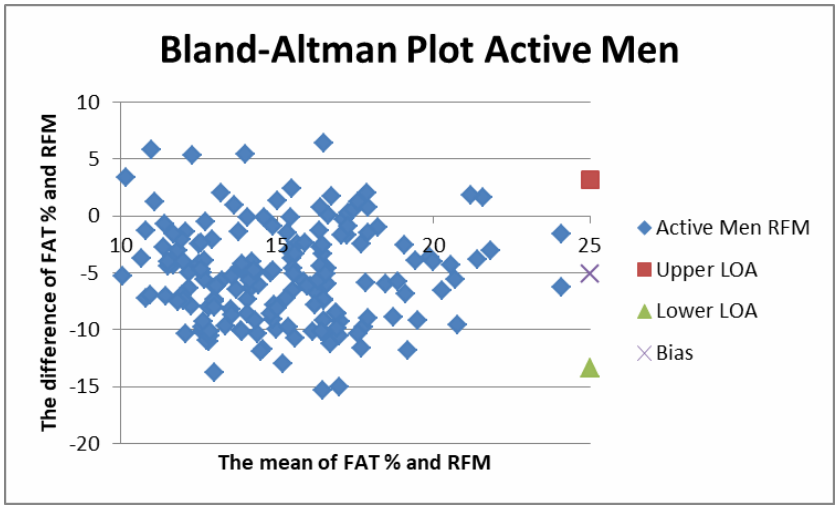


Figure 5. Bland-Altman Plot of agreement between FAT % and RFM in active men

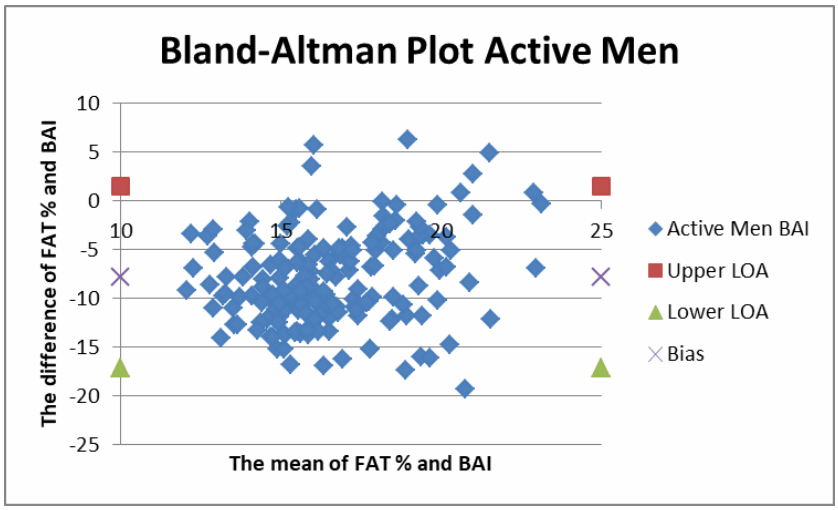


Figure 6. Bland-Altman Plot of agreement between FAT % and BAI in active men

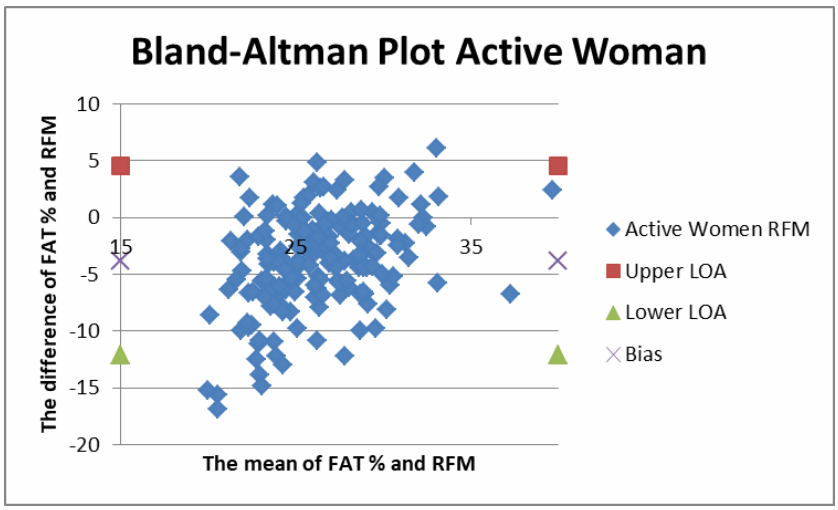


Figure 7. Bland-Altman Plot of agreement between FAT % and RFM in active women

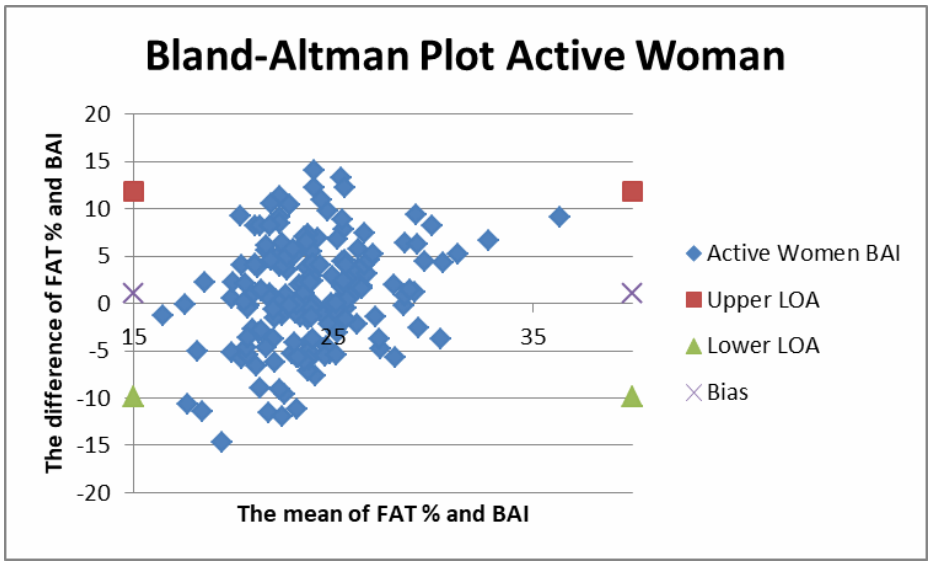


Figure 8. Bland-Altman Plot of agreement between FAT % and BAI in active women

Table 2. Characteristics of physically active male and female students (mean ± SD)

Variables	Males (n = 180)	Females (n = 176)
Age [years]	20.7 ± 1.7 [a]	20.4 ± 1.4
Weight [kg]	78.2 ± 9.8 [a]	61.0 ± 7.9
Height [cm]	181.7 ± 6.4 [a]	168.1 ± 5.7
Fat [%]	13.0 ± 4.2 [a]	23.3 ± 5.1
Fat [kg]	10.2 ± 4.5 [a]	14.2 ± 4.8
LBM [kg]	68.0 ± 6.9 [a]	46.8 ± 4.4
WC [cm]^	80.0 ± 6.6 [a]	71.1 ± 5.8
HC [cm]	94.3 ± 6.4 [a]	90.1 ± 7.7
WHR	0.85 ± 0.06 [a]	0.79 ± 0.07
WHtR	0.44 ± 0.04 [a]	0.42 ± 0.03
AVI	13.1 ± 2.2 [a]	10.4 ± 1.7
BAI	20.5± 2.9 [a]	23.3± 3.5
RFM	18.6 ± 3.7 [a]	28.7 ± 3.5

Abbreviations: LBM – lean body mass; WC – waist circumference; HC – hip circumference; WHR – waist-to-hip ratio; WHtR – waist-to-height ratio; AVI – abdominal volume index; BAI – body adiposity index; RFM – relative fat mass; [a] $P < 0.001$ – significantly different vs. females.

(Bland-Altman index = 6,25% for RFM and 5,68% for BAI) (Fig. 7 and 8).

Discussion

Our study yielded the following important conclusions. Firstly, among the analyzed indicators of fatness, in the group of men regardless of the level of physical activity, RFM and BAI agree with total body obesity. In the group of sedentary women, such compliance was demonstrated only for BAI, and not for RFM. However, in the group of active women, no compliance was found for the total body obesity, as well as for RFM and BAI. This discovery is clearly supported by the Bland-Altman plots.

Secondly, both in sedentary and active males WC, WHtR and AVI are higher than in females, despite lower measured body fatness, thus cannot be used to determine sex-related differences in body adiposity. In contrast, BAI and RFM are lower in males vs. females similarly to body adiposity.

Both findings are important for anthropometry practice facilitating the choice of proper methods of body fat measurements in young adults. It is well documented that the most commonly used measure of body fat – the body mass index (BMI) expressed as body mass (kg) divided by the height in meters squared, does not provide information concerning fat distribution and in consequence may underestimate health consequences of excessive body fat [26, 32, 38, 42]. It is worth mentioning that some individuals have a normal BMI but have increased percentage of body fat characterizing the term known as "normal weight obesity" (NWO), and present an increased risk of developing metabolic disorders [33]. Moreover, it was shown that differences in the content of adipose tissue between first-year male and female students of physical education (16.6% vs

26.2%) do not determine significant differences in BMI values (23.3 vs 22.5) [21]. In turn, it seems possible that increased age and body fatness together with low physical activity increase BMI validity as an index of adiposity. In addition, in American young adults BAI and RFM were found to overestimate body fatness [15]. In contrast, in young Brazilian males RFM was recognized to be significantly associated with measured body fat [10]**.** However, the analysis of the above data have to be done carefully due to marked race/ethnicity differences in body fat content and distribution. It is known that body composition also differs within the same sex and racial/ethnic group in adulthood due to presumably both secular and age-related biological mechanisms [16, 27, 28]. In consequence, from our data and the cited studies it could be postulated that, similarly to BMI and WC, all calculated indices of fatness and their agreement with measured adiposity have to be established separately for different populations [23]. Additionally, it is worth noting that body circumferences also reflect bone mass which is markedly higher in young males than in females (47).

All the above findings seem to be of importance taking into account the worldwide obesity epidemic and adverse health consequences of excessive body fat [1, 9, 20, 22, 25, 36, 44]. Moreover, this issue is important especially in the context of health risk among students considered to be a high-risk population due to unhealthy eating habits, low physical activity, smoking, alcohol consumption and high levels of stress [12, 35].

Conclusions

Our study showed that in the Polish population of active and sedentary men, RFM and BAI are reliable indicators of measured body obesity. However, regardless of the level of physical activity in the group of women, who were characterized by a significantly higher percentage of adipose tissue compared with the corresponding male groups, RFM did not turn out to be a reliable indicator of measured obesity.

However, our study has limitations which are due to measurements of body composition using skinfold measurements and have to be confirmed with bioimpedance analysis (BIA) or dual X-ray absorptiometry (DEXA).

Conflict of interest: Authors state no conflict of interest.

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