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Original Articles

Body composition of undergraduates – comparison of four different measurement methods

Authors' Contribution:

A – Study Design
B – Data Collection
C – Statistical Analysis
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Abstracts. *The objective of this study was to determine body composition of university students using four different methods and to find out the extent of agreement between these methods regarding the measurement of body fat percentage in body composition. The study group consisted of 52 students of the P.J. Šafárik University in Košice (29 males and 23 females) whose average age was 22.4 ± 1.9. The study group was formed by convenience sampling. Basic somatometric parameters (body height and weight) were determined and body mass index (BMI) was calculated. The body fat percentage was determined by indirect methods, that is by measuring skinfold thickness at 10 locations on the body using calliper Best II.K501 and by bioimpendance method using devices Bodystat 1500, Omron BF511 (tetra-polar electrode configuration) and Omron BF300 (bi-polar electrode configuration). Profile analysis based on one-sample Hotelling's test with chi-squared approximation was used for assessing agreement among given four methods of body fat measurements. Statistical analysis of differences among methods was supplemented by the Bland-Altman graphical method with the Wilcoxon paired test. The whole statistical analysis was performed using Excel and software R. Hotteling's Test ($p < 2.2e-16$) rejected the hypothesis of agreement between the methods. The greatest influence on this rejection was attributed to the Omron BF511 method. In addition, the results of Wilcoxon's matched pairs test confirmed the difference of the Omron BF511 method from the other three measurement methods. Bland-Altman graphical analysis showed that the Omron BF511 provided clearly higher values in comparison to the three remaining measurement methods of body fat percentage. The skinfold measurement, the Omron BF300 and the Bodystat 1500 were almost identical. For all the indirect methods it is necessary to validate the accuracy of their measurements using reference methods for the current local population. The skinfold thickness measurement method by Pařízková meets this requirement. Based on our results, the values determined by the devices Omron BF300 and Bodystat 1500 can also be considered applicable. The Omron BF511 does not provide results that could be considered sufficiently accurate for the purposes of research. In order to verify this conclusion the larger group of probands (n = 100 - 300) and a method of repeated measurements would be necessary.*

Keywords: *undergraduates, body composition, body fat, skinfolds, calliper, bioelectrical impedance analysis*

INTRODUCTION

At the turn of the millennium the obesity became a global epidemic. Very important factors contributing to the growth of overweight and obesity are increasingly hypokinetic lifestyle, predominantly that of children and youth, and decreasing body fitness [1, 2]. The basic parameter for assessing physical development and nutritional status is to observe body composition in studies focused on prevention and treatment of obesity [3, 4]. Body composition, commonly perceived as relative and absolute amount of body fat, makes a distinctive somatic feature, which typically evolves depending on age, sex and stage of physical development [5].
At the present time, there is a range of methods for measuring body composition. They vary depending on instrumental or personal needs, as well as in how accurately the observed values are determined. These are all significant limiting factors when their application in various conditions is considered. Malá et al. [6] state that the most suitable reference method to determine body composition is the whole body densitometry DEXA (Dual Energy X-ray Absorptiometry). However, the practical application of this method in our conditions is limited. The most accessible methods in the field conditions are anthropometry (body height and weight, body mass index, Waist-Hip Ratio, skinfold measurement using calliper) and bioelectric impedance [7, 8]. A variety of methods, determining body composition, raise a number of questions regarding its measurement. For instance, what is the level of agreement on body composition, determined by both similar and different methods, as well as to how accurate the measurements are [9]. Besides the financial and technical demands, the major problems with the application and interpretation of current methods, determining body composition, are caused by predictive equations. Pařízková [10-12] states that to minimise errors in all indirect methods, determining body composition, it is necessary to use predictive equations which were previously validated by reference methods for current local population depending on age, sex, state of health, level of movement activity as well as the amount of fat in the body.

METHODS

Participants

The study group consisted of 52 students of the P. J. Šafárik University in Košice (29 males and 23 females) whose average age was 22.4 ± 1.9. All students were informed about the objective and conditions of the research. The study group was formed by convenience sampling and comprised of students of Sport and Recreation study programme (n = 25) and University students participating in a weight management programme (n = 27).

Measures and procedures

Data acquisition was carried out on the premises of the Institute of Physical Education and Sport of the P. J. Šafárik University in Košice in the winter semester of academic year 2013/2014. The measurements were taken in the morning hours. Basic somatometric parameters (body height and weight) were determined and body mass index (BMI) was calculated. The body fat percentage was determined by indirect methods, that is by measuring skinfold thickness at 10 locations on the body using calliper Best II.K501 [5] and by bioimpedance method using devices Bodystat 1500, Omron BF511 (tetra-polar electrode configuration) and Omron BF300 (bi-polar electrode configuration). Measurement of skinfold thickness was carried out by an experienced and trained person. Another trained person conducted measurement with the bioimpedance devices.

Statistical analysis

Basic descriptive statistics was calculated for age, height, weight, and BMI and body fat percentage. The statistics also included Pearson's correlation analysis as a measure of association between results of body fat measurement methods. Profile analysis based on one-sample Hotelling's test with chi-squared approximation [13] was used for assessing agreement among given four methods. To avoid an inappropriate interpretation or use of Pearson's correlation the Bland-Altman graphical analysis with the Wilcoxon paired test were applied [14,15]. All statistical analyses were performed using MS Excel and statistical software R [16]. In particular testing normality of the dataset was performed using R package MVN [17]. Results of the profile analysis were computed in R package ICSNP [18].

RESULTS

Mean values and standard deviations for age, height, weight, BMI and percentage body fat, determined by individual methods for male and female groups, are shown in Table 1. None of the probands was underweight (BMI < 18.4 kg/m^2), 12 men and 6 women were normal weight (BMI 18.5 < 24.9 kg/m^2), 15 men and 11 women were overweight (BMI 25.0 < 29.9 kg/m^2), 2 men and 6 women were obese (BMI ≥ 30.0 kg/m^2).

When comparing the individual methods, the male group and female group were statistically assessed together. The correlation coefficient between values, determined by the bioimpedance devices and by skinfolds measurements, is shown in Table 2. The values of correlation coefficients R > 0.9 showed a strong association between the body fat percentage values determined by different measurement methods. The highest correlation coefficient was established between the measurements using the Omron type devices.

As Altman and Bland pointed out in their work [14] the obtained correlation is not the right indicator of agreement between measurement methods. As they showed [14] high correlations could be also produced in case of poor agreement between methods. Therefore profile multivariate analysis [13] supplemented with the Bland-Altmand graphical analysis was applied for this purpose. As a result, Hotteling's Test (p < 2.2e-16) rejected the agreement hypothesis. The four applied methods of body fat measurements led to statistically significantly different values of body fat. The greatest influence on this rejection was attributed to the Omron BF511 method. In addition, the results of Wilcoxon matched pairs test confirmed the difference of the Omron BF511 method from the other three measurement methods (Tab.3). The Bland-Altman graphical analysis showed that the Omron BF511 provided clearly higher values in comparison to the remaining three measurement methods of body fat percentage. The skinfold measurement, the Omron BF300 and the Bodystat 1500 were almost identical. (Fig.1)

Tab.1 Somatic characteristic and body fat percentage in the male and the female study group

	Women (n = 23)	**Men (n = 29)**	**All sample (n = 52)**
Age, years	22.5 ± 2.2	22.3 ± 1.8	22.4 ± 1.9
Height, cm	166.11 ± 5.99	179.00 ± 5.61	173.30 ± 8.64
Weight, kg	76.60 ± 12.49	81.82 ± 10.57	79.51 ± 11.73
BMI, kg/m^2	27.9 ± 4.8	25.5 ± 3.3	26.4 ± 4.1
Skinfold % fat	29.41 ± 6.19	16.91 ± 5.91	22.44 ± 8.66
Bodystat 1500 % fat	33.19 ± 7.31	15.40 ± 5.82	23.27 ± 11.01
Omron BF300 % fat	30.36 ± 6.61	14.77 ± 6.15	21.66 ± 10.04
Omrom BF511 % fat	40.31 ± 6.76	21.35 ± 5.91	29.73 ± 11.38

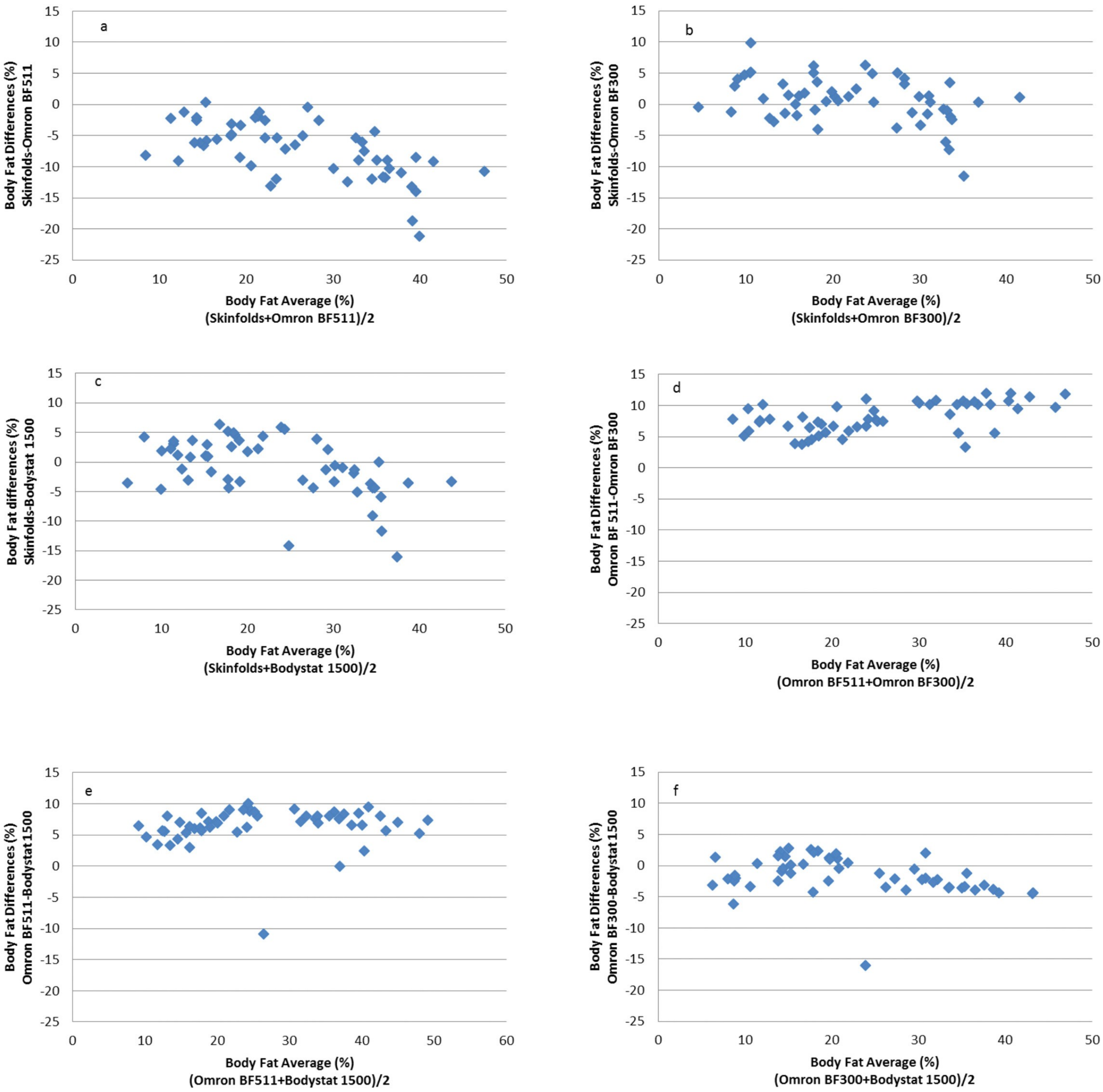

Fig. 1. The Bland-Altman graphical analysis of the differences in measured values of body fat percentage (%) between a Skinfolds and Omron BF511, b Skinfolds and Omron BF300, c Skinfolds and Bodystat 1500, d Omron BF511 and Omron BF300, e Omron BF511 and Bodystat 1500, f Omron BF300 and Bodystat 1500

Table 2. Correlation coefficient between the values determined by skinfold measurements and individual bioimpedance methods

	Skinfolds	Bodystat 1500	Omron BF300	Omron BF511
Skinfolds	-	0.9022753*	0.9304820*	0.9325912*
Bodystat 1500		-	0.9615178*	0.9608735*
Omron BF300			-	0.9820811*
Omron BF511				-

*p < 0.001

Table 3. Wilcoxon's paired match test of differences between the used methods

	Skinfolds	Bodystat 1500	Omron BF300	Omron BF511
Skinfolds	-	0.5087	0.08206	3.819e-10*
Bodystat 1500		-	0.0002099*	9.914e-09*
Omron BF300			-	3.602e-10*
Omron BF511				-

*p < 0.001

DISCUSSION

The objective of this study was to determine body composition of university students using four different methods and to find out the extent of agreement among these methods regarding the measurement of body fat percentage in body composition.

Table 1 implies that the mean BMI values in both male and female study groups fell into the category of overweight on 97th or 75th percentile of the Czech and Slovak population of the same age [19]. When assessing prevalence of overweight using BMI, it is important to take account of the fact that sporty individuals with well-developed musculature also fall into that category. This is more typical of men. The mean values of body fat percentage, which in the male group fell within the recommended body fat percentage for given age group, confirmed that fact, too. In the female study group the mean values of body fat percentage were in an obesity range, i.e., more than a half of the female probands were overweight or obese. Higher values of body fat percentage in the female group also relate to the fact that some of these women were participants of a weight management programme.

The results of individual values of body fat percentage considerably varied. Bigger differences between methods were observed in the female study group rather than in that of men. The biggest differences in the female study group, when compared with the one of the men, we observed between the Omron BF511 and the Skinfold (11%, or 4%), the Omron BF300 (10% or 6.5%), the Bodystat 1500 (7% or 6%). The Omron BF511 apparently overestimates body fat percentage when compared to the other measurement methods (Tab.3). It was the Omron BF511 method that had the greatest influence on rejection of the agreement hypothesis by Hotelling's test. The results of Wilcoxon's paired match test also confirmed that. The differences between the skinfold measurement, the Bodystat 1500 and the Omron BF300 were not significant and were ranging within the measurement error (3 - 4%). From the statistical point of view, we could consider these three methods equivalent. Gutin et al. [3] and also Altman and Bland [14] state that with the absence of reference method, it is not possible to determine whether some method provides 'true' values of body fat percentage. It is also not possible to substitute one with the other. From the practical point of view combining and comparing the results of the used methods against one another it is therefore useless for decision which method is more accurate [20], only agreement among methods can be decided.

When measuring by means of these methods, a measurement error needs to be taken into consideration. The human factor plays an important part when measurements are carried out using callipers. It is important for the person conducting the measurements to be sufficiently experienced. This requirement was, however, met in this study. It is also necessary to take into account the differences in skinfold compressibility between men and women [8, 21]. Measurements based on BIA methods bring some other factors that significantly influence accuracy of these measurements, such as body hydration, abnormalities in body composition, underweight or overweight. Therefore, when using BIA methods, the only results considered valid are those of individuals with BMI ranging between 18.5 and 34 kg/m^2 [10-12, 21-24].

For all the indirect methods it is necessary to validate the accuracy of their measurements using reference methods for the current local population. Unless such validation is carried out, we cannot regard the measured values as valid for our population [10, 25]. Despite being developed 50 years ago, the skinfold thickness measurement method by Pařízková meets this requirement. From the researcher's point of view and based on our results, the values determined by the devices Omron BF300 and Bodystat 1500 can also be considered applicable.

In agreement with Bosy-Westphal et al. [25] we can state that the Omron BF511 does not provide results that could be considered sufficiently accurate for the purposes of research. In order to verify this conclusion the larger group of probands (n = 100 - 300) and a method of repeated measurements would be necessary. Moreover, such method would result in conclusion regarding accuracy of all used methods [15].

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REFERENCES

1. Bunc V: Nadváha a obezita dětí-životní styl jako příčina a důsledek. In Česká kinantropologie, 2008; 12(3): 61-69
2. Ferreira I, Twisk JWR, Mechelen W, Kemper HCG, Stehouwer CDA: Development of fatness, fitness, and lifestyle from adolescence to the age of 36 years: determinants of the metabolic syndrome in young adults: The Amsterdam Growth and Health Longitudinal Study. In Archives Internal Medicine, 2005; 165(1): 42-48
3. Gutin B, Litaker M, Islam S, Manos T, Smith C, Treiber F: Body-composition measurement in 9-11-y-old children by dual-energy X-ray absorptiometry, skinfold-thickness measurements, and bioimpedance analysis. In Am J Clin Nutr, 1996; 63 (3): 287-92
4. Pichard C, Kyle UG, Bracco D, Slosman DO, Morabia A, Schutz Y: Reference values of fat-free and fat masses by bioelectrical impedance analysis in 3393 healthy subjects. In Nutrition, 2000; 16(4): 245-254
5. Pařízková J: Rozvoj aktivní, telesné hmoty u dětí a mládeže. Praha SZN, 1962 [in Czech]
6. Malá L, Malý T, Zahálka F, Teplan J: Dual-Energy X-Ray Absorpciometria-referenčná metóda určenia telesného zloženia a denzity kostí. In Česká kinantropologie, 2012; 16(3): 211-220
7. Kinkorová I, Heller J: Využitelnost antropometrických parametru pro odhad tělesného složení u

dětí. In Med Sport Boh Slov, 2007; 16(1): 40-47
8. Větrovská R, Lačňák Z, Haluzíková D, Fábin P, Hájek P, Horák L, Haluzík M, Svačina Š, Matoulek M: Srovnání různých metod pro stanovení množství tuku v těle u žen s nadváho u a obezitou. In Vnitř Lék, 2009; 55(5): 455-461
9. Pacy PL, Quevedo M, Gibson NR, Cox M, Koutedakis Z, Millward J: Body composition measurement in elite heavy weight oarswomen: a comparison of five methods. In J Sport Med Phys Fitness, 1995; 35: 67-74
10. Pařízková J: Složení těla, metody měření a využití ve výzkumu a lékařské praxi. In Med Sport Boh Slov, 1998; 7(1): 1-6
11. Pařízková J: K diskusi o rovnicích pro výpočet % depotního tuku. In Med Sport Boh Slov, 1998; 7(2): 54-55
12. Pařízková J, Hainer V, Kunešová M: Zkušenosti s vyšetřováním tělesného složení normálních a obézních osob u nás a v zahraničí. In Med Sport Boh Slov, 1998; 7(3): 103
13. Rencher AC: Methods of Multivariate Analysis (2nd ed.). John Wiley & Sons. New York, 2003
14. Bland JM, Altman DG: Statistical methods for assessing agreement between two methods of clinical measurement. In International Journal of Nursing Studies, 2010; 47(8): 931-936
15. Alanen E: Everything all right in method comparison studies? In Statistical Methods in Medical Research, 2012; 21(4): 297-309
16. R Core Team: R: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing, 2012. http://www.R-project.org/
17. Korkmaz S: MVN: Multivariate Normality Tests. R package version 1.0. 2013. http://CRAN.R-project.org/package=MVN
18. Nordhausen K, Sirkia S, Oja H, Tyler DE: ICSNP: Tools for Multivariate Nonparametrics, R package version 1.0-9. 2012. http://CRAN.R-project.org/package=ICSNP
19. Bláha P: W/H^2 Body mass index of the current czechoslovak population between the ages of 3 and 70. Institute of Sports Medicine Prague, 1991
20. Kutáč P, Gajda V: Validity of measuring the body composition by means of the BIA and skinfold method in male population with regular motion activities. In Acta Facultatis exercitationis corporis universitatis Presoviensis, 2009; 1(1): 44
21. McRae, MP: Male and female differences in variability with estimting body fat composition using skinfold calipers. In Journal of Chiropractic Medicine, 2010; 9: 157-161
22. Kyle UG, Bosaeus I,. De Lorenzo AD, Deurenberg P, Elia M, Gómez JM, Heitmann BL, Kent-Smith L, Melchior JC, Pirlich M, Scharfetter H, Schols AMWJ, Pichard C: Composition of the ESPEN Working Group: Bioelectrical impedance analysis-part I: review of principles and methods. In Clinical Nutrition, 2004; 23: 1226-1243
23. Kyle UG, Bosaeus I,. De Lorenzo AD, Deurenberg P, Elia M, Gómez JM, Heitmann BL, Kent-Smith L, Melchior JC, Pirlich M, Scharfetter H, Schols AMWJ, Pichard C: Bioelectrical impedance analysis-part II: utilization in clinical practice. In Clinical Nutrition, 2004; 23: 1430-1453
24. Shafer KJ, Siders WA, Johnson LK, Lukaski HC: Validity of segmental multiple-frequency bioelectrical impedance analysis to estimate body composition of adults across a range of body mass indexes, In Nutrition, 2009; 25: 25-32
25. Bosy-Westphal A, Later W, Hitze B, Sato T, Kossel E, Glüer CC, Heller M, Müller MJ: Accuracy of Bioelectrical Impedance Consumer Devices for Measurement of Body Composition in Comparison to Whole Body Magnetic Resonance Imaging and Dual X-Ray Absorptiometry. In Obesity Facts The European Journal of Obesity, 2008; 1(6): 319-324

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