ANTHROPOLOGIE • LX/2 • pp. 319–328 • 2022

DARINA FALBOVÁ, LENKA VOROBEĽOVÁ, RADOSLAV BEŇUŠ

GENDER-SPECIFIC ANTHROPOMETRIC AND BODY COMPOSITION ANALYSIS IN SLOVAK YOUNG ADULTS

ABSTRACT: The purpose of this study was to obtain the body composition (BC) characteristics, anthropometric parameters and indices and to investigate the correlation between selected BC parameters and obesity indices in the examined sample of 19–30 years old Slovak population. The studied sample consisted of 143 men with mean age 22.89 ± 2.48 and 238 women with mean age 22.09 ± 2.19. InBody 770 BC analyzer was used to detect the human BC. Results revealed statistically significant sex differences in all main anthropometric measurements. We observed that men had statistically significantly higher average values of body mass index (BMI), waist to hip ratio (WHR), waist to height ratio (WHtR), fat free mass index (FFMI) and body cell mass index (BCMI) and lower fat mass index (FMI) compared to women ($p < 0.001$). Furthermore, men had significantly more fat free mass, lean body mass, skeletal muscle mass, total body water, intracellular and extracellular water, protein and mineral content, bone's minerals and less fat mass, visceral fat and percent of body fat than women ($p < 0.001$). The highest positive correlation coefficients were observed between FMI and FM ($r = 0.985$ for men, $r = 0.981$ for women; $p < 0.001$), FMI and visceral fat area ($r = 0.964$ for men, $r = 0.961$ for women; $p < 0.001$); BMI and FM ($r = 0.849$ for men, $r = 0.792$ for women; $p < 0.001$), BMI and visceral fat area ($r = 0.820$ for men, $r = 0.769$ for women; $p < 0.001$) in both genders. In the present pilot study we found, that Slovak young men had significantly higher average values of active body components and the Slovak young women had statistically significantly higher average values of non-active body components. Furthermore, we confirmed positive correlation between BC and indices. These findings will be also helpful for future research to examine the associations between BC and physical fitness status, health parameters and others.

KEY WORDS: Body composition – Young adulthood – Obesity indices – InBody 770

Received 1st November 2021; Accepted 21 March 2022. Available online 23 May 2022.

DOI: https://doi.org.10.26720/anthro.22.03.21.2

INTRODUCTION

Obesity is defined as abnormal or excessive fat accumulation that may impair health. It is acknowledged as one of the burning public health problems reducing life expectancy and quality of life (Withrow, Alter 2011, Hruby *et al.* 2016). The primary goal of assessing obesity is to determine the proportion of fat mass (FM) relative to lean body mass (LBM). FM comprises essential fat and storage fat, the former being the fat necessary to sustain normal physiological function and the latter consisting primarily of adipose tissue. LBM, on the other hand, includes several components, including muscle, water, bone, connective tissue and internal organs (Daver 2015).

Until recently, it was perceived that obesity mostly affected middle age adults. However, a steadily increasing trend of obesity among young adults, especially college and university students, is becoming evident (Poobalan, Aucott 2016). Young adults aged 18 to 24 are at the highest risk of becoming overweight or developing obesity in the next decade of their life compared to adults in any other age group (Katsoulis *et al.* 2021). Previous studies have also documented that the amount of weight gain in young adults depends on their sex and being a male is the strongest predictor of weight gain (Cluskey, Grobe 2009, Girz *et al.* 2013).

Body composition (BC) measurements not only indicate systemic nutritional status and health status, but also provide valuable information for the diagnosis and treatment of various diseases, whose quality and distribution are closely related to the health status of people at all ages (Chomtho *et al.* 2006, Liang *et al.* 2018).

Because no data are available about the body composition parameters defined by InBody 770 analyzer in the group of Slovak young adults, the purpose of this pilot study was to determine and examine the values and differences in BC characteristics between women and men. In addition, we determined correlation between indicators of obesity and selected BC parameters in both genders.

MATERIALS AND METHODS

The sample comprised 381 Slovak young adults ranging in age from 19 to 30 years, who were enrolled in this cross-sectional research during 2019–2020. All study participants were evaluated in the Biomedical laboratory of Department of Anthropology at Comenius University during the morning. Women and men were approached and recruited using a nonrandom procedure (based on volunteering and convenience). Each participant provided written informed consent for this study which adhered to the Declaration of Helsinki principles.

Anthropometric measurements were taken using standard anthropometric techniques by trained anthropologists. Body mass index (BMI) was calculated as body weight in kilograms divided by height squared (WHO 2000) and values below 24.9 kg/m^2 were considered as optimal. Waist-to-hip ratio (WHR) was calculated as the circumference of the waist divided by the circumference of the hips (WHO 2000) and values less than 0.84 for women and less than 0.89 for men were considered as optimal. Waist-to-height ratio (WHtR) was calculated as the circumference of the waist divided by height squared (Schneider *et al.* 2010) and values below 0.48 for women and less than 0.52 for men were considered as optimal. Normal weight obesity (NWO) was defined as a BMI < 25 kg/m^2 and a % fat mass (% FM) over the gender-specific in young adults (25.5% for men and 38.9% for women).

InBody 770 BC analyzer (Biospace Co., Korea) was used to detect the human BC based on the recommendation provided in the user manual. Participants were tested in the quiet state after fasting and emptying in the morning. Participants stood barefoot on the pedal plate electrode. The hands were naturally hanging and held the hand electrode gently, keeping the angle at 15° between the torso and the upper limbs. The test included basal metabolic rate (BMR), lean body mass (LBM), intracellular fluid (intacellular water, ICW), extracellular fluid (extracellular water, ECW), protein content, mineral content, body water content (total body water, TBW), skeletal muscle (skeletal muscle mass, SMM), body fat (FM) and body cell mass (BCM). Body cell mass index (BCMI) was calculated as BCM divided by height squared (kg/m^2). Fat mass index (FMI) was calculated as FM divided by height squared (kg/m^2) and fat free mass index (FFMI) was calculated as FFM divided by height squared (kg/m^2). FM (%) was divided into three sub-groups; values under normal (% FM < 10% for men and % FM < 18% for women), range within 10% to 20% for men and range within 18% to 28% for women were considered as normal and values over normal (% FM > 20% for men and % FM > 28% for women). Visceral Fat Area (VFA) is based on the estimated amount of fat surrounding internal organs in the abdomen. Values of VFA under 100 cm^2 were considered as optimal. These detailed body composition variables were displayed in computer through LookinBody programme software.

All statistical analyses were performed with IBM SPSS for Windows (Statistical Package for the Social Science, version 20.0, Chicago, IL) and statistical significance was defined as $p \leq 0.05$. Kolmogorov–Smirnov test was used for checking for the normality of data distribution. General linear models (GLMs) were used to determine differences in BC between women and men, with age as the covariate. To assess correlation between the variables the Pearson's chi-square test was used in case of normally distributed variable and Spearman nonparametric test for data with non-normal distribution.

RESULTS

The basic anthropometric parameters and indices in both genders are summarized in *Table 1*. Results revealed significant differences in all anthropometric variables between men and women ($p < 0.001$). Men attained mean values of all investigated parameters higher than the women except for mean value of FMI. Among the group of women, 15.12% participants had the BMI higher than optimal (i.e. BMI > 24.9 kg/m^2), 2.52% had higher values of the WHR index than optimal (i.e. WHR > 0.84) and 7.56% had higher values of the WHtR index than optimal (i.e. WHtR > 0.48). On the other hand, in the sample of men were 43.35% of subjects with higher value of BMI than optimal, 4.90% men with higher value of WHR index and 6.29% men with higher value of WHtR index than optimal. Differences in distribution of BMI categories between men and women were statistically significant (χ^2 = 38.399, df = 2, $p < 0.001$). Differences in distribution of WHR and WHtR categories between men and women were not statistically significant (χ^2 = 1.528, df = 1, p = 0.216 vs. χ^2 = 3.907, df = 2, p = 0.142). NWO (BMI < 25 kg/m^2 and %FM > 25.5%) was found only in group of men (n = 4; data not shown in table).

The mean values of bioelectric impedance variables are shown in the *Table 2*. After adjustment for age we found statistically significant differences between men and women practically in all examined parameters. The men attained significantly higher fat free mass (FFM; $p < 0.001$), lean body mass (LBM; $p < 0.001$), skeletal muscle mass (SMM; $p < 0.001$), total body water (TBW; $p < 0.001$), intra- and extracellular water (ICW and ECW; $p < 0.001$), body cell mass (BCM; $p < 0.001$), phase angle (PA; $p < 0.001$) and basal metabolic rate (BMR; $p < 0.001$) and significantly less fat mass (FM; p = 0.020), fat mass in percentage (FM%; $p < 0.001$) and visceral fat area (VFA; $p < 0.001$) than women of studied sample of

TABLE 1: Anthropometric characteristic and obesity indices of young adults. SD, standard deviation; p^a, value of statistical significance adjusted for age; BMI, body mass index; WHR, waist to hip ratio; WHtR, waist to height ratio; BCMI, body cell mass index; FMI, fat mass index; FFMI, fat free mass index.

	Men		**Women**		
Number of participants	n = 143		n = 238		
	Mean	SD	Mean	SD	p^a
Height, cm	180.25	± 7.29	166.86	± 6.23	**<0.001**
Weight, kg	80.08	± 12.94	61.11	± 10.80	**<0.001**
Waist circumference, cm	82.18	± 8.40	70.02	± 7.67	**<0.001**
Hip circumference, cm	100.64	± 7.02	95.03	± 8.51	**<0.001**
BMI, kg/m^2	24.63	± 3.63	21.94	± 3.66	**<0.001**
WHR	0.82	± 0.04	0.74	± 0.05	**<0.001**
WHtR	0.46	± 0.05	0.42	± 0.05	**<0.001**
BCMI	13.14	± 1.32	10.13	± 0.89	**<0.001**
FMI	4.67	± 2.40	6.32	± 2.79	**<0.001**
FFMI	19.93	± 2.03	15.61	± 1.34	**<0.001**

young adults. Furthermore, women had higher percentages of increased values of %FM as well as VFA (cm^2) than men (44.12% vs. 35.66% for FM, 18.90% vs. 12.60% for VFA). However, these differences were not statistically significant ($p = 0.232$; $p = 0.070$).

Table 3 shows correlation coefficient between indicators of obesity, i.e. BMI, WHR index, WHtR index, FFMI, FMI and BCMI and selected BC parameters examined in sample of men. In the men's group we observed the highest positive correlation coefficients between BMI and FM (kg; $r = 0.849$; $p < 0.001$); BMI and VFA (cm^2; $r = 0.820$; $p < 0.001$); WHtR and FM (kg; $r = 0.827$; $p < 0.001$), WHtR and VFA (cm^2; $r = 0.790$; $p < 0.001$), FMI and FM ($r = 0.985$; $p < 0.001$) and FMI and VFA ($r = 0.964$; $p < 0.001$).

Correlation coefficients between indicators of obesity and selected BC parameters examined in the women's group are presented in *Table 4*. The highest positive correlation coefficients for women we observed between BMI and FM (kg; $r = 0.792$; $p < 0.001$), FMI and FM (kg; $r = 0.981$; $p < 0.001$); FMI and VFA (cm^2; $r = 0.961$; $p < 0.001$).

TABLE 2: Selected body composition characteristics of young adults. SD, standard deviation; p^a, value of statistical significance adjusted for age; p^b, value of statistical significance (Pearson Chi square test).

	Men			**Women**			
Number of participants	n = 143			n = 238			
	Mean	SD		Mean	SD		p^a
Fat Mass, kg	15.12	±	7.58	17.55	±	7.72	**0.020**
Fat Mass Percentage, %	18.26	±	6.86	27.83	±	7.16	**<0.001**
Visceral Fat Area, cm^2	62.67	±	35.18	77.31	±	39.43	**<0.001**
Fat Free Mass, kg	64.87	±	8.59	43.53	±	5.3	**<0.001**
Lean Body Mass, kg	61.24	±	7.93	40.91	±	4.72	**<0.001**
Protein, kg	12.90	±	1.67	8.52	±	0.99	**<0.001**
Mineral content, kg	4.55	±	0.67	3.13	±	0.38	**<0.001**
Bone mineral content, kg	3.77	±	0.57	2.61	±	0.32	**<0.001**
Skeletal Muscle Mass, kg	36.94	±	5.04	23.73	±	2.99	**<0.001**
Total Body Water, l	47.55	±	6.16	31.87	±	3.67	**<0.001**
Intracellular Water, l	30.07	±	4.63	19.73	±	2.29	**<0.001**
Exracellular Water, l	17.69	±	2.32	12.13	±	1.40	**<0.001**
Body Cell Mass, kg	42.76	±	5.53	28.26	±	3.28	**<0.001**
Phase Angle	6.42	±	0.62	5.16	±	0.46	**<0.001**
Basal Metabolic Rate, kcal	1774,08	±	183,08	1310,20	±	108,55	**<0.001**
	N		**%**	**N**		**%**	**p^b**
Fat Mass Percentage category, %							
Under	11		7.70	13		5.46	
Normal	81		56.64	120		50.42	0.232
Over	51		35.66	105		44.12	
Visceral Fat Area, cm^2							
Normal	125		87.40	193		81.10	0.070
Over	18		12.60	45		18.90	

TABLE 3: Correlation coefficient between obesity indicators and selected body composition characteristics of men. BMI, body mass index; WHR, waist to hip ratio; WHtR, waist to height ratio; BCMI, body cell mass index; FMI, fat mass index; FFMI, fat free mass index; r, correlation coefficient; ** < 0.01, *** ≤ 0.001, n.s, the difference was not statistically significant.

		BMI	WHR	WHtR	FFMI	FMI	BCMI
Fat Mass, kg	r	0.849***	0.527***	0.827***	0.333***	0.985***	0.328***
Visceral Fat Area, cm^2	r	0.820***	0.511***	0.790***	0.305***	0.964***	0.296***
Fat Free Mass, kg	r	0.528***	0.344***	0.363***	0.784***	0.155 n.s.	0.740***
Lean Body Mass, kg	r	0.544***	0.330***	0.362***	0.752***	0.165 n.s.	0.757***
Skeletal Muscle Mass, kg	r	0.544***	0.332**	0.365***	0.766***	0.154 n.s.	0.772***
Total Body Water, l	r	0.543***	0.329***	0.360***	0.748***	0.167 n.s.	0.752***
Intracellular Water, l	r	0.502***	0.313***	0.367***	0.672***	0.174 n.s.	0.677***
Exracellular Water, l	r	0.536***	0.319***	0.348***	0.711***	0.186 n.s.	0.710***
Body Cell Mass, kg	r	0.544***	0.333***	0.365***	0.766***	0.155 n.s.	0.773***

TABLE 4: Correlation coefficient between obesity indicators and selected body composition characteristics of women. BMI, body mass index; WHR, waist to hip ratio; WHtR, waist to height ratio; BCMI, body cell mass index; FMI, fat mass index; FFMI, fat free mass index; r, correlation coefficient; ** < 0.01, *** ≤ 0.001, n.s, the difference was not statistically significant.

		BMI	WHR	WHtR	FFMI	FMI	BCMI
Fat Mass, kg	r	0.792***	0.509***	0.768***	0.267***	0.981***	0.257***
Visceral Fat Area, cm^2	r	0.769***	0.506***	0.738***	0.254**	0.961***	0.242**
Fat Free Mass, kg	r	0.506***	0.065 n.s.	0.306***	0.763***	0.294***	0.754***
Lean Body Mass, kg	r	0.505***	0.063 n.s.	0.304***	0.763***	0.293***	0.754***
Skeletal Muscle Mass, kg	r	0.509***	0.064 n.s.	0.309***	0.771***	0.295***	0.766***
Total Body Water, l	r	0.504***	0.064 n.s.	0.303***	0.762***	0.293***	0.752***
Intracellular Water, l	r	0.508***	0.065 n.s.	0.308***	0.770***	0.293***	0.765***
Exracellular Water, l	r	0.492***	0.063 n.s.	0.293***	0.740***	0.289***	0.723***
Body Cell Mass, kg	r	0.508***	0.064 n.s.	0.309***	0.771***	0.294***	0.766***

DISCUSSION

Our study demonstrated differences in anthropometric parameters, BC and obesity indices between young adults. Men had significantly higher mean values of body height, body weight, as well as waist and hip circumference. Similarly, men had significantly higher mean values of obesity indices (BMI, WHR, WHtR, FFMI, BCMI) compared to women. Between categories of BMI, we recorded statistically significant differences between the group of men and the group of women ($p < 0.001$). Higher value of BMI than optimal had 43.35% of men and 15.12% of women. This higher percentages of BMI in men may be due to the fact that BMI does not take into account the person's body fat vs. muscle content. Because muscle weighs more than fat, BMI can class muscly, athletic people as fatter than they really are. Rothman (2008) and McAllister *et al.* (2009)

also pointed out that individuals classified according to BMI categories as overweight generally had the same or in some cases better results in terms of their health profile compared to those who had normal values according to BMI. Mahadevan and Ali (2016) reported that BMI does not correspond to BC and if a man and a woman have the same height and weight, they may have the same BMI, but the woman has more body fat than a man. Jackson *et al.* (2002), Pischon *et al.* (2008) and Melmer *et al.* (2013) pointed out that there are discrepancies between increased FM and BMI because BMI cannot distinguish muscle tissue from adipose tissue or the distribution of adipose tissue in the body, and therefore some individuals, despite having optimal BMI, may have an increased amount of FM. According to Zeng *et al.* (2014), Babai *et al.* (2016), Dimitriadis *et al.* (2016) BMI should therefore be used with caution in predicting metabolic and cardiovascular diseases associated with obesity, because even individuals with low BMI have an increased risk of these diseases, and therefore it is difficult to determine their optimal extent of BMI. However, BMI continues to be widely used in various types of studies, despite objection of several authors that BMI has little diagnostic value (Kyle *et al.* 2004, Amir, Rakhshanda 2009, Gába *et al.* 2014). Higher average values of WHR and WHtR are the result of higher values of body height, waist and hip circumference in the group of men. Similar conclusions were reached in the studies of Mandel *et al.* (2004) and Heymsfield *et al.* (2009), in which they pointed to a significant influence of greater musculature in men than in women on these anthropometric parameters and indices. In our study, higher average values of WHR, WHtR in men may also be due to the fact that men accumulate more fat in the abdominal area, as reported in the study by Nauli and Matin (2019), where pointed out to different hormonal mechanisms of body fat storage in men and women in the abdominal area. WHtR index can be according to Ehramphoush *et al.* (2017) a good indicator of body fat, especially in adults whose body height does not change relatively. Similarly, Shneider *et al.* (2007) reported the WHtR index as a better predictor of the risk of cardiovascular disease compared to other anthropometric indices. Melmer *et al.* (2013) demonstrated a high correlation of cardiovascular risks with the WHtR index and, as in our study, in the study of Ehramphoush *et al.* (2017), the WHtR index showed a strong correlation with FM. Swainson *et al.* (2017) indicated that the WHtR index is the best predictor of FM and viscellar fat percentages in both men and women, while BMI as a predictor of body fat percentages in both gender is not reliable. According to a study by Ehramphousha *et al.* (2017), where data from 1,360 men and women from Iran were analyzed, BMI and WHtR were the most appropriate indices for determining FM. VFA has been considered in several studies to be a potential marker for cardiovascular risk detection (Després, Lemieux 2006, Katzmarzyk *et al.* 2014, Neeland *et al.* 2016). Similar conclusions were reached by Máximo *et al.* (2018), who examined 50 obese individuals from Brazil and correlated selected BC parameters with BMI, WHR, and WHtR obesity indices, and found that FM had the highest correlation with BMI in both gender. However, Máximo *et al.* (2018) reported that VFA correlates only with BMI, WHR, WHtR, excusively in women. They attributed this difference to a small sample of men who were included in the study and considered WHR to be a poor predictor of obesity, as they showed a weak correlation with physical parameters.

Our study women had a statistically significant higher average value of FMI and lower mean values of FFMI and BCMI compared to men. Similar results were found in the study of Sengupta (2014), where women from India between the ages of 18 and 22 had higher values of FMI than men in the same age range. In this study the higher value of FMI is the result of higher total FM and FM percentage in women compared to men. Our men had also significantly higher average values of BCMI ($p < 0.001$) compared with women, but in both groups were optimal range of this index. In the study of Talluri *et al.* (2003) reported that BCMI is a very good identificator of muscle mass and protein in the body, and therefore compared in their study the differences in muscle mass between athletes, patients with renal dialysis, mental anorexia, and relatively healthy individuals. It is clear from the results of this study that healthy men and athletes had significantly higher BCMI values than patients on renal dialysis and observed the same differences in women divided into the same groups. On the other hand, men and women who have low BCMI values may suffer from malnutrition, and therefore Talluri *et al.* (2003) argued that BCMI is more sensitive to monitoring the nutritional status of individuals than BMI.

We observed significant differences in all body parameters between men and women. SMM and FFM had higher average values in men. Results showed that men had also more active body mass and LBM than women, which is confirmed by a study of Janssen *et al.* (2000) and Lu *et al.* (2012). In the study by Schorr *et al.* (2018) also found, that men and women differed significantly in FM and women had higher FM levels than men. The higher amount of muscle mass in men may be interpreted in the same sense as the sexual dimorphism in stature height, as a result of sexual selection. Gender differences in BC, first of all in FM, seem to reflect gender typical energetic demands of reproductive physiology. FM, in particular subcutaneous fat of the lower body region, represents an important energy store, which enables the female body to bear the energetic costs of pregnancy and lactation (Ellison 1990, Kirchengast, Huber 2001, Kirchengast 2010). Our women had a lower mean metabolic expenditure (1310 ± 108.55 kcal) than men (1774.08 ± 183.08). Similar, in the study of Buchholz *et al.* (2002) reported that low basal metabolic levels in women associated it with the fact that women have a higher average amount of FM compared to men. Zhang *et al.* (2016) showed in their study that basal metabolic expenditure is higher in people with overweight and obesity. Our results also showed that men had significantly higher mean amounts of TBW (l; 47.55 ± 6.16) as well as ICW (l; 30.07 ± 4.63) and ECW (l; 17.69 ± 2.32 l) than women (31.87 ± 3.67; 19.73 ± 2.29; 12.13 ± 1.40). The amount of water in the body but also in the cells reflects not only the state of tissue function, but also the proper physiology of the cells. Liang *et al.* (2018) investigated that men and women under the age of 30 also had different average amounts of ECW and ICW, while in men it was on average 14.32 l of ECW, in women 10.21 l as well as ICW was slightly less in women compared to men (16.51 vs. 24.06 l). Changes in the volume of ECW and ICW may reflected metabolic conditions and overall body nutrition in both genders (Liang *et al.* 2018). A significant imbalance of ECW to TBW was demonstrated also in studies of patients with chronic obstructive pulmonary disease, acute heart failure, chronic liver disease, HIV-positive patients, and in dialysis patients. In addition, excess ECW has also been observed especially in patients with liver cirrhosis (Schwenk *et al.* 2000, Jones, Newstead 2004, Nescolarde *et al.* 2004, Slinde *et al.* 2005, Kahraman *et al.* 2010, Omata *et al.* 2017).

Despite our interesting findings, there are some limitations that need to be acknowledged. The sample size of study women and men were relatively small (n = 381) and for future studies, it would be paramount to enlarge the study sample for a detailed analysis. Further, the study is cross-sectional and may have had selection bias during participation recruitment, and the particular study design may limit result generalization to all Slovak young adults.

CONCLUSION

In the present pilot study we found, that Slovak young men had significantly higher average values of active body components. In contrast, the Slovak young women had statistically significantly higher average values of non-active body components, such as body fat mass, visceral fat and body fat in percentages. Furthermore, we confirmed positive correlation between BC and indices. In the future, these pilot findings will be used to analyze associations between body composition parameters and physical fitness status, health parameters and others.

ACKNOWLEDGMENT

This publication is the result of the project implementation: Comenius University in Bratislava Science Park supported by the Research and Development Operational Programme funded by the ERDF. Grant number: ITMS 26240220086.

REFERENCES

AMIR H. S., RAKHSHANDA B., 2009: Body composition, its significance and models for assessment. *Pakistan Journal of Nutrition* 8, 2: 198–202. doi: 10.3923/pjn.2009.198.202

BABAI M., ARASTEH P., HADIBARHAGHTALAB M., NAGHIZADEH M. M., SALEHI A., ASKARI A., HOMAYOUNFAR R., 2016: Defining a BMI cut-off point for the Iranian population: the Shiraz Heart Study. *PLoS One* 11, 8: e160639. doi: 10.1371/journal.pone.0160639

BUCHHOLZ A. C., RAFII M., PENCHARZ P. B., 2001: Is resting metabolic rate different between men and women? *British Journal of Nutrition* 86, 6: 641–646. doi: 10.1079/bjn2001471

CHOMTHO S., FEWTRELL M. S., JAFFE A., WILLIAMS J. E., WELLS J. C. K., 2006: Evaluation of arm anthropometry for assessing pediatric body composition: evidence from healthy and sick children. *Pediatric Research* 59, 6: 860–865. doi: 10.1203/01.pdr.0000219395.83159.91

CLUSKEY M., GROBE D., 2009: College weight gain and behavior transitions: Male and female differences. *Journal of the American Dietetic Association* 109, 2: 325–329. doi: 10.1016/j.jada.2008.10.045

DAVAR V., 2015: Body composition analysis of university students by anthropometry and bioelectrical impedance analysis. *International Journal of Medical Research and Health Sciences* 9, 6: 492–496. doi: doi.org/10.5281/zenodo.1106901

DESPRÉS J. P., LEMIEUX I., 2006: Abdominal obesity and metabolic syndrome. *Nature* 444, 7121: 881–887. doi: 10.1038/nature05488

DIMITRIADIS K., TSIOUFIS C., MAZARAKI A., LIATAKIS I., KOUTRA E., KORDALIS A., KASIAKOGIAS A., FLESSAS D., TENTOLOURIS N., TOUSOULIS D., 2016: Waist circumference compared with other obesity parameters as determinants of coronary artery disease in essential hypertension: a 6-year follow-up study. *Hypertension Research* 39, 6: 475–479. doi: 10.1038/hr.2016.8

EHRAMPOUSH E., ARASTEH P., HOMAYOUNFAR R., CHERAGHPOUR M., ALIPOUR M., NAGHIZADEH M. M., HADIBARHAGHTALAB M., DAVOODI S. H., ASKARI A., RAZAZ J. M., 2017: New anthropometric indices or old ones: Which is the better predictor of body fat? *Diabetes & Metabolic Syndrome: Clinical Research & Reviews* 11, 4: 257–263. doi: 10.1016/j.dsx.2016.08.027

ELLISON P.T., 1990: Human ovarian function and reproductive ecology: new hypotheses. *American Anthropologist* 92, 4: 933–952.

GÁBA A., PŘIDALOVÁ M., ZAJAC-GAWLAK I., 2014: Posouzení objektivity hodnocení výskytu obezity na základě body mass indexu vzhledem k procentuálnímu zastoupení tělesného tuku u žen ve věku 55–84 let. *Časopis lékařů českých* 153, 1: 22–27.

GIRZ L., POLIVY J., PROVENCHER V., WINTRE M. G., PRATT M. W., PANCER M. S., BIRNIE-LEFCOVITCH S., ADAMS G. R., 2013: The four undergraduate years. Changes in weight, eating attitudes, and depression. *Appetite* 69: 145–150. doi: 10.1016/j.appet.2013.06.002

HEYMSFIELD S. B., SCHERZER R., PIETROBELLI A., LEWIS C. E., GRUNFELD C., 2009: Body mass index as a phenotypic expression of adiposity: quantitative contribution of muscularity in a population-based sample. *International Journal of Obesity* 33, 12: 1363–1373. doi: 10.1038/ijo.2009.184

HRUBY A., MANSON J. E., QI L., MALIK V. S., RIMM E. B., SUN Q., WILLETT W. C., HU F. B., 2016: Determinants and consequences of obesity. *American Journal of Public Health* 106, 9: 1656–1662. doi: 10.2105/AJPH.2016.303326

JACKSON A. S., STANFORTH P. R., GAGNON J., RANKINEN T., LEON A. S., RAO D. C., SKINNER J. S., BOUCHARD C., WILMORE J. H., 2002: The effect of sex, age and race on estimating percentage body fat from body mass index: the heritage family study. *International Journal of Obesity and Related Metabolic Disorders* 26, 6: 189–196. doi: 10.1038/sj.ijo.0802006

JANSSEN I., HEYMSFIELD S. B., WANG Z. M., ROSS R., 2000: Skeletal muscle mass and distribution in 468 men and women aged 18–88 yr. *Journal of Applied Physiology* 89, 1: 81–88. doi: 10.1152/jappl.2000.89.1.81

JONES C. H., NEWSTEAD C. G., 2004: The ratio of extracellular fluid to total body water and technique survival in peritoneal dialysis patients. *Peritoneal Dialysis International* 24, 4: 353–358.

KAHRAMAN A., HILSENBECK J., NYGA M., ERTLE J., WREE A., PLAUTH M., GERKEN G., CANBAY A. E., 2010: Bioelectrical impedance analysis in clinical practice: implications for hepatitis C therapy BIA and hepatitis. *Journal of Clinical Virology* 7: 191. doi: 10.1186/1743-422X-7-191

KATSOULIS M., LAI A. G., DIAZ-ORDAZ K., GOMES M., PASEA L., BANERJEE A., DENAXAS S., TSILIDIS K., LAGIOU P., MISIRLI G., BHASKARAN K., WANNAMETHEE G., DOBSON R., BATTERHAM R. L., KIPOUROU D. K., LUMBERS R. T., WEN L., WAREHAM N., LANGENBERG C., HEMINGWAY H., 2021: Identifying adults at high-risk for change in weight and BMI in England: a longitudinal, large-scale, population-based cohort study using electronic health records. *The Lancet. Diabetes & Endocrinology* 9, 10: 681–694. doi: 10.1016/S2213-8587(21)00207-2

KATZMARZYK P. T., GREENWAY F. L., HEYMSFIELD S. B., BOUCHARD C., 2013: Clinical utility and reproducibility of visceral adipose tissue measurements derived from dual-energy X-ray absorptiometry in White and African American adults. *Obesity* 21, 11: 2221–2224. doi: 10.1002/oby.20519

KIRCHENGAST S., HUBER J., 2001: Fat distribution in young amenorrheic females. *Human Nature* 12: 123–140. doi: 10.1007/s12110-001-1020-z

KIRCHENGAST S., 2010: Gender differences in body composition from childhood to old age: an evolutionary point of view. *Life Science Journal* 2, 1: 1–10. doi: 10.1080/09751270.2010.11885146

KYLE U. G., MORABIA A., SCHUTZ Y., PICHARD C., 2004: Sedentarism affects body fat mass index and fat-free mass index in adults aged 18 to 98 years. *Nutrition* 20, 3: 25–60. doi: 10.1016/j.nut.2003.11.019

LIANG X., CHEN X., LI J., YAN M., YANG Y., 2018: Study on body composition and its correlation with obesity. *Medicine* 97, 21: e10722. doi: 10.1097/MD.0000000000010722

LU Y., SHU H., ZHENG Y., LI C., LIU M., CHEN Z., HE X., 2012: Comparison of fat-free mass index and fat mass index in Chinese adults. *European Journal of Clinical Nutrition* 66, 9: 1004–1007. doi: 10.1038/ejcn.2012.86

MAHADEVAN S., ALI I., 2016: Is body mass index a good indicator of obesity? *International Journal of Diabetes in Developing Countries* 36: 140–142. doi: doi.org/10.1007/s13410-016-0506-5

MANDEL D., ZIMLICHMAN E., MIMOUNI F. B., GROTTO I., KREISS Y., 2004: Height-related changes in body mass index: a reappraisal. *Journal of the American College of Nutrition* 23, 1: 51–54. doi: 10.1080/07315724.2004.10719342

MÁXIMO L. S. N., MELO F. F., PORTO L. B., RODRIGUEZ I. C., DO PRADO M., PEDROSA H. C., 2018: Correlation of body composition parameters different methods among Brazilian obese adults. *Revista Brasileira de Cineantropometria & Desempenho Humano* 21: 60539. doi: doi.org/10.1590/1980-0037.2019v21e60539

McALLISTER E. J., DHURANDHAR N. V., KEITH S. W., 2009: Ten putative contributors to the obesity epidemic. *Critical Reviews in Food Science and Nutrition* 49, 10: 868–913. doi: 10.1080/10408390903372599

MELMER A., LAMINA C., TSCHONER A., RESS C., KASER S., LAIMER M., SANDHOFER A., PAULWEBER B., EBENBICHLER C. H. F., 2013: Body adiposity index and other indexes of body composition in the SAPHIR study:

Association with cardiovascular risk factors. *Obesity* 21, 4: 775–781. doi: 10.1002/oby.20289

NAULI A. M., MATIN S., 2019: Why do men accumulate abdominal visceral fat? *Frontiers in Physiology* 10: 1486. doi: 10.3389/fphys.2019.01486

NEELAND I. J., GRUNDY S. M., LI X., ADAMS-HUET B., VEGA G. L., 2016: Comparison of visceral fat mass measurement by dual-X-ray absorptiometry and magnetic resonance imaging in a multiethnic cohort: the Dallas Heart Study. *Nutrition & Diabetes* 6,7: e221. doi: 10.1038/nutd.2016.28

NESCOLARDE L., PICCOLI A., ROMÁN A., NÚÑEZ A., MORALES R., TAMAYO J., DOÑATE T., ROSELL J., 2004: Bioelectrical impedance vector analysis in haemodialysis patients: relation between oedema and mortality. *Physiological Measurement* 25, 5: 1271–1280. doi: 10.1088/0967-3334/25/5/016

OMATA M., CHENG A. L., KOKUDO N., KUDO M., LEE J. M., JIA J., TATEISHI R., HAN K. H., CHAWLA Y. K., SHIINA S., JAFRI W., PAYAWAL D. A., OHKI T., OGASAWARA S., CHEN P. J., LESMANA C. R. A., LESMANA L. A., GANI R. A., OBI S., DOKMECI A. K., SARIN S. K., 2017: Asia-Pacific clinical practice guidelines on the management of hepatocellular carcinoma: a 2017 update. *Hepatology International* 11, 4: 317–370. doi: 10.1007/s12072-017-9799-9

PISCHON T., BOEING H., HOFFMANN K., BERGMANN M., SCHULZE M. B., OVERVAD K., VAN DER SCHOUW Y. T., SPENCER E., MOONS K. G., TJØNNELAND A., HALKJAER J., JENSEN M. K., STEGGER J., CLAVEL-CHAPELON F., BOUTRON-RUAULT M. C., CHAJES V., LINSEISEN J., KAAKS R., TRICHOPOULOU A., TRICHOPOULOS D., BAMIA C., SIERI S., PALLI D., TUMINO R., VINEIS P., PANICO S., PEETERS P. H., MAY A. M., BUENO-DE-MESQUITA H. B., VAN DUIJNHOVEN F. J., HALLMANS G., WEINEHALL L., MANJER J., HEDBLAD B., LUND E., AGUDO A., ARRIOLA L., BARRICARTE A., NAVARRO C., MARTINEZ C., QUIRÓS J. R., KEY T., BINGHAM S., KHAW K. T., BOFFETTA P., JENAB M., FERRARI P., RIBOLI E., 2008: General and abdominal adiposity and risk of death in Europe. *The New England Journal of Medicine: Research & Review* 359, 20: 2105–2120. doi: 10.1056/NEJMoa0801891

POOBALAN A., AUCOTT L., 2016: Obesity Among Young Adults in Developing Countries: A Systematic Overview. *Current Obesity Reports* 5, 1: 2–13. doi: 10.1007/s13679-016-0187-x

ROTHMAN K. J., 2008: BMI related errors in the measurement of obesity. *International Journal of Obesity* 32, 3: 556–559. doi: 10.1038/ijo.2008.87

SCHNEIDER H. J., GLAESMER H., KLOTSCHE J., BÖHLER S., LEHNERT H., ZEIHER A. M., MÄRZ W., PITTROW D., STALLA G. K., WITTCHEN H. U., 2007: Accuracy of anthropometric indicators of obesity to predict cardiovascular risk. *The Journal of Clinical Endocrinology & Metabolism* 92, 2: 589–594. doi: 10.1210/jc.2006-0254

SCHNEIDER H. J., FRIEDRICH N., KLOTSCHE J., PIEPER L., NAUCK M., JOHN U., DÖRR M., FELIX S., LEHNERT H., PITTROW D., SILBER S., VÖLZKE H., STALLA G. K., WALLASCHOFSKI H., WITTCHEN H. U., 2010: The predictive value of different measures of obesity for incident cardiovascular events and mortality. *The Journal of Clinical Endocrinology & Metabolism* 95, 4: 1777–1785. doi: 10.1210/jc.2009-1584

SCHORR M., DICHTEL L. E., GERWECK A. V., VALERA R. D., TORRIANI M., MILLER K. K., BREDELLA M. A., 2018: Sex differences in body composition and association with cardiometabolic risk. *Biology of Sex Differences* 9, 1: 28. doi: 10.1186/s13293-018-0189-3

SCHWENK A., BEISENHERZ A., RÖMER K., KREMER G., SALZBERGER B., ELIA M., 2000: Phase angle from bioelectrical impedance analysis remains an independent predictive marker in HIV-infected patients in the era of highly active antiretroviral treatment. *The American Journal of Clinical Nutrition* 72, 2: 496–501. doi: 10.1093/ajcn/72.2.496

SENGUPTA P., 2014: Comparing the physiological, socioeconomics and nutritional status among male and female undergraduate college students of metropolitan city of kolkata. *Annals of Medical and Health Science Research* 4, 4: 537–542. doi: 10.4103/2141-9248.139304

SLINDE F., GRÖNBERG A., ENGSTRÖM C. P., ROSSANDER-HULTHÉN L., LARSSON S., 2005: Body composition by bioelectrical impedance predicts mortality in chronic obstructive pulmonary disease patients. *Respiratory Medicine* 99, 8: 1004–1009. doi: 10.1016/j.rmed.2004.09.024

SWAINSON M. G., BATTERHAM A. M., TSAKIRIDES C., RUTHERFORD Z. H., HIND K., 2017: Prediction of whole-body fat percentage and visceral adipose tissue mass from five anthropometric variables. *PLoS One* 12, 5: e0177175. doi: 10.1371/journal.pone.0177175

TALLURI A., LIEDTKE R., MOHAMED E. I., MAIOLO C., MARTINOLI R., DE LORENZO A., 2003: The application of body cell mass index for studying muscle mass changes in health and disease conditions. *Acta Diabetologica* 40, 1: 286–289. doi: 10.1007/s00592-003-0088-9

WHO, 2000: Obesity: preventing and managing the global epidemic. World Health Organization. https://www.who.int/nutrition/publications/obesity/WHO_TRS_894/en/. [Accessed 20 May 2018].

WITHROW D., ALTER D. A., 2011: The economic burden of obesity worldwide: a systematic review of the direct costs of obesity. *Obesity Reviews* 12, 2: 131–141. doi: 10.1111/j.1467-789X.2009.00712.x

ZENG Q., HE Y., DONG S., ZHAO X., CHEN Z., SONG Z., CHANG G., YANG F., WANG Y., 2014: Optimal cut-off values of BMI, waist circumference and waist: height ratio for defining obesity in Chinese adults. *The British Journal of Nutrition* 112, 10: 1735–1744. doi: 10.1017/S0007114514002657

ZHANG Y., WU J., HONG P., MAO D., ZHUO Q., CHEN X., YANG X., 2016: Basal metabolic rate of overweight and obese adults in Beijing. *Wei Sheng Yan Jiu* 45, 5: 739–748.

Darina Falbová*
Lenka Vorobeľová
Radoslav Beňuš

Department of Anthropology
Faculty of Natural Sciences
Comenius University in Bratislava
Mlynska Dolina, Ilkovicova 6
842 15 Bratislava
Slovakia

E-mail: falbova6@uniba.sk
E-mail: lenka.vorobelova@uniba.sk
E-mail: benus1@uniba.sk

*Corresponding author.