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Associations between anthropometric indicators of adiposity and body fat percentage in normal weight young adults

Mustafa Söğüt[1], *Kübra Altunsoy*[1], *Maria Inês Varela-Silva*[2]

[1]Faculty of Sport Sciences, Kırıkkale University, Kırıkkale, Turkey
[2]School of Sport, Exercise and Health Sciences, Loughborough University, Loughborough, UK

Abstract: The purpose of this cross-sectional study was to determine the associations between various anthropometric adiposity screening indices and body fat percentage estimated by bioelectrical impedance analysis (BIA). A total of 186 (95 male and 91 female) normal weight (body mass index [BMI] = 18.5-24.9 kg/m2) young adults (mean age= 20.96 ± 2.03 years) were measured on body fat percentage, body height, body mass, waist and hip circumferences. Abdominal volume index, body adiposity index, BMI, body roundness index, conicity index, reciprocal ponderal index, waist to height ratio, waist to height 0.5 ratio, and waist to hip ratio were calculated accordingly. Results revealed significant gender effects in all main anthropometric measurements. Except for waist to hip ratio, results indicated significant associations between anthropometric indices and BIA in both male and female participants. BIA results were found to be largely associated with BMI and abdominal volume index in both genders. Bland-Altman analysis showed good agreements between these indices and BIA. Considerable associations and agreements highlight the potential importance and the use of several anthropometric proxies to estimate body adiposity among male and female non-overweight/obese young adults. Despite continuing discussion regarding its accuracy, BMI seems to be useful for monitoring body adiposity within this cohort.

Key words: adiposity, anthropometric indices, bioelectrical impedance, body composition, young adults, body mass index

Introduction

Physical inactivity and elevated caloric-dense food consumption is associated with excessive adiposity worldwide (Leonard 2010) and this is turning into a global public health problem (Caballero 2007; Roberto et al. 2015; Vandevijvere et al. 2015). As mentioned in previous studies (Frisard et al. 2005; Jakicic and Otto 2005; Moyer 2012), it also yields consequences for the diverse chronic diseases. Thus, a precise exploration of this condition to comprehend its epidemiology and treatments becomes crucial (Welborn and Dhaliwal 2007).

The estimation of various components of body composition, especially body fat percentage, and where in the body this subcutaneous fat is stored (regional dis-

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tribution of fat) has become an important focus of research among health researchers and practitioners in an attempt to curb the risks of obesity (Jebb et al. 2000) and its associations with non-communicable diseases. The methods to evaluate body compositions parameters are usually divided into criterion (gold-standard) methods: dual-energy x-ray absorptiometry, doubly labeled water, underwater weighting, air displacement plethysmography computed tomography, and magnetic resonance imaging and field methods: BIA, anthropometric measures and derived indices (Duren et al. 2008; Lee and Gallagher 2008). The preference of the techniques generally depends on the designated purpose and the convenience of the technology (Ackland et al. 2012) but the majority of fieldwork-based research relies on field methods.

BIA is a widely used method to reliably estimate percentage of the body fat as a whole and in specific parts of the body. It is portable, noninvasive, relatively inexpensive, quick, and useful in large-scale studies of populations from different ages and body sizes (Phillips et al. 2003; Lee and Gallagher 2008; Rush et al. 2006; Karelis et al. 2013). However, earlier studies provide inconsistent results regarding the validity of BIA against criterion techniques (Frisard et al. 2005; Azcona et al. 2006; Thomson et al. 2007; Bosy-Westphal et al. 2008; Radley et al. 2009; Hurst et al. 2016). The discrepancy among the findings might be explained by several factors affecting the sensitivity of BIA such as hydration status, fluid and food intake and intensity of exercise before testing, medical conditions, and environmental changes (Caton et al. 1988; Kyle et al. 2004; Deghghan and Merchant 2008).

Anthropometric indices (AIs), consist of the combination of basic anthropometric measurements (WHO Working Group 1986), which are also practical, quantitative, and non-invasive ways to estimate the composition of human body (de Onis and Habicht 1996). Since their high standard equivalents require expensive and special devices (Bergman et al. 2011) they are vastly preferred by scientists to estimate the level of adiposity. A vast number of previous studies have documented the use of AIs in predicting the body adiposity evaluated via reference methods (Revicki and Israel 1986; Gallagher et al. 1996; Taylor et al. 2000; Neovius et al. 2005; Ketel et al. 2007; Völgyi et al. 2008; Flegal et al. 2009; Bergman et al. 2011; Lambert et al. 2012; Thomas et al. 2013; Segheto et al. 2017). Nonetheless, current literature presents limited evidence on the relation between these methods and other predictive techniques among different samples. Thus, the purpose of this study is to determine the relations and agreements between various anthropometric adiposity screening indices and body fat percentage estimated with BIA in male and female normal weight young adults.

Materials and methods

Participants

The inclusion criteria for the study were male or female young adults with normal weight by BMI (18.5-24.9 kg/m^2) (WHO 2000). A total of 300 university students from a state university, located in central Anatolia (Turkey), were invited to take part in the study. Among them, 232 gave their consent to the study. They were initially informed of the testing procedures and the purpose of the study and then administered to a brief verbal questionnaire regarding their health status in order to ensure that they had no acute or chronic disease and/or implanted electrical stimulators. Informed consent forms were signed by the participants. Ethical approval was obtained from the Human Subjects Ethics Committee of Middle East Technical University. For the purpose of the study, participants were excluded if their BMI values were higher than 25 kg/m^2 (n= 33, 14.2 %) or lower than 18.5 kg/m^2 (n= 13, 5.6 %). Then, the data of 186 (80.2 %) (n_{male}= 95, n_{female}= 91) normal weight students (mean age= 20.96 ± 2.03 years) were used for the analysis.

Measures

Body height was measured with a portable stadiometer (Seca 213, Hamburg, Germany) to the nearest 0.1 cm. Body weight (0.1 kg) and body fat percentage was evaluated with BIA (Tanita, BC-418, Japan). Waist and hip circumferences (cm) were measured with a flexible steel tape to the nearest centimeter.

Procedures

Anthropometric measurements were performed in accordance with the reference manual (Lohman et al. 1988). Participants were asked to wear minimal clothing and stand barefoot for the assessments. Waist girth was measured at the smallest circumference between the ribs and iliac crest. Hip girth was measured at the level of maximum protuberance of the buttocks. Abdominal volume index ([AVI], Guerrero-Romero and Rodríguez-Morán 2003), body adiposity index ([BAI], Bergman et al. 2011), BMI, body roundness index ([BRI], Thomas et al. 2013), conicity index [(CI), Valdez 1991], reciprocal ponderal index ([RPI], Khosla and Lowe 1967), waist to height ratio (WHTR), waist to height$^{0.5}$ ratio ([WHT.5R], Nevill et al. 2016) and Waist to Hip Ratio (WHR) were calculated according to following formulas presented in Table 1.

Table 1. Formulas for the anthropometric indicators

AIs	Formulas
AVI	$[2(\text{waist})^2 + 0.7(\text{waist - hip})^2]$ / 1000
BAI	[(hip / height$^{1.5}$) -18]
BMI	weight / height^2
BRI	364.2 - 365.5 x [1 - [(Waist / 2π) / (0.5 x Height)]^2]$^{0.5}$
CI	waist / [0.109 x square root of (weight / height)]
RPI	height / weight$^{1/3}$
WHTR	waist / height
WHT.5R	waist / height$^{0.5}$
WHR	waist / hip

AIs - anthropometric indicators, AVI - abdominal volume index, BAI - body adiposity index, BMI - body mass index, BRI - body roundness index, CI - conicity index, RPI - reciprocal ponderal index, WHTR - waist to height ratio, WHT.5R - waist to height$^{0.5}$ ratio, WHR - waist to hip ratio

Statistical analysis

All data were analyzed using SPSS v. 20 for Windows. Descriptive statistics (mean ± *SD)* were calculated for the variables. An independent sample t-test was used to analyze differences between genders. Pearson correlation coefficient was conducted to determine the relationship between variables. Correlations were classified as 0.0-0.1 = trivial, 0.1-0.3 = small, 0.3-0.5 = moderate, 0.5-0.7 = large, 0.7-0.9 = very large, and 0.9-1.0 (near perfect) (Cohen 1988). The limits of agreement for standardized values of the variables were examined by Bland-Altman approach (Shaw et al. 2007). The statistical significance level was set at $p < 0.05$.

Results

A summary of descriptive statistics and the t-test results by gender for the main anthropometric characteristics and the fat percentages are presented in Table 2. Results revealed significant gender differences in all anthropometric variables.

The correlation results between AIs and body fat percentages for each gender are presented separately in Table 3. Results revealed (except for WHR) significant relations between indices and BIA values in both male and female participants. BIA results were found to be largely associated with BMI and AVI in both genders.

Table 4 represents the biases (SD±) between BIA and AIs. The results of the Bland-Altman analyses showed good agreement between variables.

Discussion

The aim of this cross-sectional study was to examine the associations and agreements between the aforementioned nine anthropometric adiposity screening indices and body fat percentage assessed by BIA in healthy-weight male and female young adults. Except for WHR, results indicated significant associations between

Table 2. Comparison of anthropometric characteristics and body fat percentages by gender

Variables	Male	Female	*t*	*P*
Body Height (cm)	176.3 ± 5.69	162.8 ± 5.49	16.450	0.000
Body Mass (kg)	69.7 ± 6.87	56.5 ± 5.21	14.694	0.000
Waist Circumference (cm)	75.6 ± 4.16	66.7 ± 3.84	15.143	0.000
Hip Circumference (cm)	92.6 ± 4.38	95.7 ± 4.34	- 4.850	0.000
Body Fat Percentage (%)	10.71 ± 3.78	23.98 ± 5.26	- 19.806	0.000

Table 3. Descriptive statistics and correlations results between AIs and body fat percentages

Gender	Male			Female		
	Mean (SD)	*r*	*P*	Mean (SD)	*r*	*P*
AVI	11.48 (1.27)	0.534	0.000	8.93 (1.03)	0.557	0.000
BAI	21.63 (1.93)	0.551	0.000	28.15 (2.34)	0.214	0.042
BMI	22.42 (1.61)	0.573	0.000	21.32 (1.54)	0.506	0.000
BRI	2.14 (0.37)	0.564	0.000	1.85 (0.40)	0.368	0.000
CI	1.10 (0.04)	0.267	0.009	1.04 (0.04)	0.238	0.023
RPI	42.89 (1.13)	- 0.535	0.000	42.47 (1.17)	- 0.333	0.001
WHTR	0.43 (0.02)	0.573	0.000	0.41 (0.03)	0.363	0.000
WHT.5R	5.70 (0.29)	0.580	0.000	5.23 (0.30)	0.476	0.000
WHR	0.82 (0.03)	0.064	0.539	0.70 (0.04)	0.144	0.175

AIs - anthropometric indicators, AVI - abdominal volume index, BAI - body adiposity index, BMI - body mass index, BRI - body roundness index, CI - conicity index, RPI - reciprocal ponderal index, WHTR - waist to height ratio, WHT.5R - waist to height$^{0.5}$ ratio, WHR - waist to hip ratio

Table 4. Bland-Altman results regarding SD(±) of biases between BIA and AIs

SD biases	AVI	BAI	BMI	BRI	CI	RPI	WHTR	WHT.5R	WHR
Male	0.97	0.95	0.92	0.93	1.21	1.75	0.93	0.92	1.36
Female	0.94	1.25	0.99	1.26	1.23	1.63	1.26	1.02	1.30

AIs - anthropometric indicators, AVI - abdominal volume index, BAI - body adiposity index, BMI - body mass index, BRI - body roundness index, CI - conicity index, RPI - reciprocal ponderal index, WHTR - waist to height ratio, WHT.5R - waist to height$^{0.5}$ ratio, WHR - waist to hip ratio

AIs and BIA in both genders. Individual characteristics like pelvic structure, skeletal frame, fat mass, and muscles mass around the hip area may have large effect on the accuracy of WHR (Ley et al. 1992; Molarious and Seidell 1998).

Results are in line with the findings of the earlier studies that focusing on this association from the samples possessing discrete status (age, gender, or health), such as in stunted children (boys) aged 7-9 years and their mothers (Wilson et al. 2011), healthy children (girls and boys) aged 3-8 years (Eisenmann et al. 2004), men aged 20-95 years (Ravaglia et al. 1999), obese women (Geliebter et al. 2012), women with BMIs over 18.5 (Suchanek et al. 2012), women aged 80 years and older (Zarzeczny et al. 2016), and adult men and women (Akindele et al. 2016; Ehrampoush et al. 2016). They reported significant correlations between various anthropometric proxies and BIA.

High correlations were found between BIA and BMI, and BIA and AVI in both male and female participants. Supportively, Ehrampoush et al. (2016) obtained strong relationships between BIA and BMI, AVI, and WHTR in healthy adults of both genders. Similar findings were found in the studies of Akindele, et al. (2016) and Ravaglia et al. (1999). They found strong association between BMI and BIA in males aged over 20 years. Correspondingly, Geliebter et al. (2012) and Suchanek et al. (2012) obtained a high degree of correlation between BMI and BIA in adult women.

In conclusion, this study attempted to gain an understanding of the associations and limits of agreement between various adiposity screening indices and BIA in male and female young adults. Although this study was limited by sample size and purposive sampling, which may weaken the interpretation of the results, considerable correlations highlight the potential importance and the use of several anthropometric proxies to estimate adiposity among normal weight collegiate students. Despite continuing debates regarding its accuracy, BMI seems to be useful for monitoring body adiposity among non-overweight/obese young adults. Further studies are recommended to investigate associations between those AIs and BIA in overweight and obese individuals.

Authors' contributions

MS conceived the study. MS and KA collected the data. MS performed the analysis and wrote the manuscript. MIVS critically revised the paper. All authors discussed the results and contributed to the final version of the article.

Conflict of interest

The authors declare that there is no conflict of interests.

Corresponding author

Mustafa Söğüt, Faculty of Sport Sciences, Kırıkkale University, Kırıkkale, 71450, Turkey
Email address: msogut@kku.edu.tr

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