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Fast Track Article

Reliability of anthropometric parameters in the prediction of the visceral fat area among adult women

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With 6 tables

Summary: Visceral fat accumulation is a risk factor for cardiometabolic diseases. Magnetic resonance imaging (MRI) and computed tomography (CT) provided the most accurate techniques of abdominal fat assessment, but these methods are very expensive. The aim of this study was to examine and compare the predictive ability of simple anthropometric parameters for visceral fat area (VFA) among adult women in different age and obesity status groups. The sample consisted of 133 adult women (aged 18–76 years). All subjects underwent anthropometric measurements. Body composition and VFA were determined with a multi-frequency bioimpedance analyzer (BIA). 16.9 % of the younger women (age < 45) were obese with a body-mass index (BMI) $\geq$ 30.0 kg/m^2, and 23.2 % of the older individuals (age > 45) had BMI $\geq$ 30 kg/m^2. After age and BMI adjustment, the best correlation was observed between VFA and waist circumference (WC) in younger women (R = 0.347, p = 0.002). In the case of the older women, the best correlation efficient values were for SAD (R = 0.560, p < 0.001) and hip circumference (R = 0.550, p < 0.001). The partial correlation coefficients were consistently higher for younger subjects with excessive fat accumulation (overweight & obese subgroup; individuals with WC > 80 cm) compared to women without obesity. Results of the multiple linear stepwise regression analyses showed the significance of age and BMI in prediction of VFA. In addition, hip circumference (HC) was one of the methods that best reflected VFA in older women independently from obesity status. Using single anthropometric parameters is not usually sufficient for predicting with good accuracy the VFA, but the convenient combination of these parameters could be a suitable way for the reliable prediction in Hungarian women.

Key words: obesity, anthropometry, visceral fat area, prediction.

Introduction

Obesity, defined as excessive or abnormal fat accumulation, has reached epidemic levels in developed and developing countries (James et al. 2001, Lieberman 2000, e

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Popkin & Doak 1998, Wyatt et al. 2006). The prevalence of obesity has risen considerably over the past decades, and this trend keeps on growing nowadays (Flegal et al. 2010, Kastarinen et al. 2000, Mokdad et al. 1999). According to the World Health Organization (WHO), in 2008 globally about 1.5 billion adults were overweight, more than 200 million men and nearly 300 million women were obese among them (World Health Organization Media Centre 2011). Furthermore, this problem affects not only the adults, but also adolescents and children (Quelly & Lieberman 2011, Wang et al. 2002). An increased risk of a number of life threatening diseases is linked to obesity, such as cardiovascular diseases, diabetes mellitus, musculoskeletal disorders, different types of cancer. Apart from causing health problems, obesity is also a serious financial burden both for society and for obese individuals (Bray 2004, Thompson et al. 1999).

There are strong evidences that visceral adipose tissue, through its ability to produce free fatty acids, carries greater risk of developing stroke, heart disease, type 2 diabetes and cardiometabolic disorders than subcutaneous adipose tissue or whole-body obesity (McTernan et al. 2002, von Eyben et al. 2003). Furthermore, Goodpaster et al. (2005) reported that subcutaneous thigh adipose tissue was inversely associated with the metabolic syndrome in obese subjects. Consequently, estimating fat distribution and intra-abdominal fat accumulation could be more useful to predict the risk of cardiovascular and metabolic diseases than whole body fat.

Modern imaging techniques, including dual-energy X-ray absorptiometry (DXA), computed tomography (CT) and magnetic resonance imaging (MRI) provide the most accurate in vivo estimates of abdominal visceral fat (Shen & Chen 2008). However, these methods cannot be applied in routine clinical practice because they are excessively costly and time-consuming, furthermore DXA and CT exposes the subjects to radiation. For these reasons, alternative methods are used to estimate intra-abdominal fat deposition. Ultrasonography has been reported as a precise and reliable way for the evaluation of visceral fat and cardiovascular risk (Liu et al. 2003, Ribeiro-Filho et al. 2001, Tornaghi et al. 1994). Bioelectrical impedance analysis (BIA), already put into practical use, is a simple, noninvasive and inexpensive method for body fat measurement (Jackson et al. 1988, Lukaski et al. 1986), even if it has its limitations (Kushner et al. 1996). There have been several study reports recently on visceral fat area (VFA) estimating methods using BIA, whose results suggest that they could serve as convenient and useful methods to accurately assess abdominal fat accumulation (Nagai et al. 2008, Ryo et al. 2005, Shiga et al. 2007).

Because of their simplicity, a great number of different anthropometric measurements have become commonly used indirect methods for the identification of obesity in epidemiological studies and clinical settings. While body-mass index (BMI) provides a useful method for the diagnosis of whole-body obesity, waist circumference (WC), waist-to-hip ratio (WHR) and sagittal abdominal diameter (SAD) are widely used indicators of central obesity. Moreover, it has been verified through experiments that these measurements present good predictive abilities for abdominal adipose tissue and cardiometabolic risk (Brambilla et al. 2006, Brook et al. 2001, Lorenzo et al. 2009, Pouliot et al. 1994). The main problem is that they do not distinguish visceral tissue from subcutaneous abdominal adipose tissue. Furthermore, the strength of the correlation with the VFA and metabolic abnormalities may vary at the different levels of the degree of obesity and age (Berker et al. 2010, Drapeau et al. 2007, Pou et al. 2009).

The main purpose of this preliminary study was to examine and compare the predictive ability of simple anthropometric parameters for VFA among adult women in different age and obesity status groups.

Material and methods

Subjects

The data of participants were collected through a healthy lifestyle awareness campaign advertised throughout the city of Szeged. There were no restrictions for participation in this program; anyone could volunteer to participate in the four-month, organized sport programs. The groups in the first period (from January 2010 to May 2010) consisted of 149 females and in the second period (form September 2010 to December 2010) the groups consisted of 96 females. All healthy women, above 18 years of age, were enrolled in this study. Exclusion criteria were pregnancy and incomplete data. The final number of the sample was 133 individuals. All participants were informed about the study aim and design, and they gave their informed consent. The study protocol was approved by the Institution of Physical Education and Sport Science of the University of Szeged. All subjects underwent anthropometric measurements and BIA examination on the same day. The participants were asked to avoid doing strenuous exercises for 2 hours before the measurements. During the investigation, the subjects wore only light underwear.

Anthropometric measurements

The measurements were executed by trained staff members. Anthropometric measurements included height, weight, hip width, sagittal abdominal diameter, waist, hip, upper arm and thigh circumferences, and skinfold thickness at 6 sites. The measurements were performed according to Martin's standardized technique (Martin & Saller 1956). Height and body weight were measured to the nearest 0.1 cm and 0.1 kg, respectively. Circumferential measurements were determined with steel tape. Subcutaneous fat thickness was measured by GPM-Skinfold Caliper at 6 sites: triceps, forearm, subscapular, abdominal, front thigh and medial calf. Sagittal abdominal diameter is the distance between the back surface and the top of the abdomen at the level of the iliac crest. Waist circumference was taken in standing position at the midpoint between the lowest rib and the lateral iliac crest. Hip circumference was taken at the level of the iliac crest. Body-mass index was derived as body weight in kilograms divided by the squared value of body height in meters (kg/m^2). Waist-to-hip ratio was also calculated. During the statistical analyses subjects were divided into two age groups (age < 45; age > 45) and further subcategories: obesity status subgroups by percent body fat (normal; overweight & obese) according to the recommendations of Gallagher et al. (2000). The "normal" subgroup included 5 underweight, but absolutely healthy persons. The two WC subgroups were defined (cut-off point for central fat accumulation with increased metabolic risk: 80 cm) according to the recommendations of the World Health Organization (World Health Organization 2011).

Bioelectrical impedance analysis

Body composition was evaluated by a multifrequency BIA device (Biospace InBody230 Body Composition Analyzer) with tetrapolar 8-point contact electrodes. The measurements were performed by using a frequency current of 330 μA at 20 kHz and 100 kHz between a set of electrodes attached to the hands and feet. The input information included gender, age, and height. Body fat percentage (%BF) and VFA were automatically calculated by the device. All measurements were performed by the same person.

Statistical analysis

Descriptive statistics for the variables were generated and reported for the age groups; data were expressed as mean ± standard deviation. The Mann-Whitney U test was performed to determine mean differences between the two groups. Correlations of VFA and anthropometric parameters were analyzed by Spearman correlations. Partial correlation analysis with the use of Fisher's z transformation was applied to calculate age and BMI-adjusted correlation coefficients between the anthropometric variables and VFA. We also analyzed the partial correlations for the subjects in different obesity status and WC categories, by using the anthropometric parameters with $p < 0.05$ after adjustment for age and BMI. A *p*-value of less than 0.05 was considered statistically significant. Multiple linear stepwise regression analyses were conducted to assess the efficiency of anthropometric variables in the prediction of visceral adiposity. Correlation coefficients were also investigated between each one of the anthropometric parameters to avoid multicollinearity problems. The data were analyzed with SPSS for Windows (version 17) and MedCalc (version 11.5).

Results

The descriptive characteristics of the subjects are shown in Table 1. The mean age of the younger group (women below 45 years of age) was 29.9 ± 8.5 years and the mean BMI was 25.4 ± 5.2 kg/m^2; 20.8 % of the individuals had a BMI 25.0–29.9 kg/m^2 and

Table 1. Characteristics of the subjects.

	Total (n = 133)	**Age < 45 (n = 77)**	**Age > 45 (n = 56)**	***p***
Age (years)	40.5 ± 14.6	29.9 ± 8.5	54.8 ± 7.1	< 0.001
Height (cm)	163.4 ± 6.9	165.1 ± 6.3	161.1 ± 7.1	0.001
Weight (kg)	69.6 ± 13.5	69.2 ± 15.0	70.2 ± 11.3	0.186
Hip width (cm)	28.9 ± 3.3	28.9 ± 3.2	29.2 ± 3.4	0.538
SAD (cm)	20.5 ± 4.3	18.9 ± 4.4	22.7 ± 3.3	< 0.001
WC (cm)	80.0 ± 11.8	76.9 ± 11.3	84.2 ± 11.1	< 0.001
Hip circumference (cm)	95.0 ± 10.6	93.3 ± 11.7	97.4 ± 8.5	0.004
Upper arm circumference (cm)	28.5 ± 3.7	28.1 ± 4.1	29.0 ± 2.9	0.021
Thigh circumference (cm)	59.1 ± 71	59.7 ± 8.0	58.2 ± 5.7	0.496
Skinfold thickness (mm)				
Triceps	21.6 ± 6.9	21.9 ± 7.2	21.1 ± 6.8	0.286
Forearm	10.9 ± 4.5	10.5 ± 4.6	11.6 ± 4.6	0.096
Subscapular	19.3 ± 7.8	18.3 ± 7.9	20.8 ± 7.3	0.039
Abdominal	23.5 ± 7.9	22.6 ± 7.8	24.5 ± 8.1	0.237
Front thigh	25.1 ± 7.3	25.2 ± 6.9	24.7 ± 7.6	0.724
Medial calf	16.7 ± 7.8	18.7 ± 8.6	14.0 ± 5.6	0.002
BMI (kg/m^2)	26.1 ± 4.8	25.4 ± 5.2	27.1 ± 4.1	0.003
WHR	0.84 ± 0.06	0.82 ± 0.05	0.86 ± 0.06	< 0.001
%BF (%)	32.6 ± 7.2	31.0 ± 7.5	34.3 ± 6.3	0.003
VFA (cm^2)	94.9 ± 41.2	77.2 ± 39.6	119.3 ± 29.2	< 0.001

Results are expressed as mean ± standard deviation. BMI = body-mass index, SAD = sagittal abdominal diameter, WC = waist circumference, WHR = waist-to-hip ratio, VFA = visceral fat area, %BF = percent body fat

16.9 % were obese with a BMI ≥ 30 kg/m^2. The mean WC was 76.9 ± 11.3 cm, and abdominal obesity, based on the recommendations of the World Health Organization, was present in 23 females (29.9 %). VFA measurements performed by applying BIA were 77.2 ± 39.6 cm^2; 22.1 % of the woman had their VFA levels over 100 cm^2.

On the other hand, the same parameters of the older group (women above 45 years of age) were higher and significantly different. The mean BMI was 27.1 ± 4.1 kg/m^2; 46.4 % of the individuals had a BMI 25.0–29.9 kg/m^2 and 23.2 % were obese with a BMI ≥ 30 kg/m^2. The mean WC was 84.2 ± 11.1 cm, and abdominal obesity was present in 35 females (62.5 %). VFA measurements performed by applying BIA were 119.3 ± 29.2 cm^2; 75.0 % of the women had their VFA levels over 100 cm^2. Although some mean values were lower in the case of the older women (for example: thigh circumference, triceps and front thigh skinfold thickness), only the values for body height (165.1 cm vs. 161.1 cm, $p = 0.001$) and medial calf skinfold thickness (18.7 mm vs. 14.0 mm, $p = 0.002$) were significantly different from the means of the younger group. It seems that the abnormal fat accumulation was more expressed among these older participants.

Table 2 shows the Spearman's correlation coefficients between the VFA by BIA and the anthropometric parameters. Among all subjects, all anthropometric variables correlated with VFA, except for medial calf skinfold thickness. SAD (R = 0.866, $p < 0.001$), WC (R = 0.862, $p < 0.001$), BMI (R = 0.847, $p < 0.001$) and hip circumference (R = 0.818, $p < 0.001$) correlated strongly with VFA. The other variables

Table 2. Correlations of visceral fat area and anthropometric parameters.

	Total (n = 133)		**Age < 45 (n = 77)**		**Age > 45 (n = 56)**	
	R	***p***	**R**	***p***	**R**	***p***
Age (years)	0.622	< 0.001	0.322	0.004	0.402	0.002
Height (cm)	–0.212	0.014	–0.025	0.827	–0.193	0.155
Weight (kg)	0.711	< 0.001	0.798	< 0.001	0.680	< 0.001
Hip width (cm)	0.472	< 0.001	0.548	< 0.001	0.476	< 0.001
SAD (cm)	0.866	< 0.001	0.725	< 0.001	0.808	< 0.001
WC (cm)	0.862	< 0.001	0.826	< 0.001	0.846	< 0.001
Hip circumference (cm)	0.818	< 0.001	0.825	< 0.001	0.839	< 0.001
Upper arm circumference (cm)	0.699	< 0.001	0.695	< 0.001	0.624	< 0.001
Thigh circumference (cm)	0.527	< 0.001	0.751	< 0.001	0.461	< 0.001
Skinfold thickness (mm)						
Triceps	0.343	< 0.001	0.491	< 0.001	0.375	0.004
Forearm	0.565	< 0.001	0.591	< 0.001	0.543	< 0.001
Subscapular	0.632	< 0.001	0.688	< 0.001	0.523	< 0.001
Abdominal	0.534	< 0.001	0.533	< 0.001	0.619	< 0.001
Front thigh	0.325	< 0.001	0.455	< 0.001	0.379	0.004
Medial calf	–0.053	0.548	0.098	0.395	0.207	0.127
BMI (kg/m^2)	0.847	< 0.001	0.853	< 0.001	0.850	< 0.001
WHR	0.472	< 0.001	0.213	0.063	0.423	0.001

BMI = body-mass index, R = correlation coefficient, SAD = sagittal abdominal diameter, WC = waist circumference, WHR = waist-to-hip ratio showed only moderate positive correlations (for example: thigh circumference R = 0.527, $p < 0.001$; subscapular skinfold thickness R = 0.632, $p < 0.001$) or weak positive correlations with the visceral fat accumulation (for example: WHR R = 0.472, $p < 0.001$; triceps skinfold thickness R = 0.343, $p < 0.001$). The measurements with the best correlation coefficients in both age group were BMI (age < 45: R = 0.853, $p < 0.001$; age > 45: R = 0.850, $p < 0.001$), WC (age < 45: R = 0.826, $p < 0.001$; age > 45: R = 0.846, $p < 0.001$) and hip circumference (age < 45: R = 0.825, $p < 0.001$; age > 45: R = 0.839, $p < 0.001$). In addition, the value of correlation coefficient for SAD was above 0.8 in the case of the older women. Considerable differences in the coefficients of WHR and thigh circumference were noticed between the two groups.

The values of coefficients changed considerably after age and BMI adjustment (Table 3). The association between VFA and 7 anthropometric parameters (body height, weight, hip width, upper arm circumference, forearm, subscapular and abdominal skinfold thickness) became non-significant for the full sample, furthermore, the partial correlation coefficients decreased markedly. The best relationship with the VFA measured by BIA was obtained for WC for younger women (R = 0.347, $p = 0.002$) and the second best relationship for SAD (R = 0.307, $p = 0.007$). In the case of the older women, the best correlation efficient values were for SAD (R = 0.560, $p < 0.001$) and hip circumference (R = 0.550, $p < 0.001$). Significant relationship remained between VFA and WHR only in the full sample, and this association was very weak (R = 0.219, $p = 0.012$).

Table 3. Age and BMI-adjusted partial correlation coefficients between visceral fat area and anthropometric parameters.

	Total (n = 133)		**Age < 45 (n = 77)**		**Age > 45 (n = 56)**	
	R	***p***	**R**	***p***	**R**	***p***
Height (cm)	–0.148	0.091	0.073	0.532	0.023	0.868
Weight (kg)	–0.138	0.115	0.101	0.383	0.019	0.891
Hip width (cm)	0.071	0.415	0.292	0.011	0.025	0.854
SAD (cm)	0.593	< 0.001	0.307	0.007	0.560	< 0.001
WC (cm)	0.453	< 0.001	0.347	0.002	0.358	0.007
Hip circumference (cm)	0.308	< 0.001	0.196	0.089	0.550	< 0.001
Upper arm circumference (cm)	–0.111	0.204	–0.172	0.138	–0.033	0.808
Thigh circumference (cm)	–0.354	< 0.001	–0.127	0.276	–0.128	0.351
Skinfold thickness (mm)						
Triceps	–0.254	0.005	0.058	0.620	–0.448	0.001
Forearm	–0.044	0.612	–0.016	0.890	–0.112	0.415
Subscapular	0.099	0.257	0.158	0.174	–0.004	0.977
Abdominal	0.041	0.638	0.009	0.940	0.162	0.237
Front thigh	–0.192	0.027	–0.052	0.654	–0.241	0.076
Medial calf	–0.371	< 0.001	–0.193	0.095	–0.197	0.149
WHR	0.219	0.012	0.094	0.418	–0.005	0.970

R = partial correlation coefficient, SAD = sagittal abdominal diameter,
WC = waist circumference, WHR = waist-to-hip ratio

The individuals were divided into further two subcategories according to their obesity status (normal, overweight & obese). The partial correlations between VFA and anthropometric parameters with $p < 0.05$ after adjustment for age and BMI were also determined (Table 4). In the case of the younger women, the coefficients were consistently higher for subjects with excessive fat accumulation (the overweight & obese subgroup), except for two parameters (front thigh skinfold thickness and WHR). Concerning the older women, similar trend was not found. Comparing to the two age groups, it was observed that the most of the coefficients were higher for the older women. The best coefficient values that the normal subgroups showed were for hip circumference in younger age group (R = 0.269, $p = 0.049$) and SAD for older women (R = 0.558, $p = 0.002$). In the case of the overweight and obese subgroups the

Table 4. Age and BMI-adjusted partial correlations of visceral fat area and anthropometric variables in individuals with different obesity status.

		Total (n = 133)		Age < 45 (n = 77)		Age > 45 (n = 56)	
		R	***p***	**R**	***p***	**R**	***p***
Hip width (cm)	Normal[a]	–0.013	0.909	0.082	0.553	0.231	0.237
	Overweight & obese[b]	0.124	0.406	0.509	0.022	0.041	0.842
SAD (cm)	Normal	0.534	< 0.001	–0.154	0.265	0.558	0.002
	Overweight & obese	0.621	< 0.001	0.438	0.053	0.439	0.025
WC (cm)	Normal	0.292	0.087	0.063	0.652	0.350	0.068
	Overweight & obese	0.579	< 0.001	0.525	0.018	0.293	0.146
Hip circumference (cm)	Normal	0.226	0.038	0.269	0.049	0.409	0.031
	Overweight & obese	0.281	0.055	0.335	0.149	0.773	< 0.001
Thigh circumference (cm)	Normal	–0.344	0.001	–0.062	0.645	–0.123	0.531
	Overweight & obese	–0.392	0.006	–0.064	0.794	–0.019	0.927
Skinfold thickness (mm)							
Triceps	Normal	–0.257	0.011	0.189	0.171	–0.331	0.085
	Overweight & obese	–0.203	0.172	0.387	0.092	–0.444	0.023
Front thigh	Normal	–0.085	0.441	0.199	0.149	–0.050	0.799
	Overweight & obese	–0.356	0.014	–0.162	0.496	–0.379	0.056
Medial calf	Normal	–0.308	0.004	0.158	0.254	–0.158	0.423
	Overweight & obese	–0.502	< 0.001	–0.328	0.158	–0.173	0.398
WHR	Normal	0.094	0.395	–0.257	0.060	0.115	0.561
	Overweight & obese	0.375	0.009	0.225	0.340	–0.231	0.256

R = partial correlation coefficient, SAD = sagittal abdominal diameter, WC = waist circumference, WHR = waist-to-hip ratio, [a]n = 85, [b]n = 48 best correlation coefficient values were for WC in younger women (R = 0.525, *p* = 0.018), and hip circumference in older participants (R = 0.773, *p* < 0.001).

The partial correlations were calculated also for sub-samples with (Group II) and without (Group I) abdominal obesity as defined by the WHO (Table 5). A similar tendency was observed, i.e. the correlation coefficients between VFA and anthropometric parameters showed relatively stronger associations among individuals with abdominal obesity in the case of the younger age group. In the analysis of Group I sub-samples, the highest coefficients were found between hip width and VFA for younger women (R = 0.275, *p* = 0.047) and SAD for the older individuals (R = 0.661, *p* = 0.001). In the analysis of Group II sub-samples, the highest coefficients were observed for WC in younger age group (R = 0.512, *p* = 0.015) and hip circumference for the older women (R = 0.473, *p* = 0.005).

Table 6 shows the results of the multiple linear stepwise regression analyses. In the case of the full sample (without classification into age and obesity status groups), we found that the parameters best predicting VFA were SAD, hip width, age and triceps skinfold thickness (75.4 %, 4 %, 4.7 % and 2.5 % of the VFA change could be

Table 5. Age and BMI-adjusted partial correlations of visceral fat area and anthropometric variables in subjects with and without central obesity.

		Total (n = 133)		**Age < 45 (n = 77)**		**Age>45 (n = 56)**	
		R	***p***	**R**	***p***	**R**	***p***
Hip width (cm)	Group I[a]	–0.078	0.508	0.275	0.047	0.202	0.393
	Group II[b]	0.117	0.386	0.331	0.132	–0.182	0.303
SAD (cm)	Group I	0.521	< 0.001	0.200	0.150	0.661	0.001
	Group II	0.518	< 0.001	0.429	0.046	0.361	0.036
WC (cm)	Group I	0.056	0.635	0.079	0.572	0.133	0.577
	Group II	0.477	< 0.001	0.512	0.015	0.112	0.530
Hip circumference (cm)	Group I	0.119	0.314	0.213	0.125	0.268	0.253
	Group II	0.174	0.195	0.164	0.458	0.473	0.005
Thigh circumference (cm)	Group I	–0.183	0.118	–0.046	0.746	0.039	0.871
	Group II	–0.439	0.001	–0.227	0.309	–0.057	0.749
Skinfold thickness (mm)							
Triceps	Group I	–0.215	0.066	–0.146	0.298	0.098	0.681
	Group II	–0.268	0.044	0.284	0.201	–0.352	0.041
Front thigh	Group I	–0.093	0.430	–0.047	0.736	0.133	0.576
	Group II	–0.246	0.065	–0.077	0.735	–0.343	0.047
Medial calf	Group I	–0.374	0.001	–0.265	0.064	–0.101	0.672
	Group II	–0.308	0.020	–0.092	0.684	–0.085	0.631
WHR	Group I	–0.072	0.545	–0.150	0.284	–0.050	0.833
	Group II	0.320	0.015	0.354	0.106	–0.266	0.128

R = partial correlation coefficient, SAD = sagittal abdominal diameter, WC = waist circumference, WHR = waist-to-hip ratio, [a] Sub-sample: subjects without abdominal obesity as defined by the World Health Organization (n = 75), [b]Sub-sample: subjects with abdominal obesity as defined by the World Health Organization (n = 58)

Table 6. Results of multiple regression analyses using visceral fat area as the dependent variable and anthropometric parameters as independent variables.

Groups	Models	Variables	B	SE	β	*p*	R^2	SEE	VIF
Total	Overall	Intercept	–165.437	12.489		< 0.001	0.865	15.35	
	N = 133	SAD	6.198	0.400	0.655	< 0.001			1.695
		Hip width	2.760	0.466	0.222	< 0.001			1.331
		Age	0.918	0.116	0.327	< 0.001			1.618
		Triceps skinfold	0.956	0.197	0.181	< 0.001			1.328
	Normal	Intercept	–115.284	12.227		< 0.001	0.887	9.47	
	N = 85	Age	1.371	0.084	0.666	< 0.001			1.169
		BMI	4.115	0.505	0.395	< 0.001			1.662
		Abdominal skinfold	0.607	0.19	0.144	0.002			1.438
		Hip width	0.963	0.436	0.098	0.030			1.376
	Overweight & obese	Intercept	–118.146	15.602		< 0.001	0.871	11.63	
	N = 48	WC	0.798	0.300	0.257	0.011			3.172
		Age	1.012	0.122	0.519	< 0.001			1.337
		BMI	4.383	0.703	0.603	< 0.001			3.185
Age	Overall	Intercept	–176.057	11.158		< 0.001	0.939	9.95	
< 45	N = 77	BMI	6.251	0.261	0.823	< 0.001			1.414
		Age	1.346	0.135	0.289	< 0.001			1.004
		Hip width	1.883	0.423	0.153	< 0.001			1.411
	Normal	Intercept	–144.376	16.001		< 0.001	0.870	8.09	
	N = 56	BMI	4.643	0.514	0.546	< 0.001			1.431
		Age	1.507	0.147	0.585	< 0.001			1.279
		Hip width	1.455	0.512	0.150	0.006			1.086
		Abdominal skinfold	0.568	0.207	0.164	0.008			1.399
	Overweight & obese	Intercept	–338.358	58.032		< 0.001	0.938	10.65	
	N = 21	BMI	6.151	0.491	0.769	< 0.001			1.038
		Age	1.885	0.276	0.420	< 0.001			1.042
		Body height	1.288	0.342	0.229	0.002			1.017

Table 6. Continued

Groups	Models	Variables	B	SE	β	*p*	R^2	SEE	VIF
Age > 45	Overall N = 56	Intercept	–194.751	19.828		< 0.001	0.852	11.55	
		Hip circumference	2.431	0.200	0.706	< 0.001			1.183
		Abdominal skinfold	1.833	0.359	0.289	< 0.001			1.125
		Age	1.021	0.226	0.248	< 0.001			1.059
	Normal N = 29	Intercept	–58.982	31.927		0.001	0.727	10.57	
		Abdominal skinfold	1.274	0.348	0.492	0.001			1.654
		Age	0.786	0.268	0.312	0.007			1.034
		Hip circumference	0.954	0.331	0.387	0.008			1.656
	Overweight & obese N = 27	Intercept	–143.659	24.162		< 0.001	0.901	6.92	
		Hip circumference	1.895	0.315	0.550	< 0.001			1.932
		BMI	3.576	0.684	0.626	< 0.001			3.316
		Triceps skinfold	0.682	0.264	0.246	0.016			2.088

B = regression coefficient, SE = standard error, β = standardized regression coefficient, R^2 = coefficient of determination, SEE = standard error of the estimate, VIF = variance inflation factor, SAD = sagittal abdominal diameter, WC = waist circumference.

explained by these parameters, respectively). The association between VFA and the anthropometric parameters was investigated by stratification by obesity status. The results showed that in the case of participants with normal obesity status, the parameters best predicting VFA were age, BMI, abdominal skinfold thickness and hip width (coefficients of determination were 61.4 %, 24.5 %, 2.1 % and 0.7 %, respectively); in the group of overweight and obese participants, WC (coefficient of determination: 65 %), age (coefficient of determination: 10.7 %) and BMI (coefficient of determination: 11.4 %). Analyses of the younger women revealed that the parameters best predicting VFA were BMI, age, hip width (84.2 %, 8 %, 2 % and 1.7 % of the VFA change could be explained by these parameters, respectively). Analyses of the older women revealed the next anthropometric parameters: hip circumference, abdominal skinfold thickness and age (coefficient of determination of these variables were 73 %, 6.4 % and 5.8 %, respectively).

Discussion

Visceral fat tissue accumulation is an independent risk factor for different kinds of cardiometabolic diseases, such as hypertension, stroke, insulin resistance and type 2 diabetes (Bergman et al. 2006). The use of different anthropometric parameters to assess obesity-related risk is a widespread technique in clinical and research practice, so it is important to investigate the reliability and accuracy of these alternative ways in connection with VFA. The major findings of this study demonstrated that SAD, WC, BMI, hip width and hip circumference, as single anthropometric parameters, had an adequate, significant relationship with visceral adipose tissue, although these measurements represented correlation differences at different levels of obesity and age groups. On the other hand, it seems possible that the combinations of different anthropometric parameters ensure a considerable way to improve the efficiency of prediction for the VFA.

BMI is the most widely used and the simplest measurement of body size, which is frequently used for the estimation of obesity prevalence within a population. Sebo et al. (2008) reported that BMI was the most reliable parameter to detect obesity in medical practice, while other researchers emphasized that increased BMI should be associated with an increased risk of cardiovascular and metabolic diseases (Field et al. 2001, Mokdad et al. 2001). However, the strongest criticism BMI has ever received is that it does not take into account any variations in body composition and fat distribution, and its association with body fatness depends on gender and age (Gallagher et al. 1996, Michels et al. 1998, Smalley et al. 1990).

In our study, BMI showed very high correlation with VFA (all subjects: R = 0.847, $p < 0.001$; younger women: R = 0.853, $p < 0.001$; older women: R = 0.850, $p < 0.001$). Berker et al. (2010) also reported a significant correlation between BMI and visceral fat area (R = 0.885) for females. Similar results were observed by Oka et al. (2009). They investigated nearly 2500 Japanese adults and they found that BMI was significantly and positively correlated with visceral adipose tissue in females (R = 0.68). However, they emphasized that BMI was a better predictor of subcutaneous adipose tissue. Rankinen et al. (1999) found that the correlation coefficient between abdominal visceral fat and BMI in a group of women below 45 years of age was higher with more than 0.1 compared to the women above 45 years of age. In our study, similar difference between the two age groups was not observed. Examining the two obesity subgroups separately, we found that the correlation coefficient was higher for subjects with excessive fat accumulation (normal: R = 0.646, $p < 0.001$; overweight & obese: R = 0.700, $p < 0.001$), which was similar to the findings of Berker et al. (2010). Differences could also be seen in the coefficients between the central obesity groups (Group I vs. Group II): stronger associations were observed for subjects in Group II (R = 0.667, $p < 0.001$). The multiple linear stepwise regression analyses revealed that BMI was among the best parameters to assess VFA. In the case of the full sample and the older age group with normal obesity status, BMI was excluded from the regression models because of the multicollinearity. These results suggest that BMI can be useful to predict the accumulation of visceral fat tissue, but this predictive ability may be less reliable when influenced by amount of body fat.

WC and SAD are widely advocated simple anthropometric indicators of abdominal fat accumulation, and several studies have shown that these measurements are strictly correlated to different cardiometabolic risk factors, morbidity and mortality (Ball et al. 2006, Brambilla et al. 2006, Lorenzo et al. 2009, Zamboni et al. 1998). However, WC and SAD do not distinguish visceral and subcutaneous abdominal adipose tissues, and there is no consensus about the best cut-off points for SAD to be used for identifying individuals at risk. In our study, WC had a stronger correspondence with VFA in comparison with SAD for both age groups, although this difference in the case of the women above 45 years of age was relatively small. After age and BMI adjustment, the partial correlation coefficient of WC was higher only in younger age group, while the coefficient for SAD showed a higher value for the older participants. SAD lost its correlation with VFA in the younger women when individuals were divided into obesity status groups, but sustained the significant association in the case of the older women, irrespective of obesity status. WC showed significant relationship with VFA only in the case of younger women with excessive fat accumulation. When correlations were presented according to the WC categories, the results were very similar to the results in Table 4. Furthermore, significant association was found between SAD and VFA among the younger women. Similar results were published by Berker et al. (2010), they did not find any significant correlation between WC and VFA in the case of females with BMI < 30 kg/m^2. Demura & Sato (2007a) also reported that WC was not significantly related to VFA in the overweight subjects (BMI $\geq$ 25 kg/m^2). Yim et al. (2010) reported that SAD showed the strongest correlation to visceral adipose tissue, irrespective of gender and the degree of obesity. Linear stepwise analyses revealed that when the subjects were grouped by obesity status, WC showed high consistency with VFA for overweight and obese women. SAD was the best parameter explaining the VFA change for the full sample.

WHR is used to measure relative overall body fat distribution and has been widely applied in adults. In our study, the prognostic value of WHR appeared to be low because it weakly correlated with the VFA in older women (R = 0.423). After adjustment for age and BMI the values of the coefficients decreased more noticeably, and the significant relationship disappeared when participants were divided into two age groups. Moreover, significant association was observed only in subsamples, which represented a higher risk for cardiovascular and metabolic events (overweight & obese, Group II) for all individuals. Regression analyses revealed no statistically significant relationship between WHR and VFA in any subgroups. In conformity with our results, several studies have found that WHR is a poor indicator of abdominal visceral fat and cardiovascular risk compared to SAD and WC (Dobbelsteyn et al. 2001, Petersson et al. 2007, Picon et al. 2007, Risérus et al. 2004, Taylor et al. 2000).

The measures of hip are less investigated parameters as single predictors of visceral obesity. Our findings showed significant association with VFA for both age groups concerning hip width and hip circumference, but the values of correlation coefficient of hip circumference were higher. In contrast to our results, it has been reported by Chen et al. (2007) that hip circumference did not correlated with log visfatin, which is an adipocytokine secreted from visceral adipocytes and its plasma level correlated strongly with the amount of visceral fat. After age and BMI adjustment, hip width sustained its correlation with VFA in younger age group, while correlation was found between hip circumference and VFA only for older women. These differences remained between the two age groups when participants were separated further by obesity status and central fat accumulation, although significant association was observed between hip circumference and VFA among younger women without obesity. Multiple linear stepwise regression analyses categorizing participants by age showed that hip circumference was one of the methods that best reflected VFA in older women independently from obesity status. Hip width demonstrated consistency with VFA for the younger age group and the full sample (except for "overweight & obese sub-samples").

Regression analyses were used to identify the best regression models (using the combinations of anthropometric parameters) for all groups and subgroups. One of the most notable results was the importance of the variable age. The analyses revealed statistically significant relationship between age and VFA in women below and above 45 years of age when assessed separately, and in all individuals. The significant effect of age remained when participants were separated into further two subcategories according to their obesity status. The results of the correlation analyses also indicated positive, significant associations between age and parameters best representing obesity (percent body fat: $R = 0.244$; VFA: $R = 0.622$; BMI: $R = 0.248$). These findings support the statement that total fat mass and visceral adiposity increase with age in women (Kuk et al. 2009). BMI also seems a key factor to predict the visceral fat accumulation because most of the regression models contained this index, with exception for the full undivided sample and the older women with normal obesity status. Hip circumference also seems to be an important parameter for estimating visceral adiposity in women above 45 years of age. Among the studied skinfold measurements, triceps and abdominal skinfold thickness appeared the most valuable predictors.

Compared to the coefficients of determination, the values were higher in the subgroups of individuals having excessive amounts of fat accumulation, for both younger and older individuals. It was not true for the full sample without separating by age, although the differences between the coefficients were not significant (normal: $R^2 = 0.887$, overweight & obese: $R^2 = 0.871$). In the regression models, the values of coefficient of determination were 0.727 to 0.939. The variance of inflation factors (VIF) were less than 3.5. Kaysen et al. (2008) assessed the estimation of visceral adipose tissue from anthropometric variables (age, race, maximum abdominal circumference), and their model explained 77.6 % of the variances in visceral adipose tissue. Demura & Sato (2007b) predicted VFA from anthropometric characteristics, including three skinfolds, WHR, gender and age, and about 75 % of the variances of VFA could be explained. Our results are comparable to these previously published data.

It has to be mentioned that our study had some limitations. First of all, the VFA was not directly measured. Although it has been suggested that BIA is a reliable method to assess visceral fat accumulation because of its simplicity and accuracy (Nagai et al. 2008, Ryo et al. 2005, Shiga et al. 2007), further investigations with reference methods (CT or MRI) should be executed to assess the amount of visceral fat. On the other hand, the number of the participating individuals was relatively small. While, in the frequency distribution of the BMI values of our sample showed considerable similarity to the findings of recent Hungarian representative, population-based surveys, the same was not true for the distribution of age values (Hablicsek 2009, KSH 2010). In our opinion, these limitations and the mode of the recruitment (voluntary participation without restrictions) could cause distortion on the representativeness of the sample. Reproductive status has a profound influence on body composition; the menopause transition is a key event in women's life, because it is associated with significant changes in body composition and fat distribution (Toth et al. 2000). Unfortunately in our study, data on reproductive status were not available for the participants. These limitations should be considered in the planning of further data collection.

Summarizing the results of our study, although numerous investigated parameters showed significant relationship with the visceral adiposity, the differences in age and obesity status groups call the attention to the fact that using single anthropometric parameters are not usually sufficient for predicting with good accuracy the VFA. On the other hand, the results of the multiple linear regression analyses yield to conclude that the convenient combination of these parameters could take these effects into consideration, so these methods could be a suitable way for reliable prediction of VFA.

In future, we plan to expand the sample size – including more age and obesity status groups – and number of the variables, to give more reliable results toward understanding the associations between VFA and simple anthropometric parameters. In addition, reference methods should be applied to determine the amount of visceral adipose tissue in further research activities. The ultimate goal of our work is to appraise the possibility of developing a generalized predictive model of VFA for Hungarian women.

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