Classification of excess weight and obesity using skinfolds in female university students from Slovenia

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Abstract
This study investigates the relationship between the adipose factor defined by the skinfolds and body composition of female students from the University of Ljubljana. The purpose was purpose to test a simple technique to identify obese subjects using skinfolds. We anthropometrically examined 169 participants and determined their percent of body fat (%BF) by BIA. Principal component analysis (PCA) was utilized to extract the obesity factor (FF), resulting from five skinfolds. The distribution of the FF scores was divided into under-fat (FatU), normal-fat (FatN) and overweight or obese (FatO) categories using the lower and the upper bound (1.56 in 2.04) for central 95% of data. The new model was validated through testing fat categories for anthropometric indicators of obesity; %BF, waist circumference (WC) and BMI. The emerged FF as: 0.89·subscapular skinfold + 0.90·suprailiac skinfold + 0.86·abdominal skinfold + 0.86·triceps skinfold + 0.78·calf skinfold was expressed in logarithm. Most of the participants (158) were included in the normal-fat group, 5 were declared as under-fat and 6 as overweight or obese. BMI was increasing ($F = 6.12$; $p < 0.01$) from FatU to FatO and was positively correlated ($r=0.2$; $p<0.05$) to FF. No relationship was found between FF and %BF. There are indications the FF in female students could be associated with an inappropriate body weight for a given height but is not applicable to determine %BF.

KEYWORDS: skinfold thickness, body fat, factor analysis, young adult, females

Introduction
Obesity is a public health problem that has become epidemic worldwide (Chan & Woo 2010). Overweight and obesity are defined as excessive fat accumulation that represents a risk factor for several chronic illnesses, including diabetes type II, cardiovascular diseases and some types of cancer (Mc Ardle et al. 2010). The fact that obesity increases among youth is of particular concern, mainly because they are likely to be obese also as adults (Dietz 2004). In 2011 the share of obese youth in Slovenia aged 17 and 18 years was approximately two times higher than two decades earlier (Kovač et al. 2012), but there is a lack of reliable data on the prevalence of overweight and obesity among

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adults in Slovenia. Tomazo-Ravnik and Jezernik (2008) established that young Slovenian females demonstrate higher values for fat mass compared to other suitable groups, while in 2015 (Jurak et al. 2016) gathered the objectively measured data on the prevalence of overweight and obesity among students of the University of Ljubljana and established the prevalence of obesity among female students to be 0.6% and overweight including obesity only 7.1%.

Body mass index (BMI) is widely used as a measure of obesity (Garn et al. 1986), although the cut-off points of overweight and obesity do not necessarily correspond to health risks (Lee et al. 2008). Many researchers have already pointed out the weaknesses of the BMI classification of overweight (Must, Dallal & Dietz 1991; Kennedy, Shea & Sun 2009); in Slovenia, Starc and Strel (2011) have suggested that nationally specific BMI cut-off points, based on more recent data than international references, would be appropriate for defining the nutritional status of Slovene school-aged population. As a measure of obesity, body fat (BF) may be a better indicator and can be quantified by assessing body composition (Heyward & Stolarczki 1996).

Some procedures have been proposed to determine the amount of fat for Slovenian populations. Škerlj (1954a, b) based the fat tissue analysis on the anthropometrical approach through body volumes. The investigation was continued by Pogačnik (1961, 1966). One of his studies showed that many female students are hyperplastic with a well-developed fat mass and less hypoplastic body types (Pogačnik 1969). The factor analysis of several anthropometric dimensions in female students has extracted the skeletal, muscular and fatness factor, the last as a linear combination of body circumferences and skinfold thicknesses (Brodar 1981). Utilising an anthropometric method for determining five-compartment body composition, Tomazo-Ravnik (1996) identified that female students on average have 32% of BF. It has been shown that athletes among Slovenian students had significantly thinner skinfolds (Štefančič & Tomazo-Ravnik 1992; Zerbo-Šporin & Štefančič 2004). Regarding the anthropometrical measurements of the visceral fat amount, females from the Faculty of Sports do not significantly differ from others, which is most likely due to the sufficient physical activity levels of the non-athlete group (Zerbo-Šporin 2013). From the comparison of %BF and waist circumference (WC) for Slovenian female students, Zerbo-Šporin (2014) concluded WC to be suitable to determine both abdominal and overall body fat.

About 80% of all body fat is typically in the subcutaneous areas (Wajchenberg 2000). There are clinically significant differences between adipose tissue present in subcutaneous areas and visceral adipose tissue in the abdominal cavity (Ibrahim 2010). A predominantly upper body fat distribution, commonly associated with increased visceral fat, carries a greater cardio-metabolic risk over a wide range of body mass indexes (Kissebah et al. 1994; Koutsari et al. 2012; Pischon et al. 2008).

Principal component analysis (PCA) resulting from the skinfolds was utilised in some body-fat-related research studies. Three major components usually emerged: the first component is general obesity, the second includes fat distribution contrasting trunk and extremity, and the third distributional component includes the contrast between leg and arm fat (Mueller et al. 1981). A significant correlation (0.89) was found between the scores for the first component and fat masses determined densitometrically, indicating that skinfolds are useful for body fat determination (Norgan & Ferro-Luzzi 1985; Li et al. 1996).

Understanding fat patterning has a major role in public health, especially in youth. The screening of individuals at health risk linked to excessive fat using the available methods to determine body composition is usually impractical for field work. It is, therefore, desirable, to have handy anthropometric methods to estimate body fatness (Yeong & Gallagher 2008). Durnin and Womersley suggested (1974) that a larger amount of subcutaneous tissue is associated with lower body density and thus with greater BF. The aim of this study was to test a technique for calculating body fatness in female students using skinfolds and determining an indicator called Fat Factor (FF) that was partially presented by Zerbo-Šporin & Štefančič 2004. The newly formed simple screening method could be applicable to identifying obesity and related co-morbidity risk from easily obtainable skinfolds. Tailoring interventions for body weight and waist circumference reduction should also be ensured for female students with expressed excessive weight or obesity.

On the methods

Subjects

In this cross-sectional research, 169 female students from different faculties of the University of Ljubljana volunteered as subjects. They were invited to participate through advertising implemented at the Department of Biology of the Faculty of Biotechnology. All applicants were accepted in the study, and the data for all participants were analysed. The measurements were conducted in the frame of doctoral research and as such were carried out in the 1999/2000school year. The average age of the sample at the time of measurements was 22 years (Table 1). The study was performed in accordance with the ethical standards of the Declaration of Helsinki/Tokyo. All volunteers were fully informed of the procedures before written consents were obtained.

Anthropometry and body composition

Body height (BH), body weight (BW), waist (WC), and hip (HC) circumference, skinfold thickness at five sites were measured according to a standardized International Biological Programme protocol (Weiner & Lourie 1996). Paired parameters were taken on the right side of the body. All measurements were carried out in the morning by the same examiner in a quiet, properly illuminated, and thermally neutral environment. The participants were wearing light indoor clothing. The subjects' height was measured to the nearest 0.1 cm with a Martin's anthropometer (SiberHegner, Swiss). The BW was determined with Tanita TBF-305 scale (Tanita Corporation, Arlington Heights, IL) to 0.1 kg accuracy. WC was estimated halfway between the costal edge and iliac crest on the side and between *processus xyphoideus* and *umbilicus* in front (Tran & Weltman 1989). HC was measured at the greatest circumference around the buttocks (Lohman 1981). Both circumferences were measured twice with a flexible inextensible tape, and the mean value was recorded to 0.1 cm accuracy. Skinfold thicknesses were specified using a John Bull calliper with a constant pressure of 10 g/cm² and expressed in mm. Follow the opinion of different authors (Baumgartner et al. 1986; Rebato et al. 1998), five skinfolds were selected for the evaluation of body fatness: subscapular skinfold (SubScSk) was measured just below the angulus inferior of the right scapula and the suprailiacal skinfold (SupIlSk) just above the right *crista iliaca*. Abdominal skinfold (AbdSk) was taken horizontally, on the right side, 3 cm laterally and 1 cm bellow the centre of the umbilicus. The triceps skinfold (TriSk) was measured on the upper right arm, vertically, halfway between the processus acromialis and the olecranon. The final, calf skinfold (CSk) was taken vertically on the median side, at the largest right calf circumference with the foot on the elevated basis and the knee flexed at 90° (Lohman 1981). Three consecutive measurements of each skinfold were taken in the order mentioned, and the average value was recorded to 1 mm accuracy. Body composition (total percentage body fat – %BF) was assessed by using bioelectrical impedance (BIA) analyser Tanita TBF-305 and the data analysed with the software provided by the manufacturer. Impedance was measured in accordance with the principles of the BIA method protocol (Nunez et al. 1996). A high positive correlation ($r^2 = 0.95$, $p < 0.001$) was determined by the body composition estimated with TBF-305 and dual energy x-ray absorptiometry meaning that the analyser can be used for body composition assessment (Rubiano et al 1999). Overweight and obesity were defined by elevated %BF (>31% of body weight as fat) or BMI higher than 25.0 kg/m². Abdominal obesity was characterized by increased waist circumference (> 80 cm) (Hoffman 2006; Rotar-Pavlič 2008).

Data analysis

Before the statistical analysis, all variables were tested for normality with the Kolmogorov-Smirnov test. Descriptive statistics, such as minimal (Min) and maximal (Max) value, mean (M) and standard deviation (SD), were determined. The PCA model was used to identify the components of obesity, resulting from five skinfolds. The analysis was computed from raw data. Using the PCA method, a set of correlated skinfold variables (Table 2) was replaced by a set of uncorrelated principal components or factors, which still contains most of the information of the basic set (Jackson 1991). Only principal components with eigenvalues equal or larger than 1 were retained. The obesity component (FF) represents a linear transformation of the original; skinfolds variables (X_n), including PCA-derived factor loadings (β_n): $\beta_1 \cdot X_1 + \beta_2 \cdot X_2 + \ldots\ldots \beta_n \cdot X_n$. A transformation in logarithmic values was computed for a skewed FF distribution. The logarithmic values distribution from 1.47 to 2.17 (Figure 1) were further divided into three groups to determine the overall fat intensity: under-fat (FatU), normal fat (FatN) and obese (FatO). The lower and the upper boundaries for the central 95% of data was used to identify the groups with different amounts of fat. The FatU group (2.5% of the lower log FF distribution) includes female students with the smallest body fat amount and log FF scores lower than 1.56. The second, FatN group, includes participants with an appropriate quantity of body fat and log FF scores between 1.56 and 2.04. Female students with logarithmic FF values higher than 2.04 belong to the FatO group, which is characterised by a larger fat amount and covers the upper 2.5% of FF data. For testing the mean differences of anthropometric and body composition parameters between fat categories, one-way analysis of variance and the Bonferroni post hoc test was utilised (Vincent 2005). Pearson's correlation analysis was performed for testing the potential relationship between log FF and anthropometric parameters. A statistical analysis was performed with the SPSS software package.

Results

Anthropometric measurements for the female students from the University of Ljubljana are presented in Table 1. With a waist circumference of 69.3 cm on average, they do not show visible signs of abdominal obesity. With 29.1% of body weight as fat, they belong to the group of an acceptable range of body fat for their age, on the average. The mean BMI 21.1 kg/m² represents a suitable body weight for their height.

Table 1: Descriptive statistic for anthropometry of 169 female students

Anthropometry	Min	Max	M±SD
Age (years)	19.0	29.0	22.0 ± 2.5
Body height (cm)	154.0	179.4	167.7 ± 5.3
Body weight (kg)	45.2	101.0	60.4 ± 8.4
Waist circumference (cm)	60.3	103.0	69.3 ± 5.7
Hip circumference (cm)	84.3	121.5	97.3 ± 6.5
Subscapular skinfold (mm)	6.8	31.3	12.1 ± 3.8
Suprailiac skinfold (mm)	5.3	39.5	12.6 ± 5.6
Abdominal skinfold (mm)	6.2	42.3	17.5 ± 6.5
Triceps skinfold (mm)	5.6	29.8	15.0 ± 4.5
Calf skinfold (mm)	6.7	43.8	19.6 ± 7.3
Body mass index (kg/m²)	15.9	27.6	21.1 ± 2.2
* % total body fat	5.6	53.8	29.1 ± 5.7

* % total body fat was assessed by using the bioelectrical impedance method on Tanita-TBF 305 and represents the % of body weight as fat; Min=minimal value; Max=maximal value; M ± SD= mean ± standard deviation

Since skinfolds were strongly correlated (Table 2), principal component analysis was used to identify new independent fatness factors.

Table 2: Pearson's correlation coefficients for skinfold thickness of 169 female students

Skinfolds	Suprailiac	Abdominal	Triceps	Calf
Subscapular(mm)	0.79*	0.71*	0.71*	0.58*
Suprailiac (mm)		0.82*	0.68*	0.52*
Abdominal (mm)			0.62*	0.52*
Triceps (mm)				0.69*

*$p < 0.05$; $r \geq 0.16$

The PCA for five selected skinfolds extracted one principal component (PC1) with an eigenvalue greater than 1 that represents 73.3% of the variance among skinfolds (Table 3). The solution was not rotated. The PC1 was named 'FF' and reflects generalised fatness, since factor loadings (β) are approximately equal for all five skinfolds (Table 4). Using β; coefficients that indicate the contribution of each original variable to the linear combination forming the FF, a technique to calculate body fatness for individual subjects was developed:

$$FF = 0.89 \cdot SubScSk + 0.90 \cdot SupIlSc + 0.86 \cdot AbdSk + 0.86 \cdot TriSk + 0.78 \cdot CSk$$

(skinfolds are expressed in mm).

Table 3: Principal components and the variance explained for five skinfolds of female students

Principal component	Eigenvalues	% of variance explained by PC
PC1 (Fat Factor)	3.66	73.28
PC2	0.63	12.51
PC3	0.31	6.13
PC4	0.25	5.10
PC5	0.15	2.97

Table 4: Component matrix loadings for FF extracted from five skinfolds of female students

Skinfolds	Factor loadings
Subscapular (SubScSk)	0.89
Suprailiac (SupIlSc)	0.90
Abdominal (AbdSc)	0.86
Triceps (TriSc)	0.86
Calf (CSc)	0.78

The log – FF values distribution with scores between 1.47 and 2.17 was sorted into three categories: the first, FatU group comprised of 5 female students with log FF scores smaller than 1.56 and covered the lowest 2.5% of FF distribution. Most of the participants (158) with a normal quantity of body fat (log FF scores from 1.56 to 2.04) were found in the FatN group, which covered the central 95% of FF distribution. The third, FatO group, included 6 female students with FF over 2.04 and represented the highest 2.5% of FF distribution (Figure 1).

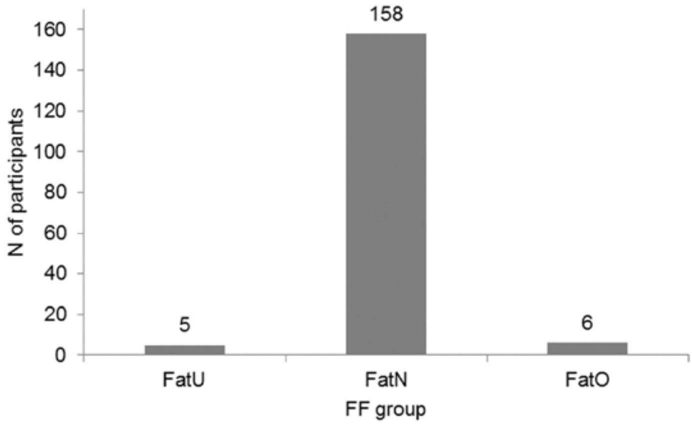

Figure 1: Distribution of female students in under-fat (FatU), normal-fat (FatN) and obese (FatO) group among Fat Factor

Significant differences (F = 6.12; $p < 0.01$) in BMI between the newly formed fat categories were found (Table 5). The mean BMI increased from 18.6 kg/m² in FatU to 23.1 kg/m² in FatO: it was for 4.49 kg/m² ($p < 0.01$) higher in FatO and for 2.60 kg/m² ($p < 0.05$) in FatN to the FatU group, respectably. The FF categories also varied in WC and %BF with both increasing from FatU to FatO (Table 5), but the differences were not statistically significant. In average, the %BF in FatO amounts to 32.1% and corresponds to excessive body fat (Hoffman 2006). In contrast, the average WC (73.4 cm) and BMI (23.1 kg/m²) in FatO do not represent obesity (Rotar-Pavlič 2008).

Table 5: Analysis of variance for anthropometric parameters between fat categories: under-fat (FatU), normal-fat (FatN) and obese (FatO) group and post hoc analysis for BMI

Fat categories	N	Body height (cm)	Body weight (kg)	BMI (kg/m²)	WC (cm)	% BF
FatU	5	170.7 ± 7.9	61.1 ± 7.5	18.6 ± 1.9	67.5 ± 5.8	26.1± 7.1
FatN	158	166.9 ± 5.6	59.0 ± 5.7	21.2 ± 2.1	69.2 ± 5.5	29.1± 5.6
FatO	6	166.0 ± 8.2	57.3 ± 5.4	23.1 ± 7.9	73.4 ± 10.2	32.1± 7.9

Paired posthoc categories	Mean differences for BMI	Standard error of estimation
FatN – FatU	2.60*	0.96
FatO – FatU	4.49**	1.29

*%BF (total body fat) was assessed by bioelectrical impedance on Tanita-TBF 305, BMI = Body Mass Index, WC = Waist Circumference, anthropometry is expressed as M ± SD; * p < 0.05; ** p < 0.01*

The correlation analysis in Table 6 confirmed the statistically significant positive correlation of FF with BMI ($p < 0.05$) and a weak but significant ($p < 0.01$) negative correlation with BH. No relationships were found between FF and WC or BW (Table 6), nor with %BF, even if the analysis was done separately: in the group with suitable %BF < 31% (N=113), and those with excessive %BF ≥ 31% (N=56).

Table 6: Pearson correlation between Fat Factor and anthropometrical parameters for 169 female students

Anthropometric parameters	r	p
Body height (cm)	-0.219**	0.004
Body weight (kg)	0,024	0.758
BMI (kg\m²)	0.176*	0,022
WC (cm)	0.024	0,761
Body fat percent (%BF)	-0.043	0.581
%BF < 31%	-0.012	0.897
%BF ≥ 31%	0.039	0.776

*Correlation is significant at the 0.05 level
**Correlation is significant at the 0.01 level

Discussion and conclusion

It is well known that subcutaneous fat alone is not an adequate predictor of cardio-metabolic health risk. Total body fat (BF), including visceral fat tissue, could be a better indicator of health status (Ibrahim 2010). However, they are related (Durnin & Womersley 1974) as a larger amount of subcutaneous fat tissue means greater BF. Our study principally examined the relationship between the FF derived from skinfolds and the body composition parameters. The purpose was to test a simple anthropometric method for fieldwork settings that enables the calculation of excesses or deficits in BF from easily obtainable skinfolds, instead of applying a less cost-effective BIA technology.

As shown in several studies utilising the PCA (Norgan & Ferro-Luzzi 1985; Li et al. 1996; Mueller & Reid 1979) the first two extracted components account for most of the variance among skinfolds. From the five selected skinfolds, we have identified one principal component (PC1) that explained a larger portion (73.3%) of the total variance. PC1 was termed the general Fat Factor, and its intensity was associated with overall obesity. No components that represent fat distribution had appeared, probably due to the age homogeneity of the participants. The sample of the wider age range, with age-specific fat distribution patterns, could deliver different PCA results. According to the linear combination of skinfolds variables forming the FF a score for the single subject was computed and converted to logarithmic values. Three FF groups were identified: FatU (under-fat) with logFF minor than 1.56, FatN (normal-fat) with logFF between 1.56 and 2.04 and FatO (overweight/obese) showing logFF values higher than 2.04. On the basis of the selected distribution mainly, 158 participants were found in the normal-fat group, 5 female students were classified as underweight and 6 as overweight or obese.

The usefulness of the newly developed model to assess body fatness was validated through marking FF with parameters defining obesity: a %BF determined by BIA, WC, and BMI. The last has shown significantly lower values in FatU than FatN ($p < 0.05$) or FatO ($p < 0.01$). Since FF was positively correlated with body mass index ($p < 0.05$) and negatively with body height ($p < 0.01$), it seems that it behaves similarly as BMI does, with taller individuals having lower values. The result is not surprising; as BMI is, a standardized measure of nutritional status (WHO, 2000) and FF tends to represent overweight and obesity.

The FF categories also varied in WC and %BF with both in average increasing from FatU to FatO, but the differences were not statistically significant. Oliveira et al. (2011) concluded that the PC1 of general fatness might be associated with larger WC, but the FF categories in our study were probably more uniform in the amount of abdominal fat. This can also be deduced by the average WC 73.4 cm in the FatO group, which does not represent abdominal obesity. The observed is most likely due to the narrow age composition of the sample and the selection bias: all the participants in our research are young adult females, characterized by a gynoidal or low body fat distribution with a pronounced adipose tissue on the hips instead of on the abdomen. They also belong to the academically more successful part of the population, which is also probably linked to their increased physical activity and physical fitness.

Although the mean %BF 32.1 is indicating that the students in FatO have an increased proportion of body fat (Hoffman 2006), no correlations of FF and %BF was found. It seems that newly formed FF does not provide useful information about the %BF. The subcutaneous fat might not adequately represent the total BF due to the excessive intraabdominal fat depots, but the average WC 73.4 cm in FatO group does not indicate a central obesity (Rotar-Pavlič 2008). Alternatively, the relationship of FF and %BF was not expressed due to the large ectopic amount of fat within the obese group (N=56) with %BF ≥ 31(Table 6), which is questionable since the correlation of FF and %BF is also not significant in the non-obese group. The reason is probably due to the individual contribution of single skinfold to FF. Leahy et al. (2012) suggested that the upper limb skinfolds representing 10% of the fat mass, the trunk region 40% of the fat mass and the lower limb skinfolds represent 50% of the fat mass.

In conclusion, as indicators of overweight or obesity, a derived FF and BMI perform similarly, without overlapping in FatO. FF was not related to %BF, therefore is not applicable instead of BIA for defining an excessive fat amount. For determining a new independent FF, in further studies, a weighted contribution of the regional subcutaneous fat amount for a better explanation of general obesity should be considered.

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Povzetek

Prepoznavanje prekomerne hranjenosti že med mladimi, je z vidika preventive pred kroničnimi nenalezljivimi bolezni velikega pomena. Namen naše raziskave, ki je vključevala 169 študentk Univerze v Ljubljani, je bil preveriti enostavno metodo za vrednotenje hranjenosti s pomočjo debelin kožnih gub: pod lopatico *(SubscSk)*, nad črevnico (*SupilSk)*, na trebuhu (*AbdSk)*, na nadlahti *(TriSk)* in goleni (*CSk)*. Z metodo glavnih komponent (PCA) je bil določen maščobni faktor (FF): *0.89·KGSubsc+0.90·KGSupil+0.86·KGT+0.86·KGTri+0.78·KGG,* čigar vrednosti so bile logaritmirane. Porazdelitev log FF je bila s kritičnima vrednostma1.56 in 2.04, ki ločujeta 95% osrednjih podatkov, razdeljena v tri kategorije: slabo prehranjene (FatU) , primerno hranjene (FatN) ter čezmerno hranjene ali debele (FatO). Kategorije hranjenosti so bile med seboj primerjane v antropometričnih kazalcih indeksa telesne mase (BMI), obsega pasu (WC) ter z bioimpedanco (BIA) določenega deleža telesnega maščevja (%BF). Večina (158) deklet je bila v FatN skupini primerno hranjenih, 6 študentk je bilo prekomerno hranjenih ali debelih (FatO) ter 5 v skupini podhranjenih (FatU). Vrednosti BMI se od FatU proti FatO povečujejo ($F=6.12$; $p<0.01$) in BMI je tudi pozitivno povezan ($r=0.2$; $p<0.05$) s FF. Povezanosti FF in %BF v raziskavi nismo opazili. Kaže, da so višje vrednosti izpeljanega FF v populaciji študentk v povezavi s prekomerno maso ob dani telesni višini. Se pa FF ni izkazal kot primeren za določanje deleža maščevja v telesu.

KLJUČNE BESEDE: kožne gube, maščevje, faktorska analiza, mladi odrasli, ženske

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