® Postepy Hig Med Dosw (online), 2019; 73: 572–580
e-ISSN 1732-2693

www.phmd.pl
Original Article

Received: 29.03.2019
Accepted: 19.09.2019
Published: 5.11.2019

Evaluation of the relationship between body composition and weight-height index – BMI

Ocena współzależności między składem ciała a wskaźnikiem wagowo-wzrostowym – BMI

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

Katarzyna Banach[1,A,B,C,D,E,F], Paweł Glibowski[1,A,D,E], Paulina Skorek[1,B,D,E]

[1] Department of Biotechnology, Microbiology and Human Nutrition, Faculty of Food Science and Biotechnology, University of Life Sciences in Lublin

Summary

Aim: Body composition, especially the mass of adipose tissue, affects the risk of developing the metabolic and cardiovascular diseases as well as some cancers. The aim of this study was to determine the relationship between the body composition of adults and their Body Mass Index.

Material/Methods: The study involved 120 subjects (69 women and 51 men) aged 19 – 66 (30.55 ± 10.41). The recruited subjects were assigned to three subgroups: with normal body weight, overweight and obesity, depending on the BMI value. There were 40 subjects in each subgroup, including 23 women and 17 men. Besides the measurements of height and body mass, the SECA mBCA515 analyser was applied for the body composition analysis using the bioelectric impedance method.

Results: A significant association was found between the BMI index and fat mass, lean mass and muscle mass, both in the whole group and after taking into account the sex. The correlation coefficient R range was from –0.88 to 0.97. The incidence of obesity in the studied group according to body fat content criteria (>25% for men and >30% for women) was 57%, while according to BMI criteria –33%. BMI cut-off points for obesity were 27.8, 26.4 and 26.4 kg/m^2 for men, women and for all, respectively.

Conclusions: In epidemiological studies, to identify obese people, body fat should also be taken into account in addition to BMI. If obesity is understood as excess fat, and not excess weight, the cut-off points for BMI-based obesity should be lowered.

Keywords: **Body Mass Index • BIA • body composition • obesity • fat tissue**

GICID 01.3001.0013.5564
DOI: 10.5604/01.3001.0013.5564
Word count: 5278
Tables: 3
Figures: 4
References: 44

Author's address: Dr hab., prof. Paweł Glibowski, Department of Biotechnology, Microbiology and Human Nutrition, Faculty of Food Science and Biotechnology, University of Life Sciences in Lublin, 20-704 Lublin, ul. Skromna 8, e-mail: pawel.glibowski@up.lublin.pl

Abbreviations: **DEXA** – dual-energy x-ray absorptiometry, **BIA** – bioelectric impedance analysis, **MRI** – magnetic resonance imaging, **Xc** – reactance, **R** – resistance, **FM** – fat mass, **FFM** – free fat mass, **VAT** - Visceral Adipose Tissue, **WHO** – World Health Organization, **BMI** – Body Mass Index, **%BF** – % body fat, **NWO** – Normal Weight Obesity.

INTRODUCTION

Nutritional status is defined as the state of an organism resulting from the balance between usual food intake, the course of digestion processes, absorption and use of nutrients, and pathological factors influencing these processes [39]. Body composition analysis can be an important part of assessing the nutritional status of a patient. Analysis of the body composition is also useful to better understand the effects of many diseases, physiological conditions, results of introducing a specific diet, physical effort or the consequences of other environmental factors affecting the body [17]. Body composition analysis, depending on the needs, can be made by various techniques, e.g. using skinfold thickness measurements, X-ray absorptiometry (DEXA – dual-energy X-ray absorptiometry), bioelectric impedance analysis (BIA), computed tomography, ultrasonography, magnetic resonance imaging (MRI) or isotopic methods [1]. In clinical practice, most of these methods are rarely used, mainly due to the high costs of testing, lengthy and complicated measurement methods or due to negative consequences, such as irradiation of the body [22].

Bioelectrical impedance analysis is a fast, simple and non-invasive method of assessing body composition that uses various electrical properties of different body tissues. It is based on the difference in electric current impedance of fat and fat-free body mass. Both adipose tissue and extracellular water do not show capacitive resistance (reactance, Xc), but they have an active electrical resistance (resistance, R). Reactance is formed on the cell membrane of tissue with high water content and influences primarily the phase shift of the applied alternating current, while the resistance causes a voltage drop [21, 37]. Bioelectrical impedance is the total resistance of the body to the alternating current. Resistance is possible through the conductivity of electric current through body water and the electrolytes dissolved in it. In turn, reactance is formed by tissues, which act like capacitors. The third component of the impedance is phase angle (φ): phase shift between the maximum current value and the maximum voltage value due to the action of body tissues as a capacitor [24, 25].

Based on the measured values and in combination with body weight, height, age as well as sex of patients, when applying appropriate algorithms, it is possible to determine the values of fat mass (FM), fat-free mass (FFM), phase angle, total body water, the content of intracellular and extracellular water or the hydration level of the body. The combination of the above parameters shows a full body composition analysis and provides the ability to monitor the structural changes of the body over time. The BIA test can be used both in healthy people and those suffering from chronic diseases. However, there are some exclusion criteria, like diagnosed epilepsy, pregnancy, implanted cardiac pacemaker or cardioverter, and the presence of metal implants with the exception of dental implants. This technique is widely used in clinical practice to assess body composition in diseases such as cancer, sarcopenia, eating disorders or obesity [4, 26, 32].

Obesity is a disease syndrome characterized by an increase in body weight above the accepted norm, most often resulting from a long-lasting, positive energy balance. The development of obesity may also be influenced by hormone secretion, regulation of fat metabolism and many other factors determining the intake and expenditure of energy from food [35]. Currently, this disease affects more than 650 million people in the world, which is 13% (11% of men and 15% of women) of the population. In 2014, the WHO stated that the worldwide prevalence of overweight and obesity affects approximately 1.9 billion people aged 18 or over. This problem is growing in many regions of the world, especially in developing and highly developed countries [40]. Increased income and increasing urbanization combined with the interference of today's technologies in food processing facilitated the manufacturing of products containing significant amounts of fat and sugar at very low prices [9]. All these caused an increase in the ability of "fast food" producers to supply larger servings at lower prices [36]. Nowadays, the total energy supply from food increased by 40% when compared to 1970 [11].

BMI (Body Mass Index) is commonly used to classify overweight and obesity, expressing body weight in kilograms, divided by the height (in meters) raised to the square (kg/m^2). The WHO defines overweight as a condition characterized by the BMI index range between 25.00 and 29.99 kg/m^2, while the obesity index is characterized by BMI value higher or equal to 30 kg/m^2 [38, 42, 43]. This index is easy to estimate, because it does not require the use of specialized equipment, but only basic anthropometric data. However, the limitation of this method is that it does not differentiate between adipose tissue and lean body mass. Often, it is also ineffective in assessing the weight of dialysed people due to the high water content in their bodies. For the above reasons, there is the need for a simple method like BIA that can effectively monitor the level of overweight and obesity in a population. Although the BMI value is correlated with many anthropometric indicators, the percentage of fat in the body is more likely to indicate obesity compared to WHO standards based on BMI values [43].

The aim of this study was to analyse the body composition of adults and to determine the relationship between the obtained results and the BMI value. In addition, this study was an attempt to assess the prevalence of obesity among adults, according to international BMI classification and percentage of body fat.

MATERIAL AND METHODS

The test group

A cross-sectional observational study was carried out from April 2017 to May 2018 involving 120 patients of the Dietitian Service, a unit of the University of Life Sciences in Lublin. Informed consent was obtained from all of the subjects. The mean age of subjects was 30.55 ± 10.41 (Me = 26, range 19–66) years. Among the studied group, 42.5% (n = 51) were men, and 57.5% (n = 69) were women. The subjects were assigned to three subgroups: normal weight, overweight and obesity depending on the BMI value. There were 40 subjects in each subgroup, including 23 women and 17 men. The study protocol assumed the inclusion of subjects with a similar height and age in each subgroup (obesity, overweight, normal body mass) to analyse the significance of the studied characteristics. Statistical analysis confirmed the lack of significant differences in the assessment of the height and age of subjects in particular subgroups.

Anthropometric measurements

Body height in a standing position was measured by means of the SECA 216 wall mounted stadiometer with an accuracy of 0.1 cm. The waist circumference was determined halfway between the lower edge of the rib arch and the upper iliac crest according to the guidelines of the Polish Forum for Prevention of Cardiovascular Diseases [44], using SECA 201 metric tape. Body mass was recorded in lightweight clothing on a digital scale with 0.1 kg accuracy. In order to assess the relative body weight, the adult BMI classification recommended by the WHO was used [43].

Body composition analysis

SECA mBCA515 analyser was applied for the body composition analysis, using the bioelectric impedance method. The measurement was carried out using the eight-point method. Low-voltage alternating current and impedance measurement were carried out by means of two tactile electrode pairs placed under the feet and two electrode pairs located under the hands of the examined person. The electrodes of the upper limbs were at different heights, so that patients with a height of 1.6 m to 2.0 m could take the optimal position on the device for measurement. This arrangement eliminates variations in electrode placement, which is commonly associated with conventional method of BIA measurement. The SECA mBCA515 analyser compared the obtained data to the results of validation studies related to the so-called Golden Standard, such as DEXA [13] and to own standards developed by the manufacturer. In order to control these variables, the study subjects were informed about the test protocol and were instructed to come with their bladder empty and that they should avoid fluid, food and vigorous physical activity prior to recording. Subjects with symptoms of dehydration, menstruating women, subjects with metal implants inside the body, as well as subjects using diuretics were excluded from the study.

STATISTICAL ANALYSIS

Values of the measurable parameters were presented as the mean value, median and standard deviation, and with the number and percentage for non-measurable ones. For measurable features, the distribution normality of the analysed parameters was evaluated using the Shapiro-Wilk test. The Mann-Whitney U test was used to compare two independent groups. Spearman R correlations were used to evaluate the relationship between variables. In order to quantify the relationship between selected features, linear regression equations were used. A significance level of $p < 0.05$ was assumed, indicating

Table 1. Characteristics of the studied group

Variables	Women (n = 69)		Men (n = 51)	
	Mean ±SD	Range	Mean ±SD	Range
BMI [kg/m^2]	27.91±5.88	18.60–41.60	28.32±6.02	18.63–48.19
Age [years]	30.30±9.70	19.00–57.00	30.88±11.40	18.00–66.00
Weight [kg]*	76.85±17.35	47.65–120.9	91.47±20.84	58.45–152.70
Height [m]*	1.66±0.06	1.51–1.78	1.80±0.07	1.64–1.91
FM [kg]	28.83±12.41	9.31–60.01	25.66±13.07	6.46–68.46
FM [%]*	35.93±8.34	19.50–51.20	26.58±8.02	9.55–44.83
FFM [kg]*	48.02±5.97	35.53–63.87	65.80±9.26	43.32–96.46
FFM [%]*	63.20±10.01	16.30–80.50	73.42±8.02	55.17–90.45
VAT [L]*	1.18±1.06	0.00–5.8	2.94±2.35	0.00–10.9

* statistically significant difference between groups of women and men at $p < 0.0001$

statistically significant differences or dependencies, while between p <0.01 and p <0.0001 as strongly significant. All data were analysed by the STATISTICA 13.0 computer software (StatSoft, Poland).

RESULTS

The descriptive characteristics and comparison between the sex of subjects included in the study are presented in Table 1. Men were significantly taller and heavier than women. The statistical analysis did not show any significant differences in the age rating (p = 0.85), the BMI index (p = 0.80) and fat mass (p = 0.11) between the sexes (Table 1).

The obtained results showed a significant relationship between the BMI value and fat and non-fat mass expressed in units of mass and percent, FM (kg), FM (%), FFM (kg) and FFM (%), respectively in the group of women and men (Table 1). Correlations (R) for these groups took values from –0.88 to 0.97 (Table 2). The increase in the BMI index affected the increase in FM in kg and % and FFM in kg, while the FFM percentage decreased (%) (Fig. 1). As a result of the correlation analysis, a significant relationship was found between the BMI value and the assessment of muscle content in kilograms and percentage both in a group of women and men separately. Correlations took values from R = –0.81 to R = 0.83. The increase in BMI value affected the increase in muscle mass (kg), while the percentage content of muscle decreased (Table 2, Fig. 1).

Table 2. Evaluation of the relationship between BMI and selected components of the body

Variables	Women		Men	
	R	p	R	p
Fat mass (kg)	0.97	<0.000001*	0.90	<0.000001*
Fat mass (%)	0.94	<0.000001*	0.82	<0.000001*
Fat-free mass (kg)	0.70	<0.000001*	0.81	<0.000001*
Fat-free mass (%)	–0.88	<0.000001*	–0.82	<0.000001*
Muscle mass (kg)	0.77	<0.000001*	0.83	<0.000001*
Muscle mass (%)	–0.81	<0.000001*	–0.70	<0.000001*

R – Spearman correlation coefficient, * statistically significant relationship between BMI and selected components of the body

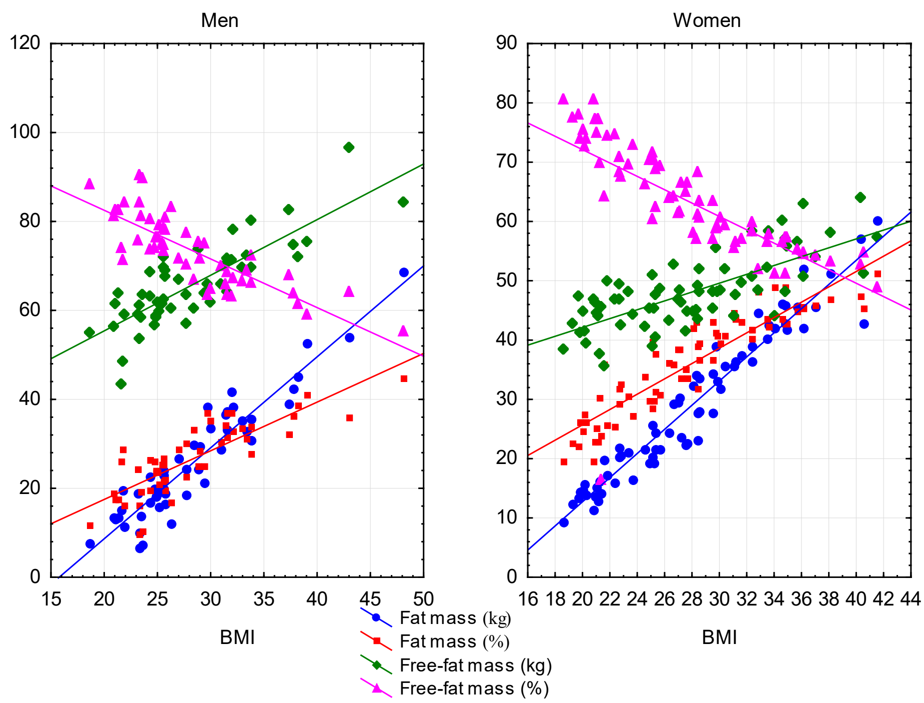

Fig. 1. Correlation between BMI and fat mass in the group of women and men

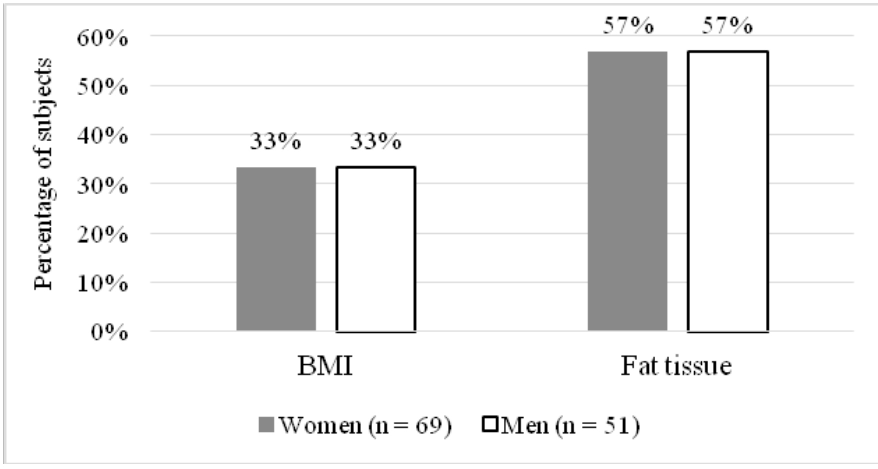

Fig. 2. Prevalence of obesity in the studied group of men and women in accordance with the BMI or fat content (%) classification

The relationship between BF percentage and BMI value can be described by the regression equations: y=1.292*BMI—0.146 ± 3.446 for a group of women and y=1.094*BMI—4.404 ± 4.623 for a group of men. This means that an increase in the BMI value by 1 kg/m^2 causes an increase in the percentage of adipose tissue by 1.292% or 1.094% depending on the sex.

According to the BMI criterion (≥30 kg/m^2), the incidence of obesity among subjects was lower than in the case of obesity based on body fat content (% BF). According to WHO guidelines [43], obesity occurs when the body fat content is above 25% in men and 35% in women. In the group of 69 women, 39 were characterized by a body fat percentage above 35% and in the group of 51 men, body fat percentage was recorded above 25% in 29 individuals (Fig. 2). However, BMI value ≥30 kg/m^2 was calculated only for 23 women and 17 men.

Figure 3 presents the classification of patients according to BMI criteria and lists the percentage of subjects with the level of fat mass (%) indicating obesity in each group. It was observed that in the group of subjects with a BMI ≤25 kg/m^2, four men and one woman had an excessive level of body fat. In the overweight group, nearly half of the men (n = 8) and 65% of the women (n = 15) were characterized by fat mass indicating obesity. These are significant numbers, indicating the need for additional descriptors of obesity or modification of existing ones.

Excessive accumulation of visceral adipose tissue (VAT) leads to visceral obesity. According to Peine et al., the correct VAT values are up to 1.2 and 2.1 L for women and men, respectively. Values in the range of 1.3–1.9 and 2.2–3.8 L, for women and men, respectively, indicate an increased VAT content, while higher volumes are tantamount to excessively high level [31]. VAT levels in the studied group are presented in Table 3. In general, the results obtained

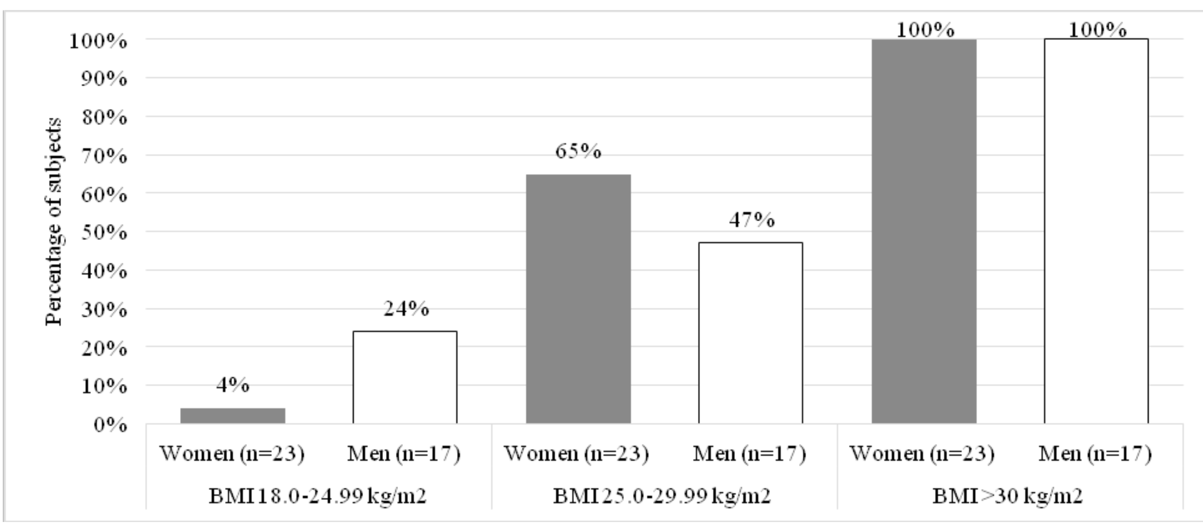

Fig. 3. Prevalence of obesity based on adipose tissue content (%) in normal, overweight and obesity groups divided according to BMI value

Table 3. Levels of visceral adipose tissue depending on the BMI value

Variables	BMI women			BMI men		
	Normal (n = 23)	Overweight (n = 23)	Obesity (n = 23)	Normal (n = 17)	Overweight (n = 17)	Obesity (n = 17)
VAT normal	100%	57%	9%	82%	29%	0%
VAT increased	0%	30%	39%	18%	29%	18%
VAT high	0%	13%	52%	0%	41%	82%

are consistent with the state of fatness of the subjects. However, in some subjects, there is a contradiction in how they are classified to the selected BMI groups and the corresponding VAT levels can be seen. More significant differences in this aspect were noted in the group of men. The relationship between the BMI value and the amount of VAT was examined. The calculated correlation coefficient was 0.74 for the whole group and 0.83 and 0.89 for women and men, respectively.

The relationship between VAT and BMI value can be described by the regression equations: y=0.149*BMI—2.991 ± 0.590 for a group of women and y=0.344*BMI—6.810±1.093 for a group of men. This means that an increase in the BMI value by 1 kg/m^2 causes an increase in the percentage of adipose tissue by 0.149 L or 0.344 L depending on the sex. Model verification showed that they meet all the necessary assumptions.

Fig. 4 presents ROC (Receiver Operating Characteristic) charts, showing the proposed cut-off point of the BMI value for the prediction of obesity in the studied group. The ROC curve is a tool for assessing the threshold value of the classifier; it provides a combined description of its sensitivity and specificity. The ROC chart is a graphical representation of the relationship between the percentage of true positive test results (sensitivity) and the percentage of false positives (1-specificity). The optimal threshold value of the test result (possibly high sensitivity of the test at high specificity) represents the cut-off point. A common practice is to calculate the area under the ROC curve, described as AUC (area under curve), and consider it a measure of the correctness and validity of the model. The value of the AUC index is within the range 0–1; the higher value the better the model [5]. Analysing BF percentage as a standard criterion, the area under the ROC curves was 0.880 for men and 0.963 for women, indicating that the BMI accuracy in the obesity diagnosis is high. However, it is worth noting that the sensitivity and specificity of BMI at the usual cut-off point ≥ 30 kg/m^2 was 60.7 and 100%, respectively, in men and 57.5 and 100%, respectively in women. In the present study, the sensitivity and specificity of BMI were 75.0 and 91.3%, respectively in men and 92.5 and 89.7%, respectively in women, when the cut-off point of BMI for men was 27.80 kg/m^2, and for women, 26.40 kg/m^2 (Figure 4).

DISCUSSION

Because there are only a few scientific reports from Central and Eastern Europe raising similar issues, this study fills an important gap in the research on this subject. This topic is well described by researchers from the Asia region, especially the Persian Gulf, where obesity affects an extremely high percentage (36.7%) of the inhabitants [2, 8, 18, 40]. For this reason, the WHO recommended a reduction in BMI values that indicate obesity to 27.5 kg/m^2 for that population [38].

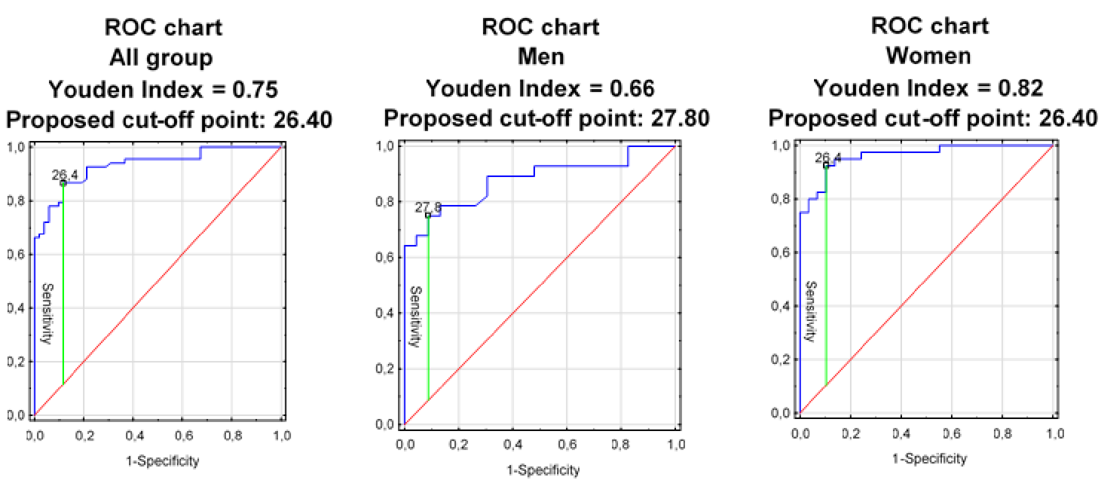

Fig. 4. ROC charts showing the proposed BMI cut-off point for predicting obesity in the study group

An important element of body composition, besides fat tissue, is lean body mass, including muscle mass. In this work, the listed components are presented as a percentage of body weight (%) and quantity in kilograms, which is rare in the literature. There was a negative correlation between the increase in BMI, and fat-free mass and muscle mass expressed as a percentage of body composition, while the amount of FFM presented in kilograms was positively correlated with the increase in BMI, both in the whole group and considering sex. Such dependence may result from the fact that excess fat tissue may be a natural ballast for the muscles, causing their growth. It should be mentioned that in the studied group, there were no subjects with high degree of physical activity, who would have extensive muscle tissue. A positive correlation between BMI and muscle mass (kg) is a beneficial phenomenon, as low muscle mass has been shown to be associated with an increased risk of type 2 diabetes in adults, regardless of obesity [34].

According to the BF percentage classification, a higher percentage of subjects, both men and women, was obese when compared to the BMI classification. Similar results were obtained by De Lorenzo et al. and Habib, noting the higher percentage of obesity estimated using BF percentage instead of BMI [7, 18]. In both cited reports, the number of obese women was higher compared to men, irrespective of the criteria. This study shows that obesity affects men and women almost equally. In recent years, many behavioural and lifestyle factors have been shown to have an impact on the increase in BMI among men compared to women. Moradi-Lakeh et al. reported that obesity is more common in males than in females, who are former smokers (2.7 vs 0.8%, $p < 0.001$) or daily shisha users (5 vs 1%, $p < 0.001$) [29]. It has been proven that the consumption of red meat and poultry is higher in men than in women (>3 servings daily, 23.1 vs 15.5%, $p < 0.001$), which may contribute to an increase in overweight and obesity due to high fat content in these products [27].

Body fat content can be measured using a variety of methods that, due to the high cost, require specialized equipment or the involvement of qualified personnel, which is rarely used in clinical practice [1]. Therefore, in population studies, the body mass index is usually used to estimate the incidence of overweight or obesity. Limit points for BMI determining the overweight and obesity are based on observational studies of the relation between BMI value and mortality as well as incidence of chronic diseases [41]. However, this index does not take into account the fat content in the body. Subjects with normal BMI, but high BF percentage are defined as normal weight obesity (NWO) [12]. The use of BMI may lower the incidence of obesity defined as excess fat, especially in overweight patients [33]. The analysis carried out in this work shows that even in the group of people with correct BMI value, there are subjects with a body fat percentage. These observations are worth noting, because for people with a high percentage of fat in the body, there is a higher probability of cardiometabolic risk or the development of type 2 diabetes, in comparison to people with a normal body fat percentage [6, 16]. The BMI value within generally accepted norms can reduce the awareness of people to health-related aspects and delay the diagnosis of a potential disease, which will lead to many negative consequences. Similar results to those presented above were published by De Lorenzo et al., who additionally pointed out that abnormalities associated with BMI are more frequent in older patients [7]. Hung showed the occurrence of NWO phenomenon significantly more frequently in the group of women than in men [19]. The current BMI classification is often incorrect and undesirable in dietitian practice; therefore it enforces the use of additional diagnostic criteria for the diagnosis of obesity.

Our results, which show a strong, positive correlation between the BMI value and adipose tissue content, confirm previous reports [10, 18, 20]. This relationship was noticed in adipose tissue expressed both in percent and kilograms, with a stronger correlation calculated for female subjects. Normal range of body fat in women is within 20–30%, while in men it is 10–20% [14]. The differences result from different effects of hormones, differences in the type and number of hormone receptors or enzyme concentrations in both sexes. For example, oestrogen in women reduces postprandial oxidation of fatty acids, increases insulin resistance and concentration of leptin, which turns directly into higher levels of adipose tissue [15, 23]. Blaak argues that higher concentration of lipoprotein lipase in women and differences in the number of receptors for epinephrine in both sexes may further explain different contents of adipose tissue in women and men [3]. Considering the body fat content, the visceral adipose tissue deserves special attention. Although the exact mechanisms initiating VAT accumulation have not been fully explained, its surplus is generally believed to be closely related to the development of a group of metabolic disorders, hypertension, cardiovascular diseases and malignancies [28]. It has been noted that more significant irregularities within VAT concern a group of men, which confirms the assumption that android obesity more often affects this sex [30].

Obesity in the studied group was assessed using the body mass index and body fat percentage, indicating that the specificity is high and sensitivity is low at the level of usual cut-off point for obesity (≥ 30 kg/m^2). When the cut-off point of the BMI was reduced to 27.8 kg/m^2 in men and 26.4 kg/m^2 in women, the sensitivity and specificity reached their maximum values reaching 83.81 and 86.27%, respectively in men and 83.33 and 83.05%, respectively in women. The obtained results coincide with the WHO guidelines for the diagnosis of obesity in the Asian population, where the cut-off point has been reduced from 30 to 27.5 kg/m^2 [38]. Subsequent reports confirm the correctness of this decision. Habib showed that the BMI value of 26.6 kg/m^2 shows the highest sensitivity and specificity in diagnosing the obesity in the Saudi population [18]. Similar results were also obtained by Babi et al. for the Iranian population [2].

LIMITATIONS OF THE STUDY

There are some limitations of this study that should be emphasized. The main one is the small research sample, which included 120 subjects, with the group of males being especially small. This was due to the fact that the study protocol assumed the inclusion of subjects with similar height, age and BMI values for each subgroup (obesity, overweight, normal body mass) to show small but potentially significant differences between them. Further research in this area should be carried out on a larger group of subjects. The present study was based on the analysis of the body composition by the BIA method, which is not as precise as, for example, MRI or DEXA, which can provide more detailed information on the body composition (e.g., the amount of liver and/or intercellular adipose tissue). The main reason for choosing the method of measuring body composition was its easy availability and low BIA costs. Further research using more advanced methods is justified, as they may show additional connections between the body composition and the occurrence of some chronic diseases, and may be helpful in determining the potential diet and exercise objectives.

CONCLUSION

This study sheds some light on a significant inconsistency between BMI and body fat percentage in classifying the obesity among adults. Based on the obtained results, it was shown that nearly 25% of men can be included in the NWO group. A large part of them, due to the correct BMI values, may not be aware of the increased cardiometabolic risk caused by high body fat percentage in their bodies. Being aware of the problem is the first and often the most important step towards making changes. Therefore, the inclusion of % BF measurements using simple methods for basic anthropometric studies seems to be important in general clinical practice. Furthermore, screening tests for obesity in people with normal BMI may better identify people with increased risk of metabolic disorders and mortality due to cardiometabolic dysregulation.

This study showed that the value of BMI is correlated with many components of the body, including fat, muscle and non-fat body mass. Further research is necessary to be carried out on a larger group of subjects to correct specific BMI cut-off points when diagnosing obesity for the European population.

REFERENCES

[1] Andreoli A., Garaci F., Cafarelli F.P., Guglielmi G.: Body composition in clinical practice. Eur. J. Radiol., 2016; 85: 1461–1468

[2] Babai M.A., Arasteh P., Hadibarhaghtalab M., Naghizadeh M,M., Salehi A., Askari A., Homayounfar R.: Defining a BMI cut-off point for the Iranian population: The Shiraz Heart Study. PLoS One, 2016; 11: e0160639

[3] Blaak E.: Gender differences in fat metabolism. Curr. Opin. Clin. Nutr. Metab. Care, 2001; 4: 499–502

[4] Böhm A., Heitmann B.L.: The use of bioelectrical impedance analysis for body composition in epidemiological studies. Eur. J. Clin. Nutr., 2013; 67: S79–S85

[5] Bradley A.P.: The use of the area under the ROC curve in the evaluation of machine learning algorithms. Pattern Recognition, 1997; 30: 1145–1159

[6] Chuang H.H., Li W.C., Sheu B.F., Liao S.C., Chen J.Y., Chang K.C., Tsai Y.W.: Correlation between body composition and risk factors for cardiovascular disease and metabolic syndrome. Biofactors, 2012; 38: 284–291

[7] De Lorenzo A., Deurenberg P., Pietrantuono M., Di Daniele N., Cervelli V., Andreoli A.: How fat is obese? Acta Diabetol., 2003; 40: S254–S257

[8] DeNicola E., Aburizaiza O.S., Siddique A., Khwaja H., Carpenter D.O.: Obesity and public health in the Kingdom of Saudi Arabia. Rev. Environ. Health, 2015; 30: 191–205

[9] Drewnowski A.: Obesity and the food environment: Dietary energy density and diet costs. Am. J. Prev. Med., 2004; 27: 154–162

[10] Fedewa M.V., Nickerson B.S., Esco M.R.: Associations of body adiposity index, waist circumference, and body mass index in young adults. Clin. Nutr., 2019; 38: 715–720

[11] Fisher J.O., Liu Y., Birch L.L., Rolls B.J.: Effects of portion size and energy density on young children's intake at a meal. Am. J. Clin. Nutr., 2007; 86: 174–179

[12] Franco L.P., Morais C.C., Cominetti C.: Normal-weight obesity syndrome: diagnosis, prevalence, and clinical implications. Nutr. Rev., 2016; 74: 558–570

[13] Fuller N.J., Jebb S.A., Laskey M.A., Coward W.A., Elia M.: Four-component model for the assessment of body composition in humans: comparison with alternative methods, and evaluation of the density and hydration of fat-free mass. Clin. Sci., 1992; 82: 687–693

[14] Gallagher D., Heymsfield S.B., Heo M., Jebb S.A., Murgatroyd P.R., Sakamoto Y.: Healthy percentage body fat ranges: an approach for developing guidelines based on body mass index. Am. J. Clin. Nutr., 2000; 72: 694–701

[15] Gogga P., Karbowska J., Meissner W., Kochan Z.: Rola leptyny w regulacji metabolizmu lipidów i węglowodanów. Postępy Hig. Med. Dośw., 2011; 65: 255–262

[16] Gómez-Ambrosi J., Silva C., Galofré J.C., Escalada J., Santos S., Millán D., Vila N., Ibañez P., Gil M.J., Valentí V., Rotellar F., Ramírez B., Salvador J., Frühbeck G.: Body mass index classification misses subjects with increased cardiometabolic risk factors related to elevated adiposity. Int. J. Obes., 2012; 36: 286–294

[17] González Jiménez E.: Body composition: Assessment and clinical value. Endocrinol. Nutr., 2013; 60: 69–75

[18] Habib S.S.: Body mass index and body fat percentage in assessment of obesity prevalence in Saudi adults. Biomed. Environ. Sci., 2013; 26: 94–99

[19] Hung S.P., Chen C.Y., Guo F.R., Chang C.I., Jan C.F.: Combine body mass index and body fat percentage measures to improve the accuracy of obesity screening in young adults. Obes. Res. Clin. Pract., 2017; 11: 11–18

[20] Kupusinac A., Stokić E., Sukić E., Rankov O., Katić A.: What kind of relationship is between body mass index and body fat percentage? J. Med. Syst., 2017; 41: 5

[21] Lee K., Lee S., Kim Y.J., Kim Y.J.: Waist circumference, dual-energy X-ray absortiometrically measured abdominal adiposity and computed tomographically derived intra-abdominal fat area on detecting metabolic risk factors in obese women. Nutrition, 2008; 24: 625–631

[22] Lukaski H.C.: Methods for the assessment of human body composition: traditional and new. Am. J. Clin. Nutr., 1987; 46: 537–556

[23] Lwin R., Darnell B., Oster R., Lawrence J., Foster J., Azziz R., Gower B.A.: Effect of oral estrogen on substrate utilization in postmenopausal women. Fertil. Steril., 2008; 90: 1275–1278

[24] Major–Gołuch A., Miazgowski T., Krzyżanowska-Świniarska B., Safronow K., Hajduk A.: Porównanie pomiarów masy tłuszczu u młodych zdrowych kobiet z prawidłową masą ciała za pomocą impedancji bioelektrycznej i densytometrii. Endokr. Otył. Zab. Przem. Mat., 2010; 6: 189–195

[25] Małecka-Massalska T., Popiołek J., Teter M., Homa-Mlak I., Dec M., Makarewicz A., Karakuła-Juchnowicz H.: Wykorzystanie kąta fazowego do oceny stanu odżywienia pacjentów z jadłowstrętem psychicznym. Psychiatr. Pol., 2017; 51: 1121–1131

[26] Marra M., Sammarco R., De Filippo E., Caldara A., Speranza E., Scalfi L., Contaldo F., Pasanisi F.: Prediction of body composition in anorexia nervosa: Results from a retrospective study. Clin. Nutr., 2018; 37: 1670–1674

[27] Memish Z.A., El Bcheraoui C., Tuffaha M., Robinson M., Daoud F., Jaber S., Mikhitarian S., Al Saeedi M., AlMazroa M.A., Mokdad A.H., Al Rabeeah A.A.: Obesity and associated factors – Kingdom of Saudi Arabia, 2013. Prev. Chronic. Dis., 2014; 11: E174

[28] Miazgowski T., Kucharski R., Sołtysiak M., Taszarek A., Miazgowski B., Widecka K.: Visceral fat reference values derived from healthy European men and women aged 20–30 years using GE Healthcare dual-energy x-ray absorptiometry. PLoS One, 2017; 12: e0180614

[29] Moradi-Lakeh M., El-Bcheraoui C., Tuffaha M., Daoud F., Al Saeedi M., Basulaiman M., Memish Z.A., Al Mazroa M.A., Al Rabeeah A.A., Mokdad A.H.: The health of Saudi youths: current challenges and future opportunities. BMC Fam. Pract., 2016; 17: 26

[30] Palmer B.F., Clegg D.J.: The sexual dimorphism of obesity. Mol. Cell Endocrinol., 2015; 402: 113–119

[31] Peine S., Knabe S., Carrero I., Brundert M., Wilhelm J., Ewert A., Denzer U., Jensen B., Lilburn P.: Generation of normal ranges for measures of body composition in adults based on bioelectrical impedance analysis using the seca mBCA. Int. J. Body Compos. Res., 2013; 11: 67–76

[32] Reiss J., Iglseder B., Kreutzer M., Weilbuchner I., Treschnitzer W., Kässmann H., Pirich C., Reiter R.: Case finding for sarcopenia in geriatric inpatients: performance of bioimpedance analysis in comparison to dual X-ray absorptiometry. BMC Geriatr., 2016; 16: 52

[33] Romero-Corral A., Somers V.K., Sierra-Johnson J., Thomas R.J., Collazo-Clavell M.L., Korinek J., Allison T.G., Batsis J.A., Sert-Kuniyoshi F.H., Lopez-Jimenez F.: Accuracy of body mass index in diagnosing obesity in the adult general population. Int. J. Obes., 2008; 32: 959–966

[34] Son J.W., Lee S.S., Kim S.R., Yoo S.J., Cha B.Y., Son H.Y., Cho N.H..: Low muscle mass and risk of type 2 diabetes in middle-aged and older adults: findings from the KoGES. Diabetologia, 2017; 60: 865–872

[35] Stanowisko Polskiego Towarzystwa Dietetyki – Standardy leczenia dietetycznego otyłości prostej u osób dorosłych. Dietetyka, 2015; 8

[36] Swinburn B.A., Sacks G., Hall K.D., McPherson K., Finegood D.T., Moodie M.L., Gortmaker S.L.: The global obesity pandemic: shaped by global drivers and local environments. Lancet, 2011; 378: 804–814

[37] Wang H., Chen Y.E., Eitzman D.T.: Imaging body fat: techniques and cardiometabolic implications. Arterioscler. Thromb. Vasc. Biol., 2014; 34: 2217–2223

[38] WHO expert consultation: Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet, 2004; 363: 157–163

[39] World Health Organization (WHO): Diet, nutrition and the prevention of chronic diseases. Report of a Joint WHO/FAO Expert Consultation. WHO Technical Report Series, 2003; 916, Geneva, Switzerland

[40] World Health Organization (WHO): Obesity and overweight, Fact sheets. http://www.who.int/mediacentre/factsheets/fs311/en/ (04.03.2019)

[41] World Health Organization (WHO): Obesity: Preventing and managing the global epidemic. Report on a WHO Consultation on Obesity., 3–5 June 1997, Geneva, Switzerland

[42] World Health Organization (WHO): Obesity: preventing and managing the global epidemic. Report of a WHO Consultation. WHO Technical Report Series, 2000; 894, Geneva, Switzerland

[43] World Health Organization (WHO): Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. WHO Technical Report Series, 1995; 854, Geneva, Switzerland

[44] Zahorska-Markiewicz B., Podolec P., Kopeć G., Drygas W., Godycki-Ćwirko M., Opala G., Kozek E., Zdrojewski T.,Pająk A., Undas A., Małecki M., Czarnecka D., Naruszewicz M., Stańczyk J., Sieradzki J.: Polish Forum for Prevention Guidelines on overweight and obesity. Kardiol. Pol., 2008; 66: 594–596

The authors have no potential conflicts of interest to declare.