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ARTYKUŁ ORYGINALNY / *ORIGINAL ARTICLE*

# New indexes of body fat distribution, visceral adiposity index, body adiposity index, waist-to-height ratio, and metabolic disturbances in the obese

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## Abstract

**Background and aim:** The aim of this study was to examine the relationship between new obesity-related indexes, anthropometric and biochemical parameters, and body composition in individuals with obesity.

**Methods:** The study group consisted of 72 women and 34 men, aged 39.0 ± 5.9 years, with a mean body mass index (BMI) of 32.6 ± 2.4 kg/m$^2$, admitted for body weight reduction. In all participants body weight (BW), height, waist circumference (WC), hip circumference (HC), BMI, waist-to-hip-ratio (WHR), visceral adiposity index (VAI), body adiposity index (BAI), and waist-to-height ratio (WHtR) were assessed. Using bioelectrical impedance (BIA, TANITA MC 180M) the following parameters were obtained: the level of visceral adipose tissue (VAT) and body fat percentage (FM%). Serum concentrations of total cholesterol (TC), high-density lipoprotein cholesterol (HDL), low-density lipoprotein cholesterol (LDL), triglycerides (TG), glucose, insulin, and insulin resistance (HOMA-IR) were determined.

**Results:** It was observed that almost all the studied indicators: WC, WHtR, BAI, VAI, and BMI, positively correlated with VAT estimated by bioimpedance, but only VAI, WC, and WHtR were strongly associated with glucose and lipid disturbances in the obese. BAI and BMI correlated with total FM%, while WC, WHtR, and VAI correlated with total body weight.

**Conclusions:** The results indicate that VAI, WC, and WHtR can be useful in the assessment of increased VAT accumulation associated with disturbances in glucose and lipid metabolism. BAI should be calculated separately for each sex, then it could be also useful for the prediction of disturbances in glucose metabolism. However, further studies are needed to recognise cut-off values for BAI, as a marker of body fatness, associated with adverse health effects.

**Key words:** fat distribution, visceral adipose tissue, obesity-related indexes, metabolic disturbances, obesity

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## INTRODUCTION

The distribution of body fat is an important factor for cardiovascular disease (CVD) risk assessment as well as prevention and treatment of metabolic disorders associated with obesity. Adipose tissue as the reservoir of fuel stored in adipocytes in the form of triglycerides (TG) controls lipid metabolism and glucose homeostasis [1]. In addition to storing energy, adipose tissue exerts an active endocrine function. Adipocytes, adipose-resident immune cells, and endothelial cells produce many bioactive factors, which regulate systemic metabolism and inflammation [2]. Enhanced accumulation of TG in adipocytes increases the lipid droplet size, which results in adipose expansion and subsequent obesity, dysregulates production and secretion of adipokines, and is implicated in obesity-induced inflammation and insulin resistance. Both inflammation and insulin resistance play a key role in the development of metabolic complications of obesity, such as type 2 diabetes, hypertension, dyslipidaemia, and atherosclerosis, leading to a high rate of

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mortality among the obese [3, 4]. The accumulation of visceral fat is so strongly associated with type 2 diabetes that the term "diabesity" was proposed.

There are many methods used to assess the content and distribution of body fat. They differ in the accuracy, the time necessary to carry out the examination, as well as the costs. Electronic methods used as the gold standard, i.e.: densitometry (dual-energy X-ray absorptiometry [DXA]), magnetic resonance imaging (MRI), computed tomography, and mechanical method, i.e. hydrostatic method (underwater weighing), are characterised by high precision of body fat assessment, and the first three methods also provide fat imaging and its location in the body [5]. These methods are technically complex procedures and they are too costly and time-consuming to be used routinely in clinical practice. Standardised, in terms of the above, alternative methods, i.e. bioelectrical impedance analysis (BIA), or measurement of skin-fold thickness, are commonly used, but they are characterised by many limitations, including difficulties in determining the measurement error [5, 6].

It was shown that waist circumference (WC) and waist-to-hip ratio (WHR) play an important role in the risk assessment of cardiovascular events, and it was postulated that these parameters be included in routine CVD risk assessment [7]. Recently published data suggest that clinical practice should also include new indexes such as body adiposity index (BAI), waist-to-height ratio (WHtR), and visceral adiposity index (VAI) [6, 8, 9]. It is suggested that these new indexes are characterised by higher sensitivity and specificity than conventional parameters such as WC and body mass index (BMI), and could significantly improve the assessment of risk of CVD associated with obesity [6, 8, 9].

The aim of this study was to evaluate the relationship between new obesity-related indexes of the amount and distribution of body fat, such as: VAI, BAI, and WHtR, and commonly used in clinical practice anthropometric and biochemical parameters, in patients with grade I obesity.

## METHODS

The study group consisted of 72 women and 34 men, aged 39.0 ± 5.9 years, with a mean BMI of 32.6 ± 2.4 kg/m$^2$, who agreed to take part in a personalised obesity treatment programme, which is not the subject of the present paper [10–12]. The patients were consecutively recruited between January 2012 and February 2014 on the basis of clinical assessments from subjects who had been directed to the Outpatient Clinic at the National Food and Nutrition Institute in Warsaw due to obesity treatment or a routine general health screening. The inclusion criteria were as follows: BMI in the range of 30–35 kg/m$^2$, no significant changes in body weight (< 3 kg), and non-use of drugs to support obesity treatment at least in the last three months before the study, non-diabetics, no history of hyperglycaemia and hyperlipidaemia treatment, and non-smoking (for at least five years). Increased serum lipid levels did not exclude subjects from the study. Nearly 26% of our patients had dyslipidaemia diagnosed according to the guidelines of to the National Cholesterol Education Programme Adult Treatment Panel III [13]. Patients had lifestyle therapies that combined diet and exercise interventions as nonpharmacological strategies for the treatment of dyslipidaemia.

Exclusion factors were: pregnancy, lactation, endocrine disorders (e.g. disease of the thyroid, parathyroid, Cushing's syndrome, polycystic ovary syndrome), chronic kidney and liver disease, autoimmune diseases, cancer, and implanted pacemaker or other metal implants. The study protocol was approved by the Ethics Committee at the National Food and Nutrition Institute. All participants signed an informed consent form after receiving an explanation of the study's objectives and methodology. Blood was collected after night fasting from all subjects in commercially available vacuum tubes and analysed on the same day. Standard assays were used to measure serum concentrations of total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), TG, glucose, and insulin. HOMA-IR index, a commonly used marker of insulin resistance, was calculated using the formula: HOMA-IR = fasting glucose levels [mmol/L] × fasting insulin levels [$\mu$U/mL]/22.5.

All subjects underwent a comprehensive medical evaluation including medical history, physical examination, and measurement of anthropometric parameters: body weight, body height, WC, and hip circumference (HC), according to standardised procedures routinely performed in the Outpatient Clinic at the National Food and Nutrition Institute. Moreover, using TANITA MC 180MA, an analysis of the body composition by bioelectric impedance was performed, and according to algorithms developed by the producer (TANITA) the following parameters were obtained: the level of visceral adipose tissue (VAT) and body fat percentage (FM%). Strong ($r > 0.8$) and significant ($p < 0.0001$) correlations between VAT area assessed by MRI and VAT estimated by BIA in men and women were recognised [14]. Based on anthropometric and biochemical measurements the following indexes were calculated: VAI, BAI, WHtR, BMI, and WHR.

— VAI was calculated for women and men according to the formulas:

VAI = [WC / 39.68 + (1.88 × BMI)] × (TG / 1.03) × (1.31 / HDL) for men; and for women: VAI = [WC / 36.58 + (1.89 × BMI)] × (TG / 0.81) × (1.52 / HDL).

The proper value of VAI has been assumed to be VAI = 1, which indicates that an individual has normal body weight, normal adipose tissue distribution, and normal serum concentrations of TG and HDL-C [6].

— BAI = [HC (cm) / height (m)$^{1.5}$] – 18 [8].

BAI cutoffs to identify obese women and men were proposed according to the relationship between FM% and BMI,

Table 1. Characteristics of the study group

| Variable; n = 106 (72 F, 34 M) | Mean ± SD |
|---|---|
| Age [years] | 39.0 ± 5.9 |
| BH [cm] | 169.6 ± 9.6 |
| BW [kg] | 91.6+11.7 |
| BMI [kg/m$^2$] | 32.3 ± 2.3 |
| FM [kg]* | 32.7 ± 5.6 |
| FM [%]* | 34.8 ± 4.9 |
| WC [cm] | 102.8 ± 8.2 |
| HC [cm] | 113.4 ± 6.3 |
| WHR | 0.9 ± 0.09 |
| VAT [U]* | 9.62 ± 3.3 |
| VAI | 2.7 ± 1.7 |
| BAI | 34.5 ± 4.9 |
| WHtR | 0.6 ± 0.03 |
| TG [mmol/L] | 1.5 ± 0.7 |
| TC [mg/dL] | 197.7 ± 39.3 |
| HDL-C [mg/dL] | 52.9 ± 14.9 |
| LDL-C [mg/dL] | 116.8 ± 33.5 |
| Glucose [mg/dL] | 88.8 ± 6.9 |
| Insulin [mU/L] | 12.3 ± 6.1 |
| HOMA-IR | 2.8 ± 1.9 |

The means and standard deviations (SD) of biochemical tests, indexes, and anthropometric parameters are presented. *Data estimated by bioimpedance (according to the algorithm developed by the manufacturer, as indicated in Methods); F — female; M — male; BH — body height; BW — body weight; BMI — body mass index; FM% — body fat percentage; WC — waist circumference; HC — hip circumference; WHR — waist to hip ratio; VAT — visceral adipose tissue; VAI — visceral adiposity index; BAI — body adiposity index; WHtR — waist-to-height ratio; TG — triglycerides; TC — total cholesterol; HDL-C — high-density lipoprotein; LDL-C — low-density lipoprotein; HOMA-IR — homeostatic model assessment for insulin resistance

recognised by Gallagher et al. [15] for the Caucasian population: > 39 for women and > 25 for men aged 20–39 years, and > 40 for women and > 27 for men aged 40–59 years.

- WHtR = (WC) (cm) / height (cm). WHtR in the range from 0.46 to 0.62 is proposed as a proper (normal) range [9].
- BMI = body mass / height$^2$ (kg/m$^2$) and BMI in the range 25.0–29.9 is commonly used to diagnose overweight and BMI > 30.0 to diagnose obesity.
- WHR = WC (cm) / HC (cm) and WHR > 1 in men and > 0.8 in women is commonly used to diagnose enhanced accumulation of abdominal adipose tissue.

### *Statistical analysis*

Results are presented as mean ± standard deviation. The correlations between the analysed parameters were determined by Spearman's test, using the Statistica data analysis software system, version 12.0 (StatSoft, Inc., 2014). The concordance of normal distribution of all variables was calculated with the Shapiro-Wilk and Kolmogorov-Smirnov tests. Because of the physiological differences in body fat distribution between men and women, obesity-related indexes of body fat distribution based on hip circumference (WHR and BAI) were calculated separately for each sex. In all analyses, a p-value $< 0.05$ was considered statistically significant.

## RESULTS

The characteristics of the study participants and the mean values of the measured and calculated parameters are presented in Table 1.

In our obese patients the VAI positively correlated with the level of VAT estimated by bioimpedance, and body mass, but not with FM% assessed by BIA (Table 2).

Body adiposity index correlated significantly with the amount of VAT and FM% estimated by BIA in both females and males, as shown in Table 2. We did not find any correlation between BAI and VAI.

In the whole group (including men and women) significant relationships between WHtR and BMI, and VAI but not with FM% assessed by bioimpedance, were recognised.

The waist-to-hip ratio, commonly used in clinical practice, in studied men positively correlated with the amount of VAT and FM% estimated by bioimpedance. WC strongly positively correlated with body weight and VAT (Table 2).

Analysis of relationships between tested obesity-related indexes and lipid parameters (Table 3) showed that total serum cholesterol concentration positively correlated with VAI, and TG concentrations were associated with WHtR and WC. HDL-C concentrations were inversely correlated with WHtR, BMI, and WC. No significant association between lipid parameters and BAI was observed. In women, WHR positively correlated with serum TG, insulin, and HOMA-IR and negatively with HDL-C. In men BAI (hip circumference to height ratio) positively correlated with glucose and insulin concentrations and HOMA-IR.

In the whole group (men and women) serum glucose and insulin concentrations were significantly associated with VAI, WHtR, and WC.

The degree of insulin resistance expressed by HOMA-IR strongly positively correlated with VAI and WHtR, followed by WC and BMI.

## DISCUSSION

Many epidemiological and experimental studies suggest that the anatomic location of adipose tissue is essential for health, life expectancy, and the risk of developing many diseases, and abdominal obesity is recognised as a key risk factor [4, 16]. VAT and abdominal subcutaneous adipose tissue (SAT) are strongly associated with the risk of CVD and metabolic disorders. Some studies also indicate that the

Table 2. Correlations between obesity indexes and anthropometric parameters

| | VAI | BAI | | WHtR | BMI | WHR | | WC |
|---|---|---|---|---|---|---|---|---|
| | | F | M | | | F | M | |
| VAI | X | NS | NS | 0.283[b] | X [E2] | X [E4] | X [E4] | X [E7] |
| BAI | NS | X | X | X [E1] | 0.287[b] | X [E5] | X [E5] | NS |
| WHtR | X [E] | 0.254[a] | 0.565[c] | X | 0.543[c] | X [E6] | NS | X [E6] |
| BW [kg] | 0.198[a] | NS | NS | 0.298[b] | X [E3] | NS | NS | 0.789[c] |
| FM [%]* | NS | 0.389[c] | 0.374[c] | NS | 0.256[b] | NS | 0.349[a] | NS |
| VAT [U]* | 0.332[a] | 0.512[c] | 0.413[c] | 0.401[c] | 0.371[b] | NS | 0.391[a] | 0.723[c] |

Data are expressed as correlation coefficients (r) with [a]$p < 0.05$, [b]$p < 0.01$, [c]$p < 0.001$; NS — not statistically significant; *Data estimated by bioimpedance; E — WC is used to calculate VAI and WHtR; E1 — height is used to calculate BAI and WHtR; E2 — BMI is used to calculate VAI; E3 — BW is used to calculate BMI; E4 — WC is used to calculate VAI and WHR; E5 — HC is used to calculate both WHR and BAI; E6 — WC is used to calculate WHR and WHtR; E7 — WC is used to calculate VAI; F — female; M — male; VAI — visceral adiposity index; BAI — body adiposity index; WHtR — waist-to-height ratio; BMI — body mass index; WHR — waist–hip ratio; WC — waist circumference; BW — body weight; FM% — body fat percentage; VAT — visceral adipose tissue (measured by bioimpedance)

Table 3. Correlations between obesity indexes and biochemical parameters

| | VAI | BAI | | WHtR | BMI | WHR | | WC |
|---|---|---|---|---|---|---|---|---|
| | | F | M | | | F | M | |
| TC [mg/dL] | 0.246[a] | NS | NS | NS | NS | NS | NS | NS |
| TG [mmol/L] | X[(E)] | NS | NS | 0.215[a] | NS | 0.359[b] | NS | 0.406[c] |
| HDL-C [mg/dL] | X[(E)] | NS | NS | –0.219[a] | –0.205[a] | –0.339[c] | NS | –0.462[c] |
| LDL-C [mg/dL] | 0.216[a] | NS | NS | NS | NS | NS | NS | NS |
| Glucose [mg/dL] | 0.366[c] | NS | 0.300[a] | 0.210[a] | NS | NS | NS | 0.219[a] |
| Insulin [mU/l] | 0.442[c] | NS | 0.364[a] | 0.414[c] | 0.297[b] | 0.297[a] | NS | 0.354[c] |
| HOMA-IR | 0.460[c] | NS | 0.399[a] | 0.435[c] | 0.296[b] | 0.321[c] | NS | 0.384[c] |

Data are expressed as correlation coefficients (r) with ap $< 0.05$, bp $< 0.01$, cp $< 0.001$; NS — not statistically significant; (E) — TG and HDL-C are used to calculate VAI; F — female; M — male; VAI — visceral adiposity index; BAI — body adiposity index; WHtR — waist-to-height ratio; BMI — body mass index; WHR — waist–hip ratio; WC — waist circumference; BW — body weight; TC — total cholesterol; TG — triglycerides; HDL-C — high-density lipoprotein; LDL-C — low-density lipoprotein; HOMA-IR — homeostatic model assessment for insulin resistance

pathogenic role of SAT may be dependent on the amount of VAT [16, 17].

The BMI, proposed nearly 200 years ago, is recommended by the FAO/WHO and commonly used to classify nutritional status [18]. However, BMI measurement is characterised by low accuracy, especially in patients with an increased amount of fat-free mass (e.g. athletes) and is not sex-specific. Significant differences between BMI and health outcomes in different ethnic groups were recognised, indicating that in different populations different cut-off values should be considered [19]. In addition, BMI does not describe body fat distribution, so additional anthropometric parameters should be used to assess enhanced accumulation of VAT. For the time being, WC is the main clinical parameter used for indirect assessment of increased visceral obesity [7]. Our previous study showed that despite a strong positive correlation between the level of VAT and WC, the same value of WC can correspond to different levels of visceral and SAT measured by bioimpedance in different subjects [10]. Furthermore, due to the presence of the same WC in patients with different body height, it is not likely for them to have the same risk of metabolic disturbances [20]. Recently the VAI was developed and validated by MRI based on anthropometric and clinical data in 1498 women and men [6]. VAI is calculated using anthropometric (WC, BMI) and metabolic (HDL-C and TG concentrations) parameters commonly measured in clinical practice. In a study by Amato et al. [21] VAI > 1.9 was recognised to be associated with the occurrence of metabolic syndrome components (ATPIII criteria) in Caucasians. In our study VAI significantly correlated with serum glucose, insulin concentrations, and HOMA-IR, as well as with the amount of VAT estimated by bioimpedance. Therefore, it could be considered as a surrogate marker of VAT dysfunction resulting in dyslipidaemia and insulin resistance, and might be useful in

daily clinical practice and in population studies for the assessment of cardiometabolic risk associated with visceral adiposity. Similar to our results, in the study of Stepien et al. [22] VAI was associated with insulin resistance in obese patients. Moreover, an inverse correlation between VAI and insulin sensitivity evaluated by hyperinsulinaemic-euglycaemic clamp in healthy subjects with normal body weight was reported by Amato et al. [6]. However, further studies are needed to recognise cut-off values of VAI associated with disturbances in glucose metabolism and increased cardiometabolic risk. It was also suggested that the ratio of visceral to subcutaneous adipose tissue should be taken into account when the relation between adipose tissue and insulin sensitivity/resistance is assessed [17].

Body adiposity index was introduced in 2011 based on the data of the "BetaGene" study in 1733 participants of Mexican origin [8], and significant correlations between thepercentage of adipose tissue measured by densitometry and hip circumference, as well as body height, were recognised. BAI was next validated in the TARA (Triglyceride and Cardiovascular Risk in African-Americans) study in a group of African Americans (n = 223), in which strong positive correlation (r = 0.85) between FM% measured by DXA and BAI was reported [8]. Also, Freedman et al. [23] in a study on 1151 individuals from different ethnic groups found a strong relationship between BAI and FM% measured by DXA, and similar correlations were observed for BMI, WC, and hip circumference. The usefulness of BAI in assessing obesity in Caucasians was also reported [24]. The available studies in different ethnic groups with widely varying degrees of obesity indicated the usefulness of BAI in body adiposity measurement. BAI is easy to use as it involves only data on body height and hip circumference. In our study, BAI correlated significantly with the amount of VAT and FM% estimated by bioimpedance in women and men. However, in the whole group (including men and women) similar correlations were observed between BMI, VAT, and FM%. Our data showed that only in males BAI was positively correlated with glucose and insulin concentrations and HOMA-IR. This indicates that in obese men BAI as well as total FM% assessed by bioimpedance could be useful to predict disturbances in glucose metabolism. Therefore, BAI should be calculated separately for each sex and as a marker of total body fatness, and it should be analysed together with other anthropometric measurements. Information on total body adiposity may help to differentiate subjects with similar BMI; however, further studies are needed to establish cutoffs for body fat ranges and for BAI, as a marker of body fatness, associated with adverse health effects.

It was suggested that WHtR, which includes body height and WC measurements, can be used in risk assessment of cardiometabolic disorders [9], and the assumption that the same WC in individuals of varying heights gives a similar cardio-metabolic risk has been questioned [20]. A meta-analysis presented by Ashwell et al. [9] including studies conducted in 18 countries on different continents, showed that WHtR was a better index of prognosis of diabetes, dyslipidaemia, hypertension, and risk of CVD, in both sexes, than WC. This data on more than 300,000 subjects indicated WHtR as a better tool than BMI for assessing the risk of metabolic disorders and CVD. Bozorgmanesh et al. [25] proposed WHtR as an independent predictor of type 2 diabetes. In our study significant correlations between WHtR and insulin and glucose concentration, and HOMA-IR were observed. However, similar associations were found for VAI, WC, and BAI (in males). Moreover, analysis of relationships between WHtR and lipid parameters showed that serum TG and HDL-C concentrations were significantly associated with WHtR, but not as strongly as with WC. Given the simplicity of WC measurement and strong significant correlation between WC and VAT assessed by bioimpedance method, as well as between WC and insulin and HOMA-IR, WC, and to a lesser extent WHtR, appear as valuable parameters of both fat distribution and dysfunction resulting in metabolic disturbances.

### *Limitations of the study*

Some limitations of the present study should be taken into consideration. This work is based on a limited number of obese patients, and the unbalanced number of male and female participants should be noted. Age-related differences in hormonal status of the female participants that may affect adipose tissue distribution and VAT status were also not taken into account. In addition, insulin resistance was measured by HOMA algorithm, not by euglycaemic clamp. We also did not differentiate patients, due to the degree of obesity according to FAO/WHO classification. Finally, individual differences in diet and physical activity may affect measured parameters and should be included in further studies.

## CONCLUSIONS

In conclusion, our data underlines the usefulness of VAI, WC, and WHtR in the assessment of increased VAT accumulation associated with disturbances in glucose and lipid metabolism. VAI, WHtR, and BAI have been examined in only a few studies to date [6, 8, 9]. The present study supports VAI as a new surrogate marker that might be used to estimate the risk of metabolic disturbances associated with VAT accumulation. However, further studies are needed to define cut-off values. BAI appears as a marker of the total percentage of body fat, but it is hard to support its clinical usefulness until further studies provide data on BAI or total body adiposity cutoffs associated with specific health effects for women and men. Also, additional studies are needed to document the usefulness of WHtR in clinical practice in assessing the risk of insulin resistance in the obese.

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# Nowe wskaźniki dystrybucji tkanki tłuszczowej (VAI, BAI, WHtR) a związane z otyłością zaburzenia metaboliczne sprzyjające rozwojowi chorób układu sercowo-naczyniowego

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## Streszczenie

**Wstęp:** Dystrybucja tkanki tłuszczowej w organizmie odgrywa szczególną rolę zarówno w ocenie ryzyka oraz prewencji, jak i w terapii zaburzeń metabolicznych, a także chorób sercowo-naczyniowych. Obok klasycznych wskaźników służących do oceny stopnia otyłości, takich jak wskaźnik masy ciała (BMI), wskaźnik talia–biodra (WHR) czy obwód talii (WC) istnieją nowe wskaźniki, których zastosowanie w praktyce klinicznej powinno zostać rozważone.

**Cel:** Celem badania była ocena przydatności związanych z otyłością wskaźników ilości i dystrybucji tkanki tłuszczowej, tj. wskaźnika wisceralnej tkanki tłuszczowej (VAI), wskaźnika otłuszczenia ciała (BAI) oraz wskaźnika stosunku biodra–wzrost (WHtR) w relacji do parametrów antropometrycznych, składu ciała, jak również w ocenie zaburzeń metabolicznych wśród pacjentów z I stopniem otyłości.

**Metody:** Badaniem objęto 72 kobiety i 34 mężczyzn w wieku 39,0 ± 5,9 roku ze średnią wartością BMI 32,6 ± 2,4 kg/m$^2$, zgłaszających się do Instytutu Żywności i Żywienia w celu redukcji masy ciała. U wszystkich pacjentów dokonano pomiaru masy ciała, wzrostu, obwodu talii, obwodu bioder, a także obliczono wskaźniki: BMI, WHR, WHtR, VAI i BAI. Opierając się na analizie bioimpedancji (TANITA MC 180MA), dokonano oceny składu ciała, w tym: zawartości tkanki tłuszczowej (FM) oraz zawartości wisceralnej tkanki tłuszczowej (VAT). Ponadto oznaczono profil lipidowy: stężenie triglicerydów (TG), cholesterolu całkowitego (TC), cholesterolu frakcji lipoprotein o niskiej (LDL) i wysokiej (HDL) gęstości, a także stężenie glukozy i insuliny, na podstawie których obliczono wskaźnik insulinooporności HOMA-IR.

**Wyniki:** Wykazano statystycznie istotne, dodatnie korelacje między związanymi z otyłością parametrami: WC, WHtR, BAI, VAI, BMI i zawartością VAT szacowanej metodą bioimpedancji, jak również między VAI, WC, WHtR a zaburzeniami metabolizmu glukozy i lipidów. Odnotowano dodatnią relację pomiędzy BAI i BMI a całkowitą zawartością tkanki tłuszczowej (FM%). Potwierdzono związek WC, WHtR i VAI z masą ciała wśród badanych osób.

**Wnioski:** Wyniki niniejszych badań potwierdzają, że VAI, WC i WHtR mogą być użyteczne w ocenie zwiększonego udziału VAT oraz związanych z nią zaburzeń metabolizmu glukozy i lipidów. Obliczana oddzielnie dla każdej płci wartość BAI może być również cennym elementem postępowania terapeutycznego i prognozowania rozwoju zaburzeń metabolizmu glukozy. Jednak konieczne jest przeprowadzenie kolejnych badań w celu określenia wartości granicznych dla BAI jako markera otłuszczenia oraz ich związku z niekorzystnymi efektami zdrowotnymi.

**Słowa kluczowe:** dystrybucja tkanki tłuszczowej, wisceralna tkanka tłuszczowa, wskaźniki związane z otyłością, zaburzenia metaboliczne, otyłość

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