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VISCERAL ADIPOSITY INDEX AS A PREDICTOR OF INSULIN RESISTANCE IN WOMEN WITH AND WITHOUT METABOLIC SYNDROME

Anna Koperska[1,2]✉, Agnieszka Wesołek[1,2], Monika Szulińska[1]

[1]Department of Treatment of Obesity, Metabolic Disorders and Clinical Dietetics, University of Medical Sciences Szamarzewskiego 82/84, 60-569 Poznań, **Poland**
[2]Doctoral School, Poznań University of Medical Sciences Fredry 10, 61-701 Poznań, **Poland**

ABSTRACT

Background. Visceral adiposity index (VAI) is a mathematical formula based on routine anthropometric and biochemical parameters: body mass index (BMI), waist circumference (WC), triglycerides (TG), c-reactive protein (CRP) and high-density lipoprotein cholesterol (HDL). It reflects visceral adipocyte dysfunction. Its increase is strongly associated with obesity-related risk. VAI as a predictive marker of insulin resistance (IR) is proposed to be a valuable tool for identifying individuals at higher cardiometabolic risk. This study aimed to assess the applicability of VAI as an indirect IR marker and investigate the association of VAI and metabolic syndrome (MetS) components.

Material and methods. The study comprised 157 individuals without MetS and 201 with MetS. All participants were female and >55 years old. The following laboratory analyses were performed: glucose, aspartate aminotransferase (AST), alanine transaminase (ALT), CRP, HDL, TG, and uric acid. Anthropometric parameters (height, weight, WC) and blood pressure (BP) were measured. The data obtained were used to calculate each participant's BMI and VAI. Based on the results, all subjects were divided into groups: Group A – without MetS, Group B – with MetS. Group B (with MetS) was additionally divided into groups C (without diabetes) and D (with diabetes).

Results. Statistically significant differences in VAI, fasting glucose, CRP, HDL, and TG were demonstrated between the non-MetS and MetS groups. In group A, there were statistically significant and positive correlations between VAI and WC, serum uric acid and TG, while there was a negative correlation between VAI and HDL. In Group B, as well as in Group C, there were statistically significant and positive correlations between VAI and BMI, WC, serum uric acid and TG, while there was a negative correlation between VAI and HDL. In group D, there were statistically significant and positive correlations between VAI and serum uric acid, TC and TG, while there was a negative correlation between VAI and HDL.

Conclusion. VAI seems to be a promising and easy-to-use primary care marker that effectively identifies individuals at high risk of cardiometabolic complications, especially with IR, unfavorable lipid profiles, and MetS accompanied by diabetes. The simplicity of VAI determination makes it a candidate for the detection of patients at risk of metabolic disorders and cardiovascular (CV) complications. Further long-term prospective studies are needed to verify the applicability of VAI in other conditions.

Keywords: visceral adiposity index, VAI, metabolic syndrome, insulin resistance, obesity

✉anna.koperska02@gmail.com

INTRODUCTION

Metabolic syndrome (MetS) is a cluster of risk factors for cardiovascular disease and diabetes. It comprises abnormalities such as central adiposity, hypertension, hyperglycemia, and atherogenic dyslipidemia (Štěpánek et al., 2019). In addition to genetic and epigenetic factors, some lifestyle and environmental factors, such as overeating and lack of physical activity, contribute to the development of MetS. These modifiable factors should be targeted first for effective prevention and therapy. Abdominal obesity is regarded as the critical element of MetS, and it activates most of the pathways of MetS (Fahed et al., 2022). The pathogenesis of MetS is complex and encompasses environmental, nutritional, and genetic factors (Zafar et al., 2018). Existing studies have reported the prevalence of MetS to be at a level of 20–25% of the adult population. For postmenopausal women, the prevalence has been estimated to be significantly higher at 31–55%. It is well known that menopause is associated with an increased risk for MetS, and most of the individual components of MetS are unfavorably modified after menopause (Pu et al., 2017)(2. Obesity occurs nearly three to five times more often in postmenopausal women than in premenopausal women (Pu et al., 2017)(2.

For years, scientists have been wondering what is the key to the diagnosis of MetS: abdominal obesity or insulin resistance? In fact, both are significant. IR is a complex pathological state of inappropriate cellular response to the hormone insulin in insulin-dependent cells. IR is a common feature of metabolic disturbance, as it occurs in MetS and type 2 diabetes (T2D) or is already present ahead of the diagnosis. Although the exact mechanisms underlying IR are still unclear, excessive production of inflammatory adipocytokines, including tumor necrosis factor α (TNFalpha) and resistin (by visceral adipose tissue), and the associated oxidative stress, inflammation, insulin receptor mutation, ER stress, and mitochondrial dysfunction, are all thought to contribute (Yaribeygi et al., 2019) cellular uptake requiring insulin. Insulin signaling is therefore critical for these tissues. However, decrease in insulin sensitivity due to the disruption of various molecular pathways causes insulin resistance (IR. IR is probably the first step of metabolic system dysfunction and is one of the main factors responsible for the onset and progression of MetS. IR is the critical pathophysiologic mechanism of diabetes (Ahn et al., 2019).

The VAI was introduced by Amato et al. as an indicator of cardiometabolic risk in a healthy population (Amato et al., 2010). It is a mathematical model that includes anthropometric (BMI and WC) and metabolic (TG, HDL) parameters. VAI is a way of estimating visceral adiposity dysfunction (Štěpánek et al., 2019). Research in different populations has reported that VAI is closely associated with IR (Ji et al., 2017). Individuals with a higher VAI have a heightened probability of having IR, which requires appropriate management. VAI might be applicable in identifying prediabetes/diabetes (Ahn et al., 2019). The VAI calculation is based on routine anthropometric and biochemical parameters that are part of preventive examinations in primary care, and it may be an IR marker, especially when fasting insulin concentration is unknown and the HOMA-IR cannot be calculated. Moreover, VAI, which is based on the measurement of waist circumference (WC) and lipid parameters determining the occurrence of atherogenic dyslipidemia, may be a more sensitive marker of IR than HOMA-IR.

The present study was designed to determine the clinical applicability of VAI as an indirect marker of IR and to assess whether VAI could be a valuable tool for identifying individuals at high cardiometabolic risk. The study aimed to evaluate the relationship of VAI with MetS components in patients with and without MetS, and among those whose MetS is or is not accompanied by diabetes.

MATERIALS AND METHODS

Postmenopausal women over the age of 55 were chosen as the subjects of the study due to their increased cardiometabolic risk. Women eligible for the study were recruited in spring 2015 during "healthy weekend" picnics. This study was a part of the project: "Wielkopolska Oncology – improvement and adjustment of cancer diagnostics and therapy to the demographic and epidemiological trends of the region, ensuring optimization of management and prevention" under the PL07 program "Improvement and better adaptation of health protection to demographic and epidemiological trends". The approval of the local bioethics committee (No.: 359/15) was received. Participation in

the study was voluntary and each participant provided written informed consent after having been informed about the project's purpose and course.

The study group was divided into women without MetS and with MetS, and those with MetS were divided into those with or without diabetes (any diabetes type) to distinguish VAI utility in individuals with and without diagnosed diabetes. It was essential to calculate the correlation of VAI with insulin sensitivity and glucose metabolism abnormalities.

Metabolic syndrome criteria were defined according to the International Diabetes Federation (IDF) consensus worldwide definition of metabolic syndrome. According to the IDF (Belgium, 2006), central obesity is defined as WC plus any two of the following four factors:

- raised TG ≥150 mg/dL (1.7 mmol/L) or specific treatment for this lipid abnormality
- reduced HDL cholesterol <40 mg/dL (1.03 mmol/L) in males <50 mg/dL (1.29 mmol/L) in females
- raised blood pressure – systolic BP ≥130 or diastolic BP ≥85 mm Hg or treatment of previously diagnosed hypertension
- raised fasting plasma glucose – (FPG) ≥100 mg/dL (5.6 mmol/L), or previously diagnosed T2D. If above 5.6 mmol/L or 100 mg/dL, an Oral Glucose Tolerance Test (OGTT) is strongly recommended but is not necessary to define the presence of the syndrome.

The participants' height was measured with an accuracy of 0.1 cm, and weight measurements were accurate to the nearest 0.1 kg. WC was measured to an accuracy of 0.5 cm at the midpoint between the lower border of the rib cage and the iliac crest at the end of a normal exhalation (Warrier et al., 2022). All participants also underwent routine physical examinations. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured three times using an automated electronic device and the non-dominant arm, and an average reading was calculated. Measurements were taken while subjects were seated and after they had rested for 10 minutes (Muntner et al., 2019). Overnight fasting blood samples were collected for biochemical measurements of glucose, AST, ALT, CRP, HDL, TG, and uric acid. Blood and urine samples were collected on an empty stomach after an overnight sleep. Before blood sampling, the patients did not consume alcohol and coffee, did not engage in heavy sports, did not smoke cigarettes, and did not change their eating habits and lifestyle. The urine specimen was taken from the midstream of the first urination after the night. LDL-C was calculated using the Friedewald formula. To calculate VAI, the following formula was used: (WC [cm]/[36.58 / 1.89 × BMI]) × (TG [mmol/L]/0.81) × (1.52/HDL [mmol/L]). BMI was calculated as the individual's weight (in kg) divided by the square of the height (in m).

STATISTICAL ANALYSIS

The calculations were made in TIBCO Software Inc. (2017) Statistica (data analysis software system), version 13. http://statistica.io. For variables expressed on a quantitative scale, the consistency of the distribution with a Gaussian curve was checked using the Shapiro-Wilk test. Since compliance was not confirmed, all analyses were performed using non-parametric tests. The comparative analysis of selected variables between the group of people with MetS and the group without MetS, as well as that between the group with MetS with diabetes and MetS without diabetes, was performed using the non-parametric Mann-Whitney U test. The relationship between VAI, the TG/HDL ratio, and the selected variables was tested using Spearman's rank correlation test. All results were considered significant at $p < 0.05$.

RESULTS

The study included 157 participants without MetS (group A) and 201 with MetS (group B) for statistical analysis. All study participants were female. The mean age of patients with MetS was 64 years, and the mean age of women without MetS was 66 years. Detailed anthropometric data (body weight, BMI, WC), SBP, and DBP for each group are presented in Table 1. There were statistically significant differences between the groups for all the variables in the table.

46 of the participants with MetS also had diabetes (group D). 155 (group C) did not have diabetes. The mean body weight, WC and SBP of women with MetS and diabetes were higher than the same parameters for women with nondiabetic MetS. Detailed data are presented in Table 2.

Table 1. Characteristics of study population without MetS (group A) and with MetS (group B)

Parameter	Group A – without MetS	Group B – with MetS	*p*-value
Participants	157	201	
Female	100%	100%	–
Age, years (mean ±SD)	64 ±7	66 ±7	–
Body mass, kg (mean ±SD)	67.51 ±12.85	79.21 ±15.08	<0,0001*
BMI (mean ±SD)	26.63 ±4.49	30.74 ±4.92	<0,0001*
WC, cm (mean ±SD)	87.19 ±13.99	100.44 ±12.52	<0,0001*
SBP, mmHg (mean ±SD)	130.39 ±16.99	147.53 ±17.39	<0,0001*
DBP, mmHg (mean ±SD)	74.71 ±8.79	85.88 ±11.77	<0,0001*

BMI – body mass index; DBP – diastolic blood pressure; SBP – systolic blood pressure; SD – standard deviation.
*Correlation coefficient that is statistically significant ($p < 0.05$).

Table 2. Characteristics of the study population with MetS without diabetes (group C) and with MetS with diabetes (group D)

Parameter	Group C – with MetS and without diabetes	Group D – with MetS and with diabetes	*p*-value
Participants	155	46	–
Female	100%	100%	–
Body mass, kg (mean ±SD)	78.54 ±14.37	81.48 ±17.26	0.2888
BMI (mean ± SD)	30.35 ±4.64	32.04 ±5.64	0.0864
WC, cm (mean ± SD)	99.29 ±11.54	104.32 ±14.87	0.0598
SBP, mmHg (mean ±SD)	146.28 ±16.73	151.72 ±19.03	0.0484*
DBP, mmHg (mean ±SD)	85.78 ±10.35	86.20 ±15.78	0.8173

BMI – body mass index; DBP – diastolic blood pressure; SBP – systolic blood pressure; SD – standard deviation.
*Correlation coefficient that is statistically significant ($p < 0.05$).

There were statistically significant differences between the VAI, glucose, CRP, HDL, and TG of the patients without MetS and the patients with MetS. Details are presented in Table 3.

There were statistically significant differences between the measurements of glucose, ALT, TC, HDL and LDL for the MetS group without diabetes and those for the MetS group with diabetes. The details are presented in Table 4.

In group A (without MetS), the correlation coefficients of VAI with WC, serum uric acid, HDL, TG and SBP were statistically significant. In Group B (with MetS) as well as in Group C (with MetS and without diabetes), statistical analysis revealed significant correlations between VAI and BMI, WC, serum uric acid, HDL, and TG. In Group D (with MetS and diabetes) the correlation coefficients of VAI with serum uric

Table 3. Anthropometric and biochemical characteristics of participants, by presence of metabolic syndrome (group A – without MetS; group B – with MetS)

Parameter	Group A – without MetS					Group B – with MetS					*p*-value
	N	mean ±SD	median	min.	max.	N	mean ±SD	median	min.	max.	
VAI	157	0.74 ±0.44	0.68	0.16	2.55	201	1.56 ±1.52	1.28	0.18	15.81	<0.0001*
Glucose, mg/dl	157	89.86 ±14.99	88.00	32.00	161.00	201	106.64 ±28.68	99.00	70.00	256.00	<0.0001*
AST, U/l	157	27.82 ±10.56	26.00	13.00	127.00	201	29.48 ±11.77	27.00	14.00	102.00	0.2317
CRP, mg/l	156	5.03 ±6.68	4.00	1.90	78.60	201	5.36 ±3.52	4.00	4.00	36.20	<0.0001*
ALT, U/l	157	27.74 ±16.10	25.00	11.00	188.00	201	32.66 ±18.12	27.00	9.00	140.00	0.0016*
TC, mg/dl	157	208.08 ±44.23	202.00	116.00	371.00	201	209.80 ±47.39	206.00	76.00	361.00	0.7536
HDL, mg/dl	157	72.63 ±17.32	69.00	34.00	132.00	201	64.40 ±16.88	62.00	1.30	121.00	<0.0001*
LDL, mg/dl	157	113.52 ±39.43	108.00	44.00	234.00	186	108.73 ±42.48	104.00	22.00	350.00	0.1981
TG, mg/dl	157	113.12 ±48.46	104.00	38.00	315.00	201	194.95 ±114.47	174.00	39.00	955.00	<0.0001*

AST – aspartate aminotransferase; ALT – alanine transaminase; CRP – C-reactive protein; TG – triglicerydes; HDL – high density lipoprotrein; TC – total cholesterol; LDL – low density lipoprotein; TG – triglicerydes; SD – standard deviation, VAI – visceral adiposity index.
*Correlation coefficient that is statistically significant ($p < 0.05$).

Table 4. Anthropometric and biochemical characteristics of participants: group C – with MetS and without diabetes; group D – with MetS and with diabetes

Parameter	Group C – with MetS and without diabetes					Group D – with MetS and with diabetes					*p*-value
	N	mean ±SD	median	min.	max.	N	mean ±SD	median	min.	max.	
VAI	155	1.47 ±1.44	1.28	0.18	15.81	46	1.84 ±1.74	1.38	0.31	7.33	0.4290
Fasting glucose mg/dl	155	100.30 ±18.90	96.00	70.00	166.00	46	127.98 ±42.77	123.00	74.00	256.00	<0.0001*
AST, U/l	155	28.94 ±10.70	27.00	14.00	102.00	46	31.30 ±14.79	27.00	16.00	91.00	0.7070
CRP, mg/l	155	5.24 ±3.50	4.00	4.00	36.20	46	5.74 ±3.57	4.00	4.00	22.20	0.3018
ALT, U/l	155	30.90 ±16.13	26.00	9.00	140.00	46	38.59 ±22.85	31.00	18.00	128.00	0.0128*
TC, mg/d]	155	214.50 ±44.22	209.00	76.00	361.00	46	193.98 ±54.39	188.50	103.00	326.00	0.0060*
HDL, mg/dl	155	65.85 ±16.80	65.00	1.30	121.00	46	59.52 ±16.41	55.00	36.00	101.00	0.0045*
LDL, mg/dl	146	114.19 ±41.82	113.00	50.00	350.00	40	88.78 ±39.20	81.00	22.00	195.00	0.0001*
TG, mg/dl	155	188.09 ±87.48	178.00	39.00	551.00	46	218.04 ±177.02	170.00	57.00	955.00	0.8433

AST – aspartate aminotransferase; ALT – alanine transaminase; CRP – C-reactive protein; TG – triglicerydes; HDL – high density lipoprotrein; TC – total cholesterol; LDL – low density lipoprotein; TG – triglicerydes; SD – standard deviation, VAI – visceral adiposity index.
*Correlation coefficient that is statistically significant ($p < 0.05$).

Table 5. Correlation of VAI and anthropometric and biochemical parameters: Group A – without MetS; Group B – with MetS; Group C – with MetS and without diabetes; Group D – with MetS and with diabetes

Parameter	Group A – without MetS	Group B – with MetS	Group C – with MetS and without diabetes	Group D – with MetS and diabetes
	VAI	VAI	VAI	VAI
BMI	0.15	0.21*	0.24*	0.09
WC, cm	0.31*	0.25*	0.31*	0.04
Fasting glucose, mg/dl	0.04	0.00	0.07	–0.19
SBP, mmHg	–0.24*	–0.07	–0.03	–0.21
DBP, mmHg	–0.09	–0.08	–0.14	0.13
CRP, mg/l	0.08	0.08	0.11	–0.02
AST, U/l	–0.02	–0.10	–0.11	–0.08
ALT, U/l	0.04	0.06	0.08	0.01
Serum uric acid, mg/dl	0.23*	0.33*	0.32	0.36*
TC, mg/dl	–0.05	0.13	0.02	0.45*
HDL, mg/dl	–0.68*	–0.75*	–0.78*	–0.65*
LDL, mg/dl	0.01	0.07	0.04	0.19
TG, mg/dl	0.85*	0.87*	0.84*	0.95*

AST – aspartate aminotransferase; ALT – alanine transaminase; CRP – C –reactive protein; TG – triglicerydes; HDL – high density lipoprotrein; TC – total cholesterol; LDL – low density lipoprotein; TG – triglicerydes; SD – standard deviation; VAI – visceral adiposity index; WC – waist circumference.
*Spearman's correlation coefficients (r) between VAI and tested parameters with statistical significance ($p < 0.05$).

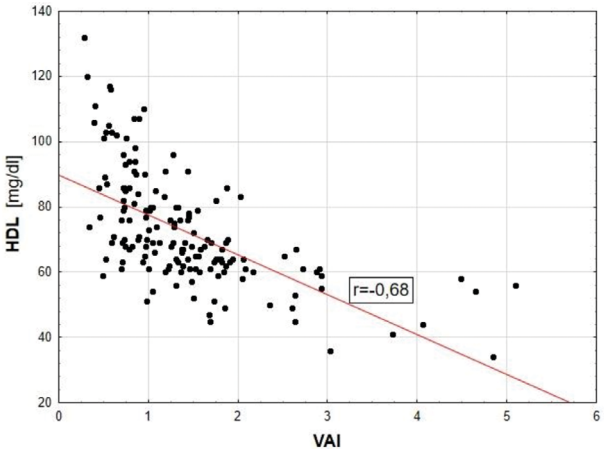

Fig. 1. Correlation of TG concentration and VAI in patients without MetS. TG – triglicerides; VAI – visceral adiposity index

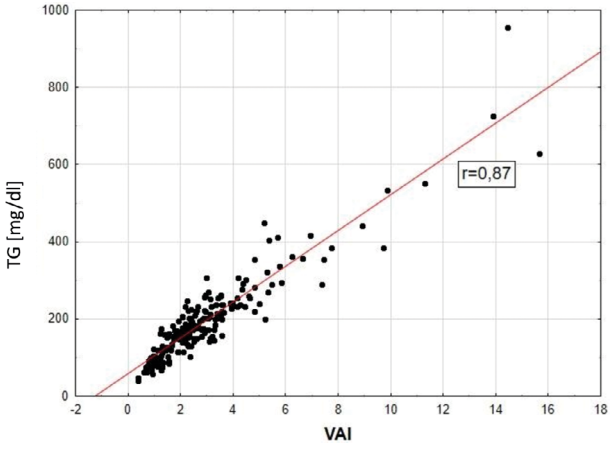

Fig. 2. Correlation of TG concentration and VAI in MetS patients. TG – triglicerides; VAI – visceral adiposity index

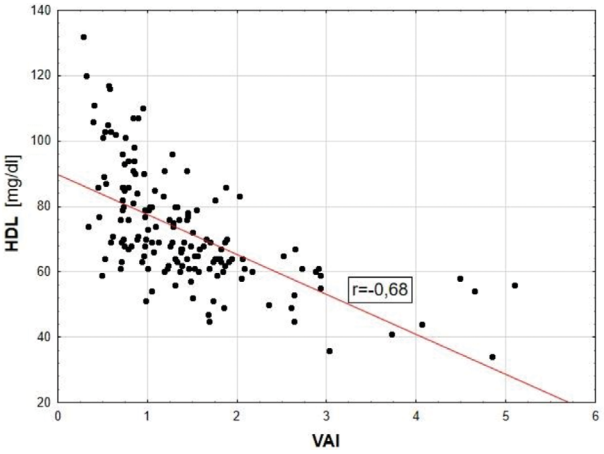

Fig. 3. Correlation of HDL concentration and VAI in patients without MetS. HDL – high-density lipoproteins; VAI – visceral adiposity index

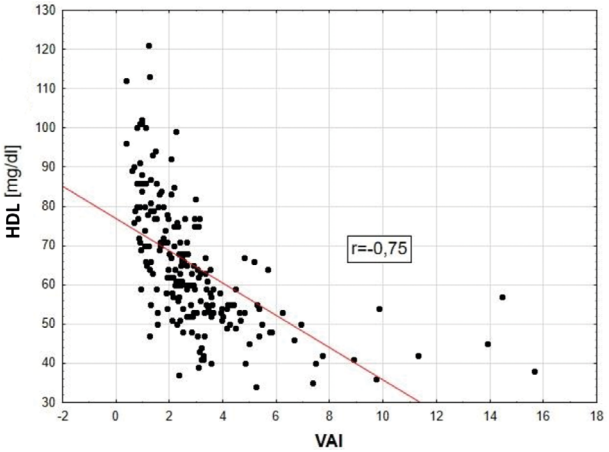

Fig. 4. Correlation of HDL concentration and VAI in MetS patients. HDL – high-density lipoproteins; VAI – visceral adiposity index

acid, TC, HDL, and TG were statistically significant. Detailed data are presented in Table 5.

The scatter diagrams below (Fig. 1 and 2) depict positive correlations of VAI and TG in subjects without and with MetS. The negative correlation between VAI and HDL cholesterol is presented in Figure 3 and Figure 4. The diagrams show VAI's relation to lipid parameters.

DISCUSSION

This study showed that VAI could be a helpful tool for identifying individuals at high cardiometabolic risk. We also presented significant positive and negative correlations between VAI and selected biochemical parameters in the four studied groups. These results indicate that VAI can be a reliable indicator of visceral adipose dysfunction, IR, dyslipidemia, and other obesity-related complications. They may suggest a role of VAI in the prognosis of MetS with or without diabetes, and they underline its potential for practical application in primary care.

It is important to emphasize that despite a statistically significant difference between the VAI values for the groups with and without MetS, there was a statistically significant positive correlation between VAI and WC within both groups. This is consistent with the results obtained by Amato et al., which suggest that VAI is also an indicator of cardiometabolic risk in healthy populations (Amato et al., 2010).

Excessive visceral adipose tissue (VAT) accumulation has been proved to be an essential trigger of metabolic diseases and is strongly associated with an elevated risk of CVD (Liu et al., 2016; Štěpánek et al., 2019). Postmenopausal women with visceral obesity should be screened due to their heightened risk. This would facilitate the implementation of preventive actions and early therapy for diagnosed disorders. WC is an anthropometric index of abdominal obesity. The gold standard for evaluating the extent of visceral fat is computed tomography (CT), magnetic resonance imaging (MRI), and dual-energy x-ray absorptiometry (DXA); however, due to availability, expense, and radiation hazards, these imaging techniques are not suitable for routine examination in a general population (Ji et al., 2017). WC is a simple parameter, easy to assess in clinical practice, but with a large measurement error depending, for example, on the number of evaluators at subsequent visits. Therefore, it is advisable to look for a more accurate, easily accessible indicator of abdominal obesity and its cardiometabolic complications.

A large number of studies have proved that obesity is a relevant etiologic factor for IR (Ji et al., 2017). The pathogenic association of IR with prediabetes/diabetes, as well as with cardiovascular disease (CVD),

is well recognized (Ahn et al., 2019). In the absence of a HOMA-IR value, VAI seems to be a reliable option to detect IR. Research in different populations has demonstrated that VAI is closely associated with IR (Ji et al., 2017). Specifically, VAI showed a strong association with both insulin sensitivity (evaluated with a euglycemic–hyperinsulinemic clamp) and visceral adipose tissue (measured by MRI; Ji et al., 2017). Data showed that VAI, the determination of which does not require glucose and insulin levels, was positively correlated with a homeostatic model assessment of insulin resistance, HOMA-IR. Additionally, VAI was independently related to HOMA-IR in patients without central obesity (Ji et al., 2017).

VAI is considered a valuable indicator of visceral adipose function and insulin sensitivity. The value of VAI increases significantly with a growing number of MetS components, demonstrating the ability of VAI to reflect the level of metabolic disorder connected with MetS (Štěpánek et al., 2019). The VAI cutoff for MetS was 2.37 (Štěpánek et al., 2019). In a study of 92 overweight and obese patients conducted by Pekgor et al., the VAI cutoff identifying MetS subjects (the same IDF criteria as for MetS) was 2.21 (Pekgor et al., 2019)and define cutoff value of VAI in the determination of patients with MetS and IR.\nMethods: Aged between 18 and 65, 92 patients with obesity were included. Levels of homeostasis model assessment of IR (HOMA-IR. In a study of 2,754 community-dwelling people by Liu et al., among all common obesity indices, VAI was the only index significantly associated with prediabetes and T2D (Liu et al., 2016). VAI was a predictor of an impaired cardiometabolic setting in obesity regardless of T2DM status. Traditional indicators of abdominal obesity may not correctly discriminate cardiometabolic risk in some populations, and more large-scale well-planned studies should confirm this for future application of VAI (Wanderley Rocha et al., 2016).

IR is related to the incidence of MetS, and for both conditions, an independent tendency towards increased uric acid levels is found. The role of IR in the relationship between MetS and uric acid levels was not clear. Previous studies have shown a significant relationship between serum uric acid and the incidence of MetS. In our study, we have confirmed the results obtained by other researchers indicating that individuals with MetS had significantly higher serum uric acid levels than those without MetS (Adnan et al., 2019; Nejatinamini et al., 2015). We have also confirmed that VAI is positively correlated with uric acid levels (Baloglu et al., 2021), and that VAI is associated with hyperuricemia among individuals free of MetS (Gu et al., 2018).

Although it was not the subject of our research, it is worth emphasizing that MetS is more prevalent in women with polycystic ovary syndrome (PCOS) as well as obesity. VAI was the strongest predictor of MetS in obese and non-obese women with PCOS (de Medeiros et al., 2021) BMI <30 kg/m^2, n = 385. VAI has substantial predictive value. It is of primary importance that VAI should be applied in clinical practice for early intervention in developing MetS, T2D, and cardiovascular disease (CVD). VAI might be beneficial in both preventive and therapeutic aspects of the clinical care of women at high risk of cardiometabolic disorder (de Medeiros et al., 2021) BMI <30 kg/m^2, n = 385.

Other researchers are also concerned with the importance of VAI in the diagnosis of MetS. The latest VAI publication from 2022 showed that lipid accumulation product (LAP) and triglyceride / glucose index (TyG index) are better markers of IR than VAI and TG/HDL index (Huang et al., 2022). Since IR may develop into diabetes, it is worth extending our study to test insulin concentration in the serum and calculate these indicators. Undoubtedly, a study comparing the above-mentioned indicators in the study groups should be conducted. Our research, apart from its scientific significance, has a practical dimension. Parameters determined during picnics can be determined in routine tests carried out in medical practice, and the determination of VAI does not require insulin concentration. Nevertheless, it is not performed routinely.

Correlations with VAI emphasize the importance of these results in the context of the prognosis and aggravation of MetS and diabetes. Göçer et al. conducted a similar study to ours, checking the correlations between VAI and biochemical parameters in patients with MetS. The VAI index was higher in the group with MetS than in the group without MetS (Bilgin Göçer et al., 2022)visceral adiposity index (VAI. In our study, however, we had a more homogeneous group. They were all women over 55, which was an innovation of the study. Our findings showed that VAI is associated

with an unfavorable lipid profile (TG, HDL) and uric acid concentration, which is the strength of our research and is an essential starting point for further investigations. Besides the anthropometric parameters, VAI includes lipid-related indicators, suggesting that it may be applied in lipid-lowering therapy for the prevention or treatment of CVD. Postmenopausal women need special attention in this regard due to the high prevalence of CVD in this group.

This study found that VAI was highest in women with MetS and diabetes (Group D – with MetS and with diabetes). These results suggest that a simple and cheap VAI can be used for population screening. This is important, as the number of overweight, obese and diabetic people continues to increase, which is associated with a greater risk of heart disease and diabetes complications. VAI screening could reduce hospitalizations, medication use, and premature deaths and thus reduce health care expenditure.

A limitation of this study is that common long-term antihypertensive and hypolipidemic therapy was present in some subjects in the study population, affecting plasma lipid levels and BP values. Hormone therapy in menopausal women may have different effects on MetS components. It would be worthwhile for future studies to measure insulin levels and take into consideration patients' lifestyles, which may affect IR.

In summary, VAI is an easily accessible prognostic marker of cardiometabolic disorders, IR, and CV complications. It's a valuable tool in clinical practice, especially in preventing and providing early treatment for cardiometabolic diseases and identifying high-risk individuals. To support our data, further longitudinal studies should be conducted and used to precisely define VAI's cutoff points, and ultimately prove that VAI can be applied in clinical practice for the early detection of risk factors in MetS patients.

CONCLUSIONS

Adipose tissue dysfunction and IR are fundamental in the pathogenesis mechanisms of MetS and associated cardiometabolic diseases. VAI could be commonly used as a straightforward indicator of early metabolic dysfunction occurring long before the development of metabolic and CV complications. The VAI calculation is derived from routine anthropometric and biochemical parameters that are part of preventive examinations in clinical practice. Further studies confirming the effectiveness of VAI may provide grounds for the widespread use of this marker to identify individuals with high cardiometabolic risk eligible for targeted preventive interventions.

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