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Research Article

The determination of cut-off points of the visceral adiposity index in predicting metabolic syndrome, insulin resistance, diabetes mellitus, and hypertension

Metabolik sendrom, insülin direnci, diabetes mellitus ve hipertansiyonu öngörmede visseral adipozite indeksi kesme değerlerinin belirlenmesi

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Abstract

Introduction: The visceral adiposity index is a reliable indicator of visceral adipose tissue dysfunction. The aim of this research was to determine the cut-off points of the visceral adiposity index in predicting metabolic syndrome, insulin resistance, type 2 diabetes mellitus, and hypertension at specific age ranges and in both sexes separately.

Methods: This research is both descriptive and analytical. The research was conducted with 951 participants aged 18 and over between July 2019 and July 2020. 51 participants that did not meet study criteria were excluded from the research. The research was completed with a total of 900 participants, 577 females and 373 males. A physical examination and anthropometric measurements (height, weight, waist circumference, and blood pressure) of all participants were conducted. After 12 hours of fasting, the HDL, TG, glucose, and insulin levels of participants were measured. The blood pressure of participants was measured after 15 minutes of rest. Adult treatment panel 3 criteria were used for the diagnosis of metabolic syndrome. A homeostatic model assessment was calculated. The visceral adiposity index is calculated in the entire population for the prediction of metabolic syndrome, insulin resistance, diabetes, and hypertension: women, men, age groups 18–30, 31–40, 41–50, 51–65, 66 and over.

Results: Cut-off points of the visceral adiposity index in predicting metabolic syndrome were 4.53 in the total population and males, 4.28 in females, 4.76 in the 18-30 age range, 4.96 in the 31-40 age range, 4.87 in the 41-50 age range, 5.04 in the 51-65 age range, and 4.59 in the age range 66 and above. Cut-off points of the visceral adiposity index in predicting insulin resistance were 4.24 in the total population and females, 4.68 in males, 3.45 in the 18-30 age range, 4.15 in the 31-40 age range, 4.66 in the 41-50 age range, and 4.87 in the 51-65 age range. Cut-off points of the visceral adiposity index in predicting type 2 diabetes mellitus were 4.89 in the total population, 6.43 in females, 7.02 in the 31-40 age range, 7.29 in the 41-50 age range, and 5.98 in the 51-65 age range. Cut-off points of the visceral adiposity index in predicting hypertension were 4.26 in the total population, 4.07 in females, 4.64 in the 18–30 age range, and 4.43 in the 51–65 age range.

Conclusions: The visceral adiposity index can be used to predict metabolic syndrome, insulin resistance, type 2 diabetes mellitus and hypertension.

Keywords: Visceral adiposity index, cardiometabolic risk, insulin resistance, metabolic syndrome, type 2 diabetes mellitus, abdominal obesity

Öz

Giriş: Visseral adipozite indeksi, visseral yağ doku disfonksiyonunun güvenilir bir göstergesidir. Bu çalışmada belirli yaş aralıklarında ve her iki cinsiyette ayrı ayrı metabolik sendrom, insülin direnci, tip 2 diabetes mellitus ve hipertansiyonu öngörmede visseral adipozite indeksi kesme noktalarının belirlenmesi amaçlandı.

Yöntem: Bu araştırma tanımlayıcı analitik bir araştırmadır. Araştırma Temmuz-2019 ile Temmuz-2020 tarihleri arasında 18 yaş ve üzeri 951 katılımcı ile planlandı. Çalışma kriterlerine uymayan 51 katılımcı araştırmadan çıkartıldı. Araştırma 577 kadın, 373 erkek toplam 900 katılımcı ile tamalandı. Tüm katılımcıların fizik muayeneleri ve antropometrik (boy, kilo, bel çevresi, ve tansiyon) ölçümleri yapıldı. Katılımcılarda 12 saat açlık sonrası HDL, TG, glukoz ve insülin düzeyleri bakıldı. Katılımcıların 15 dakika istirahat sonrasında kan basıncı ölçüldü. Metabolik sendrom tanısı için Yetişkin Tedavi Paneli III kriterleri kullanıldı. Hemostasis model assessment hesaplandı. Tüm popülasyonda, kadınlarda, erkeklerde, 18-30, 31-40, 41-50, 51-65, 66 ve üzeri yaş gruplarında; metabolik sendrom, insülin direnci, diyabet ve hipertansiyonu öngörmede visseral adipozite indeksi hesaplandı.

Bulgular: Metabolik sendromu öngörmede visseral adipozite indeksi kesme değerleri toplam nüfusta ve erkeklerde 4,53, kadınlarda 4,28, 18-30 yaş aralığında 4,76, 31-40 yaş aralığında 4,96, 41-50 yaş aralığında 4,87, 51-65 yaş aralığında 5,04, 66 yaş ve üzerinde 4,59 saptanmıştır. İnsülin direncini öngörmede visseral adipozite indeksi kesme değerleri toplam nüfusta ve kadınlarda 4,24, erkeklerde 4,68, 18-30 yaş aralığında 3,45, 31-40 yaş aralığında 4,15, 41-50 yaş aralığında 4,66, 51-65 yaş aralığında 4,87 olarak saptandı. Tip 2 diabetes mellitusu öngörmede visseral adipozite indeksi kesme değerleri toplam nüfusta 4,89, kadınlarda 6,43, 31-40 yaş aralığında 7,02, 41-50 yaş aralığında 7,29, 51-65 yaş aralığında 5,98 olarak saptandı. Hipertansiyonu öngörmede visseral adipozite indeksi kesme değerleri toplam nüfusta 4,26, kadınlarda 4,07, 18-30 yaş aralığında 4,64, 51-65 yaş aralığında 4,43 olarak saptandı.

Sonuç: Visseral adipozite indeksi; metabolik sendrom, insülin direnci, tip 2 diabetes mellitusu ve hipertansiyonu öngörmede kullanılabileceğine kanaat getirildi.

Anahtar kelimeler: Visseral adipozite indeksi, kardiyometabolik risk, insülin direnci, metabolik sendrom, tip 2 diabetes mellitus, abdominal obezite

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Key Point

The VAI cut-off valve for predicting metabolic syndrome is 4.53, 4.24 for insulin resistance, 4.89 for type 2 DM, and 4.26 for hypertension.

Introduction

In addition to storing excess energy in the body, adipose tissue also acts as an endocrine organ that affects the body's metabolic balance [1]. Fat accumulation in the body is usually in the form of subcutaneous adipose tissue (SAT) and visceral adipose tissue (VAT). While SAT has a high energy capacity and low metabolic activity, VAT affects the physiological and pathological processes with the proinflammatory and inflammatory adipocytokines secreted. Increased VAT in the body has been associated with insulin resistance, dyslipidaemia, metabolic syndrome (MetS), type 2 diabetes mellitus (DM), hypertension, and cardiovascular diseases [2-5].

Today, clinical parameters such as waist circumference (WC), waist-to-hip ratio, body shape index, and body roundness index are used to define visceral obesity [6, 7]. However, these parameters cannot distinguish between SAT and VAT. In addition, they do not have any superiority to each other in determining cardiovascular risk. Although different methods such as computed tomography (CT), magnetic resonance imaging (MRI), and densitometer (Dual-energy X-ray absorptiometry (DEXA)) are used to show the VAT and SAT distribution, the use of these methods is limited due to cost, radiation risk, and difficulty in application [8, 9].

Recently, Amato et al. have developed a simple mathematical model, visceral adiposity index (VAI), using both anthropometric (body mass index (BMI) and WC) and functional (triglyceride (TG) and high-density lipoprotein (HDL)) parameters. VAI has been recognized as an indicator of visceral adipose tissue dysfunction associated with cardiometabolic risk. This index has been shown to be associated with MetS, cardiovascular diseases, and diabetes, and to be a much stronger parameter in predicting cardiovascular and cerebrovascular diseases than its own components (WC, BMI, TG, and HDL) [10, 11]. In addition, it has been stated that VAI, which increases before the development of cardiometabolic diseases, may be a marker in the early diagnosis of these diseases [12]. However, when the literature is reviewed, apart from a few limited studies involving VAI, no cut-off points have been determined in predicting metabolic disorders such as MetS, insulin resistance, diabetes, and hypertension. The aim of this research was to determine the cut-off points of the visceral adiposity index in predicting MetS, insulin resistance, Type 2 DM, and hypertension separately in men and women at certain age ranges.

Methods

Study design and population

This descriptive and analytical study was conducted with individuals over the age of 18 who applied to the training and research hospital family medicine polyclinic and the education family health center affiliated with the hospital between July-2019 and July-2020. The universe of the research consisted of 951 people who applied between the relevant dates. The sampling method was not used in this study since it was aimed at research universe was invited to participate in the study. The exclusion criteria of the study were determined as being younger than 18, being pregnant, being in the lactation period, having malabsorption syndromes, malignancies, thyroid dysfunctions, use of steroids and lipid-lowering drugs, obesity surgery, liposuction surgery, and endocrine disorders such as Cushing's syndrome. 51 people who did not meet the study criteria were excluded from the study. A total of 900 participants, including 577 women and 373 men, were included in the study. The participants in the study were divided into groups as follows: 273 people in the 18–30 age group, 163 people in the 31–40 age group, 179 people in the 41–50 age group, 176 people in the 51–65 age group, and 109 people in the 66 and over age group.

Data collection

The research data was obtained through questionnaire forms in which sociodemographic data were questioned and biochemical and anthropometric measurements were recorded, prepared by the researchers. Participants were asked to fill out a sociodemographic data form consisting of questions about age, gender, marital status, educational status, monthly income, exercise status, smoking and alcohol use, illnesses, and drug use. Anthropometric (height, weight, waist circumference (WC), and blood pressure) measurements of all participants, performed by the researchers, were recorded in the questionnaires. WC (cm) was found by measuring the line passing through the midpoint of the iliac crest and arcus costalis while the participant was standing and inspiring. Height (cm) and weight (kg) measurements were performed by taking off the shoes and outer clothes of the participants. Blood pressure was measured with the Riva-Rocci method by selecting suitable sleeves from both arms after a 15-minute rest. The blood pressure in the upper arm was accepted as the participant's blood pressure.

The BMI (kg/m2) was found by dividing the body weight by the square of the height in meters. A BMI of 25 to 29.9 kg/m2 was considered overweight; 30 to 34.9 kg/m2 was considered obese; 35 to 39.9 kg/m2 was considered obese; and 40 kg/m2 or higher was considered morbidly obese [13]. After 12 hours of fasting, left arm serum samples were taken from the participants for HDL, TG, glucose, and insulin tests, and serum samples were studied on the same day in the biochemistry laboratory of the training and research hospital. While glucose, HDL, and TG were studied using a Beckman Coulter AU 5800 (Beckman Coulter, Inc., CA 92821, USA) brand device, insulin was studied using a Siemens Immulite 2000 brand device.

Insulin resistance was calculated according to the Homeostasis Model Assessment (HOMA) formula. HOMA = (fasting glucose (mmol/L)) x (fasting insulin (mIU/mL)) / 405. For values above 2.5, insulin resistance was considered to exist [14]. VAI was calculated using different formulas according to male and female genders: In females, VAI= [WC / [36.58 + (1.89 x BMI)]] x [(TG/0.81) x (1.52/HDL)]. In males, VAI= [BC / [39.68 + (1.88 x BMI)]] x [(TG/1.03) x (1.31/HDL)] [10].

The diagnosis of metabolic syndrome was established according to the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III) (at least 3 of the criteria should be met: fasting glucose ≥100 mg/dL or taking medication for high blood sugar; HDL < 40 mg/dL in males and <50 mg/dL in females or taking medication for low HDL cholesterol; TG ≥ 150 mg/dL or taking medication for high TG; WC≥102 cm (males) or ≥88 cm (females); blood pressure ≥130 / 85 mmHg or taking medication for hypertension) [15]. MetS was detected in 259 individuals; insulin resistance in 193 individuals; diabetes mellitus in 73 individuals; and hypertension in 135 individuals.

Ethical approvals, informed consents, and permissions

The research was approved by the Ethics Committee of the Faculty of Medicine of Selcuk University, dated 26.06.2019 and numbered 2019/178. All participants were informed about the study in accordance with the Declaration of Helsinki, and those who agreed to participate in the study signed the informed consent forms.

Statistical analysis

The analyses of the study data were evaluated using the Statistical Package for the Social Sciences for Windows version 22.0 (SPSS (SPSS Inc., Chicago, IL, USA)) software package at α=0.05 significance level. Categorical variables were presented as frequency and percentage; numerical variables were presented as median, minimum, maximum, and quarter values. In single groups, Kolmogorov-Smirnov and Shapiro-Wilk analyses, tests for descriptive statistics and the distribution compatibility of continuous data, were used. In the comparison of two groups, the Mann-Whitney U test was used in the analysis of non-normally distributed data and the Pearson chi-square test was used in the comparison of categorical variables. Pearson and Spearman correlation analyses were used to measure correlation levels. Power analysis was performed separately for all tests (chi-square, Mann Whitney U, T test) planned to be used in the study and this sample number was reached over the lowest power. For power analysis, the Minitab V18 statistical package program was used. It was planned to take a minimum of 105 participants with 80% power and a 5% margin of error. Cut-off values for the prediction of MetS, insulin resistance, type 2 DM, and hypertension were calculated according to the Receiver Operator Characteristics (ROC) curve. The cut-off value was obtained through the value approach with the smallest distance within the Euclidean distance from the point (0,1) sensitivity and (1-Specificity) values, according to the coordinate values in the creation of the ROC curve. (The cut-off value was obtained with the Youden index.) The fact that the confidence band limits belonging to the area under the curve of the variable in the ROC curves are above 0.5 shows that the variable is significant for the diagnosis. The cut-off values of the variables that are found to be significant are given in the tables in the findings section.

Results

The study was completed with 900 participants who were 18 years old or older and agreed to participate in the study. The median age of the individuals who participated in the study was 42 (18–92) years. 64.1% (n = 577) of the participants were female, and 69.4% (n = 625) were married. 49.5% of the participants had a job. When the participants were classified according to their educational level, the rate of primary school graduates was 38.2%, which was the highest. 29.6% of the participants were graduates of a college or higher educational program and 25.2% were high school graduates. 61.4% of the participants had an income higher than the minimum wage. 57.3% of the participants reported that they did not exercise at all. The sociodemographic characteristics of the participants are given in Table 1.

Table 1. Sociodemographic characteristics of the participants.

	n (%)
Age range	
18-30 years	273 (30.3%)
31-40 years	163 (18.1%)
41-50 years	179 (19.9%)
51-65 years	176 (19.6%)
66 years and older	109 (12.1%)
Gender	
Female	577 (64.1%)
Male	323 (35.9%)
Marital status	
Married	625 (69.4%)
Single	275 (30.6%)
Profession	
Unemployment	455 (50.5%)
Worker	53 (5.9%)
Officer	122 (13.6%)
Student	79 (8.8%)
Tradesman	48 (5.3%)
Private sector	77 (8.6%)
Other	66 (7.3%)
Education Status	
Illiterate	25 (2.8%)
Literate	38 (4.2%)
Primary education	344 (38.2%)
High school	227 (25.2%)
College and above	266 (29.6%)
Monthly income	
2020 TL (minimum wage) and lower	347 (38.6%)
2021 TL- 4000 TL	311 (34.5%)
4001 TL-6000 TL	170 (18.9%)
6001 TL- above TL	72 (8.0%)
Frequency of exercise	
Never	516 (57.3%)
Rarely	194 (21.6%)
Once a week	33 (3.6%)
1-3 times a week	61 (6.8%)
More than 3 times a week	96 (10.7%)

The smoking and alcohol use histories of the participants were questioned. 66.4% of the participants state that they have never smoked in their lives and 98.4% have never used alcohol. The chronic diseases and drug use histories of the individuals participating in our study were questioned. 15% of the individuals had hypertension, 8.1% had type 2 DM, and 28.8% had MetS. Individuals are classified according to their drug use. 72.7% of the individuals did not use regular medication, while the remaining 27.3% used at least one medication due to any disease.

Insulin value was not examined in 103 of 900 participants who participated in our study (those with diabetes and those taking metformin). Of the 797 participants whose insulin values were examined, 24.2% had insulin resistance. When the participants were grouped according to their BMIs, 32% had “normal weight”, 30.8% were “overweight”, 22.9% were “grade 1 obese”, 9.6% were “grade 2 obese”, and 4.7% were “morbidly obese”. While height ($p<0.001$), weight ($p<0.001$), cigarette pack/year ($p<0.001$), WC ($p0.001$), TG ($p<0.001$), glucose ($p<0.001$), insulin ($p=0.012$), HOMA ($p=0.004$), VAI ($p=0.043$) was higher in males than in females, HDL ($p<0.001$) and BMI ($p<0.001$) were lower (Table 2).

Table 2. The Comparison of Research Parameters according to Sex

	Female, n=577 median (25%-75%	Male, n=323 median (25%-75%)	p *
Age (year)	43 (29-54)	39 (27-56)	0.122
Cigarette (pack/year)	10 (3.5-20)	15 (7-30)	**<0.001**
Length (cm)	160 (155-165)	174 (169-180)	**<0.001**
Body weight (kg)	73 (62-84)	81 (72-90)	**<0.001**
BMI (kg/m^2)	29.07 (23.88-33.71)	26.73 (24.17-29.76)	**<0.001**
Waist Circumference (cm)	94 (82-105)	97 (90-106)	**<0.001**
Systolic Blood Pressure (mmHg)	120 (110-120)	120 (110-120)	0.069
Diastolic Blood Pressure (mmHg)	70 (70-80)	70 (70-80)	0.638
Triglycerides (mg/dL)	107 (78-152)	129 (94-186)	**<0.001**
HDL cholesterol (mg/dL)	52 (45-60)	42 (37-47)	**<0.001**
Glucose (mg/dL)	85 (79-92)	88 (81- 95)	**<0.001**
Insulin (mIU/L)	7 (4.73-10.9)	8.1 (5.2-12.8)	**0.012**
HOMA	1.45 (0.97-2.31)	1.75 (1.08-2.87)	**0.004**
Visceral adiposity index	3.88 (2.64-6.02)	4.31 (2.83-6.53)	**0.043**

*: Mann-Whitney U test, p<0.05 accepted as meaningful. BMI stands for Body Mass Index; HDL stands for High Density Lipoprotein; and HOMA stands for Homeostasis Model Assessment.

The weight (p<0.001), BMI (p<0.001), WC (p<0.001), systolic blood pressure (p<0.001), diastolic blood pressure (p=0.002), TG (p<0.001), glucose (p<0.001), insulin (p<0.001), and VAI (p<0.001) were higher, and HDL (p<0.001) was lower in participants with insulin resistance compared to those without insulin resistance. 40.4% of participants with insulin resistance and 17.9% of those without insulin resistance had MetS (p<0.001). In those with MetS, age (p<0.001), weight (p<0.001), BMI (p<0.001), WC (p<0.001), systolic blood pressure (p<0.001), diastolic blood pressure (p<0.001), TG (p<0.001), glucose (p<0.001), insulin (p<0.001), HOMA (p<0.001), and VAI (p<0.001) were higher.

According to the correlation analysis, VAI was found to have a positive correlation with BMI, WC, TG, glucose, insulin, HOMA, and a negative correlation with HDL (Table 3).

Table 3. Correlation Analysis Results Between Research Parameters

		BMI	WC	HDL	TG	Glucose	Insulin	HOMA	VAI
Age	r	0.385	0.436	0.019	0.337	0.388	0.012	0.068	0.314
	p	**<0.001**	**<0.001**	0.578	**<0.001**	**<0.001**	0.731	0.053	**<0.001**
Cigarette*	r	0.159	0.329	-0.254	0.238	0.287	0.054	0.084	0.259
	p	**0.009**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.405	0.194	**<0.001**
SBP	r	0.305	0.333	-0.140	0.204	0.207	0.121	0.141	0.220
	p	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.001**	**<0.001**	**<0.001**
DBP	r	0.218	0.225	-0.073	0.138	0.140	0.128	0.140	0.144
	p	**<0.001**	**<0.001**	**.028**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
BW	r	0.827	0.852	-0.340	0.376	0.290	0.507	0.519	0.407
	p	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
BMI	r	1.000	0.847	-0.161	0.349	0.312	0.459	0.478	0.403
	p	.	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
WC	r	0.847	1.000	-0.269	0.429	0.395	0.501	0.530	0.490
	p	**<0.001**	.	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
HDL	r	-0.161	-0.269	1.000	-0.361	-0.154	-0.243	-0.254	-0.559
	p	**<0.001**	**<0.001**	.	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
TG	r	0.349	0.429	-0.361	1.000	0.300	0.322	0.347	0.925
	p	**<0.001**	**<0.001**	**<0.001**	.	**<0.001**	**<0.001**	**<0.001**	**<0.001**
HOMA	r	0.478	0.530	-0.254	0.347	0.463	0.985	1.000	0.388
	p	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	.	**<0.001**
VAI	r	0.403	0.490	-0.559	0.925	0.310	0.362	0.388	1.000
	p	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	.

*: pack/year, SBP: Systolic Blood Pressure, DBP: Blood Pressure, BW: Body Weight, BMI: Body Mass Index, WC: Waist Circumference, HDL: High Density

The cut-off points of VAI in predicting the MetS were 4.53 in the total population and males, and 4.28 in females. The cut-off points of VAI in predicting insulin resistance were 4.24 in the total population and females and 4.68 in males. The cut-off points of VAI in predicting type 2 DM were 4.89 in the total population and 6.43 in females. The cut-off points of VAI in predicting hypertension were 4.26 in the total population and 4.07 in females (Table 4).

Table 4. VAI Cut-off Values in Predicting HT, DM, IR and MetS

			Cut-off value	Sensitivity (%)	Specificity (%)	AUC	AUC lower bound	AUC upper bound
All Participants		HT	4.26*	65.9	55.7	0.639	0.592	0.687
		DM	4.89*	64.4	64.8	0.689	0.621	0.753
		IR	4.24*	66.8	62.1	0.686	0.644	0.727
		MetS	4.53*	69.9	67.4	0.730	0.695	0.765
	Female	HT	4.07*	68.4	56.6	0.685	0.632	0.739
		DM	6.43*	55.3	81.1	0.727	0.654	0.800
		IR	4.24*	65.5	63.6	0.678	0.622	0.733
		MetS	4.28*	68.8	65.6	0.735	0.693	0.779
	Male	IR	4.68*	62.7	66.5	0.689	0.625	0.754
		MetS	4.53*	79.8	65.8	0.723	0.663	0.784

(%); Frequency, HT; Hypertension, DM; Diabetes mellitus, IR; Insulin Resistance, MetS; Metabolic syndrome, AUC; Area Under the Curve. *p<0.05 accepted as meaningful.

Participants were grouped according to their ages (18–30 age group, 31–40 age group, 41–50 age group, 51–65 age group, and 66 and above). The VAI cut-off points in predicting the MetS were calculated as 4.76 in the 18–30 age group, 4.96 in the 31–40 age group, 4.87 in the 41–50 age group, 5.04 in the 51–65 age group, and 4.59 in the participants aged 66 and above. The cut-off points of VAI in predicting insulin resistance were 3.45 in the 18–30 age group, 4.15 in the 31–40 age group, 4.66 in the 41–50 age group, and 4.87 in the 51–65 age group. The cut-off points of VAI in predicting type 2 DM were 7.02 in the 31–40 age group, 7.29 in the 41–50 age group, and 5.98 in the 51–65 age group. The cut-off points of VAI in predicting hypertension were 4.64 in the 18–30 age group and 4.43 in the 51–65 age group (Table 5).

Table 5. VAI Cut-off Values in Predicting HT, DM, IR, and MetS for Age Groups

		Cut-off value	Sensitivity (%)	Specificity (%)	AUC	AUC lower bound	AUC upper bound
18-30 years	HT	4.64*	100.0	78.2	0.788	0.738	0.837
	IR	3.45*	74.6	71.6	0.751	0.681	0.821
	MetS	4.76*	81.3	82.1	0.823	0.753	0.894
31-40 years	DM	7.02*	75.0	81.8	0.874	0.723	1.026
	IR	4.15*	61.9	59.7	0.613	0.517	0.709
	MetS	4.96*	73.1	70.8	0.737	0.629	0.845
41-50 years	DM	7.29*	62.5	81.0	0.707	0.561	0.854
	IR	4.66*	69.7	60.0	0.679	0.573	0.785
	MetS	4.87*	66.7	65.6	0.697	0.612	0.782
51-65 years	HT	5.43*	57.1	62.5	0.619	0.531	0.706
	DM	5.98*	55.2	67.4	0.622	0.512	0.731
	IR	4.87*	71.4	61.7	0.695	0.606	0.785
	MetS	5.04*	62.8	64.5	0.676	0.597	0.755
66 years and older	MetS	4.59*	62.3	65.6	0.656	0.547	0.766

(%): Frequency, HT: Hypertension, DM: Diabetes Mellitus, IR: Insulin Resistance, MetS: Metabolic Syndrome, AUC: Area Under the Curve. *p<0.05 accepted as meaningful.

The cut-off points of VAI in predicting MetS, insulin resistance, DM, and hypertension for each age group according to gender are detailed in Table 6.

Table 6. VAI Cut-off Points of Age Ranges by Gender for IR, DM, Hypertension and MetS

			Cut-off value	Sensitivity (%)	Specificity (%)	AUC	AUC lower bound	AUC upper bound
18-30 years	Female	IR	3.45*	67.7	77.6	0.757	0.657	0.857
		MetS	3.53*	87.5	74.0	0.810	0.703	0.917
	Male	IR	3.45*	83.3	62.8	0.736	0.638	0.835
		MetS	4.87*	100.0	77.6	0.833	0.758	0.908
31-40 years	Female	DM	7.02*	100	86.0	0.930	0.789	1.071
		MetS	6.23*	64.3	84.1	0.715	0.548	0.882
	Male	MetS	4.94*	83.3	65.3	0.751	0.614	0.890
41-50 years	Female	DM	5.03*	72.7	65.0	0.730	0.586	0.873
		IR	4.61*	68.4	62.9	0.667	0.535	0.800
		MetS	5.03*	61.5	71.6	0.680	0.579	0.782
	Male	MetS	6.98*	66.7	76.7	0.724	0.562	0.887
51-65 years	Female	HT	5.55*	65.0	65.3	0.678	0.579	0.776
		IR	5.05*	71.0	65.6	0.691	0.578	0.804
		MetS	4.98*	64.3	62.7	0.667	0.567	0.766
	Male	DM	5.01*	81.8	58.0	0.729	0.585	0.873
		IR	4.72*	72.2	63.3	0.715	0.569	0.861
		MetS	5.35*	56.7	74.2	0.688	0.554	0.822
66 years and older	Male	MetS	4.49*	75.0	70.6	0.713	0.551	0.876

(%): Frequency, HT: Hypertension, DM: Diabetes Mellitus, IR: Insulin Resistance, MetS: Metabolic Syndrome, AUC: Area Under the Curve, *p<0.05 accepted as meaningful.

While 46.3% of participants above the cut-off point had MetS, 15.5% of participants below the cut-off point had MetS (p<0.001). While 35.9% of participants above the cut-off point had insulin resistance, 14.6% of participants below the cut-off point had insulin resistance (p<0.001). While 13.9% of participants above the cut-off value had type 2 DM, 4.6% of participants below the cut-off value had type 2 DM (p<0.001). While 20.5% of participants above the cut-off value had hypertension, 10.1% of participants below the cut-off value had hypertension (p<0.001) (Table 7).

Table 7. The Comparison of MetS, Insulin Resistance, Type 2 DM, and Hypertension According to Cut-off Values

		Above Cut-off Value n (%)	Below Cut-off Value n (%)	p*
MetS	+	180 (46.3%)	79 (15.5%)	**<0.001**
	-	209 (53.7%)	432 (84.5%)	
Insulin Resistance	+	129 (35.9%)	64 (14.6%)	**<0.001**
	-	230 (64.1%)	374 (85.4%)	
Type 2 DM	+	47 (13.9%)	26 (4.6%)	**<0.001**
	-	292 (86.1%)	535 (95.4%)	
Hypertension	+	87 (20.5%)	48 (10.1%)	**<0.001**
	-	338 (79.5%)	427 (89.9%)	

*: Chi-square test, (%): Frequency, MetS: Metabolic Syndrome, DM: Diabetes Mellitus, p<0.05 accepted as meaningful

Discussion

In this research, we have tried to calculate the cut-off points of VAI, which has been used as an indicator of VAT dysfunction in recent years, in predicting MetS, type 2 DM, hypertension, and insulin resistance in different age groups of adults. However, there are not enough studies in the literature regarding this subject. We found that the cut-off point of VAI was 4.53 in predicting MetS, 4.24 in predicting insulin resistance, 4.89 in predicting type 2 DM, and 4.26 in predicting hypertension. We concluded that VAI could be used effectively to predict these diseases. In addition, we found that VAI correlated positively with BMI, WC, TG, glucose, insulin, and HOMA index, and negatively with HDL.

Obesity is a chronic public health problem with an increasing prevalence around the world. The most used BMI in the identification of obesity is not sufficient to predict obesity-related morbidity and mortality. BMI cannot distinguish between muscle mass and fat mass, which is closely associated with the risk of premature death. WC has emerged as a leading complement to BMI for indicating obesity risk. Some studies have shown that WC predicts mortality risk better than BMI. WC is insufficient to distinguish between VAT and SAT distributions. Although techniques such as CT and MRI accurately reveal visceral adiposity, they have limitations in terms of cost, radiation risk, and accessibility. Various indices have therefore been developed to estimate the VAT as closely as possible to these methods [16]. Krakauer et al. have developed the body shape index to predict early mortality due to obesity. In a study on Chinese adult men, the body shape index was found to be the best index in predicting cardiovascular risk in a study. Thomas et al. have found the body roundness index, which geometrically determines body fat. Baveicy et al. have stated that VAI is a better predictor than the body shape index and body roundness index for predicting MetS in adults [6-8]. However, there have not been enough studies on the cut-off points of VAI so far. In the literature, in a study conducted by Amato et al. on 1764 people aged 16–99 who were admitted to primary care, the cut-off points of VAI were 2.52 for the age range 18–30, 2.23 for the age range 30-42, 1.92 for the age range 42–52, 1.93 for the age range 52–66, and 2.0 for the age range 66 and above. They used the definition of VAT dysfunction for individuals whose VAI score was higher than this cut-off point. They showed that there was a significant increase in the prevalence of cardiovascular and cerebrovascular diseases in these individuals with VAT dysfunction [10]. The VAI cut-off points in predicting the MetS were calculated as 4.76 in the 18–30 age group, 4.96 in the 31–40 age group, 4.87 in the 41–50 age group, 5.04 in the 51–65 age group, and 4.59 in the participants aged 66 and above. Baveicy et al. have found VAI cut-off points in predicting MetS as 4.28 in females and 4.11 in males [8]. In our study, VAI cut-off points in predicting MetS were 4.28 in females and 4.53 in males. A study in China found the VAI cut-off point in predicting MetS as 2.0. They also found that in MetS patients, systolic blood pressure, diastolic blood pressure, WC, BMI, glucose, VAI, TG, and total cholesterol were higher, while HDL was lower [17]. Pekgor et al. have found the VAI cut-off point in predicting MetS in the overweight and obese as 2.2. They detected higher systolic blood pressure, diastolic blood pressure, BMI, WC, glucose, TG, insulin, HOMA, and VAI values, and lower HDL values in MetS patients. They found that the frequency of MetS was 66% in individuals with a value above 2.2 and 22.2% in individuals with a value below that [9]. In our study, the cut-off point of VAI was 4.53 in the whole population. While the frequency of MetS was 46.3% in participants above this cut-off point, it was 15.5% in participants below this point.

Another study found that VAI was associated with WC, glucose, TG, and HDL among MetS components, while it was not associated with blood pressure [18]. In our study, we found a correlation between VAI and all components of MetS, including systolic and diastolic blood pressure. The prevalence of insulin resistance in the normal population is around 33% for both sexes and increases with age [19]. In our study, the rate of insulin resistance was 21.4% in females and 29.3% in males, and no correlation with age was detected. In patients with insulin resistance, BMI, WC, systolic and diastolic blood pressure, TG, glucose, and VAI were higher, and HDL was lower. The VAI cut-off point was 4.24 in predicting insulin resistance. In a study by Stepanek et al. on 783 participants, they found the VAI cut-off point to be 2.37 in predicting MetS and insulin resistance (Those with HOMA: 3.8 and above were considered to have insulin resistance) [20]. In a study conducted on overweight and obese patients, the VAI cut-off points for predicting insulin resistance were found to be 2.3 [9]. A study on 1834 Chinese adults without central obesity found that the increased VAI value was an obesity-independent risk factor for insulin resistance for both sexes [21]. Similarly, Stephien et al. found that VAI was positively correlated with insulin resistance in obese patients [22]. In a study conducted on women diagnosed with PCOS in Korea, the visceral

and subcutaneous fat distribution of patients was measured using non-contrast CT. VAI was associated with the amount of visceral fat. This result suggests that VAI could replace visceral CT scanning in determining the amount of VAT. In addition, VAI was found to be an independent risk factor for insulin resistance [23].

Gu et al. have found that VAI is superior to WC in predicting diabetes and prediabetes [24]. Chen et al. initially divided the sample consisting of 3461 subjects without diabetes into 4 groups according to their VAI value and monitored them for about 6 years. While the rate of developing diabetes was 7% in the group with the highest VAI value, it was 2.7% in the group with the lowest. They reported that VAI was much more significant in determining the risk of diabetes than BMI, WC, and waist-to-height ratio compared to other body fat indices [25]. Similarly, Lui et al. emphasized the relationship between VAI and prediabetes and diabetes in the 20–50 age group [26]. In the literature review, no VAI cut-off points were found for predicting diabetes. In our study, we found the VAI cut-off point to be 4.89 in predicting type 2 DM. While 13.9% of participants above the cut-off value had type 2 DM, 4.6% of participants below the cut-off value had type 2 DM.

Hypertension, which is characterized by persistently high blood pressure, is a systemic disease that causes serious complications [27]. A study conducted by Zhang et al. on patients with prehypertension reported that, as the VAI score increased, the rate of patients' progression to hypertension also increased. It was also emphasized that evaluating VAI and WC together was more effective than other obesity indices in predicting hypertension [28]. Another study suggests that high VAI in males and females is an independent risk factor for prehypertension and hypertension [29]. However, in our literature review, we could not find any studies that calculated the VAI cut-off point in patients with hypertension. In this study, the cut-off points of VAI in predicting hypertension were found to be 4.26 in the general population.

Limitations

Our study had some limitations. Those who were morbidly obese, for whom the use of VAI was not recommended in assessing VAT dysfunction, those with flaccid abdominal skin folds, and those who had a very low-energy diet were not excluded from this study. In some age groups, the cut-off value could not be calculated due to the low incidence of hypertension and diabetes. In addition, due to its cost and radiation risk, the amount of VAT was not measured by imaging methods.

Conclusion

As a result, in this study, cut-off points for VAI were determined by age groups and gender in the research population. According to our obtained findings, it was thought that VAI could be used to predict insulin resistance, DM, MetS, and hypertension. We believe that similar studies with larger populations are needed in the future.

Conflict of interest: In this study, there is no conflict of interest between the authors.

Author Contributions		Author Initials
SCD	Study Conception and Design	HKT, SP, MAE
AD	Acquisition of Data	HKT, SP, MAE
AID	Analysis and Interpretation of Data	HKT, SP, MAE
DM	Drafting of Manuscript	HKT, SP, MAE
CR	Critical Revision	HKT, SP, MAE

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