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Potential Role of New Anthropometric Parameters in Childhood Obesity with or Without Metabolic Syndrome

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Abstract

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Keywords: Obese children; Body round index [BRI]; Visceral adiposity index [VAI]; A body shape index [ABSI]; Metabolic syndrome (MS)

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BACKGROUND: Obese children and adolescents are more prone to have metabolic syndrome (MS). MS is a cluster of cardiovascular risk factors associated with insulin resistance. Body round index [BRI], visceral adiposity index [VAI] and a body shape index [ABSI] are among the new obesity anthropometric parameters.

AIM: To evaluate the new markers for obesity in children and their possible association with other laboratory and clinical variables of MS.

METHODS: Eighty nine obese children and 40 controls aged 10-18 years were recruited. Full history taking, thorough clinical examination, anthropometric and biochemical features were performed in the studied groups. Subcutaneous fat thickness (SFT) and visceral fat thickness (VFT) were estimated by ultrasonography.

RESULTS: Obese children, exhibited significantly higher values in all anthropometric measurements ($P < 0.001$). Diastolic and systolic blood pressure were significantly higher ($P < 0.001$) in the obese group. ABSI, BRI and VAI have been found to be significantly higher in obese subjects ($P < 0.001$), with no significant gender difference. BMI, WHtR, WC/HR, SBP, DBP, subcutaneous fat thickness and visceral fat thickness, Liver Span, ABSI, BRI, VAI and HOMA-IR were significantly higher among children with MS than those without MS. Positive significant correlations of VAI with BMI, WC/Ht, WC/Hip, SBP, DBP, SFT, VFT, Liver size and HOMA-IR ($r = 0.384, 0.239, 0.268, 0.329, 0.516, 0.320, 0.254, 0.251, \text{ and } 0.278$ respectively) are shown. The area under the ROC curve (AUC) of BMI, VAI, ABSI, BRI for predicting MS was 0.802 (0.701-0.902), 0.737 (0.33-0.841), 0.737 (0.620-0.855), 0.816 (0.698-0.934).

CONCLUSION: We suggest using the VAI and WHtR indexes, as they are better predictor of MS.

Introduction

Obesity in young populations is on the increase due to changes in nutrition behaviors and lifestyle. In Egypt, obese subjects represented about 15.6 % of adolescents aged 10-19 in 2017. Egypt is predicted to rank as the sixth country suffering of having high number of obese subjects (6,818,532) aged 5-19 years in 2030 [1], [2].

Obese children and obese adolescents are also more prone to have hyperlipidemia, hypertension, type 2 diabetes and metabolic syndrome (MS). The widespread of obesity among children, leads to the increased occurrence of MS in them. The metabolic syndrome has been reported in young populations in Egypt and other countries [3], [4]. Several authors have reported the prevalence of the metabolic syndrome in children [5], [6]. There is no consensus about the definition of MS in children [7]. Magge et al.,

reported that focusing on the screening and treating the individual risk factor components of MS and cardio metabolic risk factor was emphasized over the need to define a pediatric MS [8].

The most commonly used criteria in different studies are the modified WHO, Cook and the IDF consensus criteria [9], [10]. MS is a cluster of cardiovascular risk factors associated with insulin resistance and are driven by several factors, including visceral obesity [11].

The body mass index (BMI) is a good index to diagnose general obesity, but it does not reflect fat distribution or differentiate muscle and fat masses. Waist circumference (WC) has been suggested as an alternative to BMI. It is a parameter of abdominal obesity. However, many studies have showed that WC is highly correlated to BMI; so, its value per se is limited. To solve these problems, new anthropometric parameters were developed [12]. Efforts should be

made for recognition of this metabolic risk.

Among the new obesity anthropometric parameters (body round index [BRI], visceral adiposity index [VAI]) and a body shape index [ABSI], were found to be significantly associated with arterial stiffness in adult [13].

The visceral adiposity index (VAI), is a sex-specific indicator of visceral fat distribution which depends on BMI, WC, triglyceride and high-density lipoprotein-cholesterol (HDL-C) [14].

A body shape index (ABSI), using a standardized WC based on BMI and height, reflects mortality hazard better than BMI and WC [15]. While, the body roundness index (BRI), is an indicator of body fat and visceral adipose tissue percentage, and may be useful for evaluating health status [15].

To the best of our knowledge, no study analyzing the cross-sectional relationships between these new anthropometric parameters, obesity, blood pressure, insulin resistance, and other markers of the MS in childhood. The present study aimed to evaluate these new parameters of obesity in children and their possible association with other laboratory and clinical variables of MS.

Materials and Methods

Study Population

We performed a cross-sectional study. The study protocol was approved by the Human Ethics Committee of National Research Center, and written informed consent was obtained from children's caregivers (Approval No14019). We enrolled 89 obese children (30 male, 59 female); they were attending the Pediatrics Obesity Clinic in Centre of Excellence in National Research Centre, with age range from 10 to 18 years. A child was obese if BMI > 95th percentile for age and gender percentile curves of growth for our population [16].

The obese subjects were divided into two groups: first group included patients with metabolic syndrome. We used the IDF definition of MS for children aged 10 years or older which includes BMI > 90th percentile for age and sex and presence of two or more of the following findings: (1) triglycerides >150 mg/dl; (2) HDL-cholesterol <40 mg/dl; (3) systolic blood pressure >130 mmHg, diastolic >85 mmHg; and (4) fasting plasma glucose >100 mg/dl or known type 2 diabetes [14], a second group includes patients without MS.

Exclusion criteria: medical conditions associated with obesity such as cardiac, hepatic or renal diseases, hypothyroidism, Cushing syndrome or Turner syndrome, also obesity with mental

retardation, such as Prader-Willi syndrome, Laurence-Moon-Biedl and Cohen syndrome.

A control group included 40 children (25 male, 15 female); they were age-matched healthy subjects.

Clinical Examination

The following were performed on the studied groups:

1) Full history taking through clinical examination, with emphasis on any complications or medication; 2) Blood pressure was measured according to American Heart Association guidelines; three times for patients and controls after 5-min rest in sitting position with the use of mercury sphygmomanometer. The mean value of 2nd and 3rd measurement was calculated. SBP was defined as the onset of the Korotkoff sound (K1), and DBP was defined as the fifth Korotkoff sound (K5); and 3) Anthropometric indices: Body weight measured to the nearest 0.1 kg with a balance scale and height measured to the nearest 0.1 cm. Body mass index was calculated as weight divided by height squared (kg/m²). Waist circumference (WC) was measured at the level midway between the lowest rib margin and the iliac crest. Hip circumference (HIP C) was measured at the widest level over the greater trochanters in a standing position by the same examiner; then waist to hip ratio (WHR) and Waist to height ratio (WHtR) were calculated.

Among the new obesity anthropometric parameters: body round index (BRI), and visceral adiposity index (VAI) and a body shape index (ABSI) were calculated by the following equations [9].

$$ABSI = \left(\frac{WC}{BMI^{\frac{2}{3}} \times height^{\frac{1}{2}}} \right)$$

$$BRI = 364.2 - 365.5 \times \sqrt{1 - \frac{\left(\frac{WC}{2\pi}\right)^2}{(0.5 \times height)^2}}$$

MALES

$$VAI = \left(\frac{WC}{39.68 + (1.88 \times BMI)} \right) \times \left(\frac{TG}{1.03} \right) \times \left(\frac{1.31}{HDL} \right)$$

FEMALES

$$VAI = \left(\frac{WC}{36.58 + (1.89 \times BMI)} \right) \times \left(\frac{TG}{0.81} \right) \times \left(\frac{1.52}{HDL} \right)$$

TG, and HDL-C levels are expressed in mmol/L, and WC in expressed in cm [9], [13].

Abdominal Ultrasonography

In addition to the routine abdominal ultrasound examination based on the clinical indication, ultrasonography (US) distinctively quantifies visceral fat and subcutaneous fat. We measured the maximum pre peritoneal visceral fat

thickness (VFT) and the minimum subcutaneous fat thickness (SFT) by US. The visceral fat thickness (VFT) was measured by 3.5-5 MHz convex-array probe. VFT is the distance between the internal surface of the abdominal surface of abdominal muscle and the anterior wall of the aorta 1 cm above the umbilicus. The thickness of subcutaneous fat was measured by placement of a 3.75-MHz probe perpendicular to the skin on the epigastrium. Longitudinal scans are obtained along the middle line (linea Alba). The thickness of the subcutaneous fat is defined as the distance between the anterior surface of linea Alba and the fat-skin barrier [17], [18]. Ultrasound apparatus model is SA –R3 (No S06YM3 HDC00012F) SAMSUNG MEDISON Company – South Korea.

Laboratory measurements

Ten millimeters of venous blood were withdrawn under complete aseptic precautions from fasting subjects (12-14 hrs.). Samples were labeled and left to clot at room temperature for 15 min then centrifuged, sera were collected and aliquoted for evaluation of the following parameters: 1) Determination of complete lipid profile (serum triglycerides, HDL, LDL cholesterol) was done using colorimetric methods on Olympus AU 400 supplied from Olympus Life and Material Science (Europe GmbH, Wendenstraße, Hamburg, Germany); 2) Fasting blood glucose was assessed using Hitachi 912 chemistry analyzer (Roche Diagnostics GmbH, D-68298 Mannheim, Germany) by colorimetric techniques; 3) Insulin levels were estimated by Enzyme immunoassay (ELISA); 4) Insulin resistance was calculated by the homeostasis model (HOMA-IR) using the following formula: $HOMA-IR = \text{fasting insulin (mU/L)} \times \text{fasting glucose (mmol/L)} / 22.5$; and 5) Glycosylated Hb (HbA1c) was measured using ion exchange HPLC (high performance liquid chromatography) Kit supplied by Crystal Chem, USA.

Statistical analysis

The standard computer program Statistical Package for the Social Sciences (SPSS) for Windows, release 17.0 (SPSS Inc., USA) was used for data entry and analysis. All numeric variables were expressed as mean \pm standard deviation (SD). Comparison between groups was made using Student t test for continuous variables and Chi-Square tests for categorical variables. Pearson's and Spearman's correlation tests (r = correlation coefficient) were used for correlating normal and non-parametric variables respectively. The receiver operating characteristic (ROC) curve was generated to detect the predictive capabilities of BMI, ABSI, BRI, VAI for MS. $P < 0.05$ was considered statistically significant.

Results

There were no significant differences between obese subjects (with & without MS) and control groups in terms of age ($p > 0.05$). Obese children -the characteristics of the three subgroups are included in Table 1, and Table 2. Regarding clinical data, Table 1 revealed statistically significant difference between studied groups in BMI, WC, WHtR, Systolic BP and Diastolic BP ($P = 0.000, 0.000, 0.000, < 0.001$ & 0.000 , respectively). Also other measurements by abdominal ultrasonography (SFT, VFT & liver size) showed same results ($P = 0.000, 0.002, 0.000$, respectively).

Table 1: Characteristics of the studied population

Item	Subgroups	N	Mean	Std. Deviation	ANOVA SIG
Age Years	No MS	67	11.449	2.6169	0.432
	MS	22	11.923	2.7526	
	Controls	40	10.65	4.3597	
BMI (kg/m ²)	No MS	67	24.1227	8.56	0.000
	MS	22	38.2623	6.63	
	Controls	40	17.92	4.17	
WC CM	No MS	67	78.6753	22.19	0.000
	MS	22	104.8462	11.68	
	Controls	40	69.68	18.56	
WHtR	No MS	67	0.469	0.16	0.699
	MS	22	0.5877	0.10	
	Controls	40	0.46	0.08	
WHtR	No MS	67	0.55	0.15	0.000
	MS	22	0.77	0.10	
	Controls	40	0.43	0.11	
Systolic BP	No MS	67	95.01	19.87	0.001
	MS	22	117.08	12.51	
	Controls	40	89.74	16.97	
Diastolic BP	No MS	67	63.82	8.381	0.000
	MS	22	77.92	10.544	
	Controls	40	61.67	8.883	
SFT [cm]	No MS	67	1.53	0.74	0.000
	MS	22	2.70	0.68	
	Controls	40	1.29	0.50	
VFT [cm]	No MS	67	3.44	1.51	0.002
	MS	22	4.83	1.66	
	Controls	40	2.53	0.93	
Liver Size CM	No MS	67	13.00	1.88	0.000
	MS	22	15.75	1.07	
	Controls	40	11.39	1.90	

No MS = No metabolic syndrome; MS = Metabolic Syndrome; (SBP) Systolic blood pressure; (DBP) diastolic blood pressure; (SFT), subcutaneous fat thickness; (VFT) visceral fat thickness; (WC) Waist circumference; (BMI) Body mass index; (WHtR) Waist to height ratio; (WHR) waist to hip ratio.

In the studied groups, our laboratory parameters data exhibited significant difference in HOMA-IR values, fasting insulin, HDL & LDL ($P = 0.000, 0.028, 0.003, 0.004$). Further details are in Table 2.

Table 2: Laboratory results of the studied population

Item	Subgroups	N	Mean	Std. Deviation	ANOVA SIG
FBG [mg/dl]	No MS	67	82.00	28.23	0.986
	MS	22	83.23	14.26	
	Controls	40	81.47	10.92	
HOMA_IR	No MS	67	2.47	1.70	0.000
	MS	22	4.48	1.309	
	Controls	40	2.19	1.517	
HgA1C	No MS	67	5.65	0.610	0.315
	MS	22	5.95	0.777	
	Controls	40	5.77	0.617	
Fasting Insulin [mU/l]	No MS	67	13.86	9.079	0.028
	MS	22	21.72	4.362	
	Controls	40	12.86	11.536	
Cholesterol [mg/dl]	No MS	67	157.78	30.68	0.064
	MS	22	176.15	38.71	
	Controls	40	161.47	36.54	
Triglycerides [mg/dl]	No MS	67	88.59	32.00	0.143
	MS	22	108.15	46.32	
	Controls	40	84.23	28.24	
HDL [mg/dl]	No MS	67	53.37	15.90	0.003
	MS	22	37.61	10.79	
	Controls	40	54.42	14.21	
LDL [mg/dl]	No MS	67	86.14	29.55	.004
	MS	22	116.84	36.35	
	Controls	40	101.27	33.89	

No MS = No metabolic syndrome; MS = Metabolic Syndrome; FBG = Fasting blood glucose; HOMA-IR = the homeostasis model assessment; HDL = High-density lipoprotein; LDL = Low-density lipoprotein, HbA1C Glycosylated Hb.

Among the new obesity indices, ABSI, BRI and VAI have been found to be significantly higher in obese subjects ($P < 0.001$) (Table 3). Additionally, we found no significant gender difference in all studied items.

Table 3: New anthropometric parameters of obese & non-obese children

Item	Group	N	Mean	Std. Deviation	Sig. (2-tailed)
ABSI	Controls	40	7.58	1.31	0.001
	Obese	89	5.49	3.02	
BRI	Controls	40	4.28	2.28	0.001
	Obese	89	9.14	8.29	
VAI	Controls	39	1.63	0.95	0.001
	Obese	89	3.41	3.03	

(ABSI) a body shape index; (BRI) body round index; (VAI) visceral adiposity index.

In addition, we found that 24.75% (22 subjects, 17 females & 5 males) of the obese children aged 10-16 years met the criteria for MS based on the pediatric MS definition of the IDF consensus. Table 4 shows the differences between obese with & without MS. BMI, WHtR, WC/HipR, SBP, DBP, SFT, VFT, Liver Span, ABSI, BRI, VAI and HOMA_IR were significantly higher among children with MS than those without MS.

Table 4: Comparison between obese children with & without MS

		N	Mean	Std. Deviation	Sig. (2-tailed)
ABSI	Without MS	67	4.79	3.17	0.001
	With MS	22	7.64	0.52	
BRI	Without MS	67	8.11	7.38	0.041
	With MS	22	12.26	10.16	
VAI	Without MS	67	2.42	1.95	0.001
	With MS	22	6.43	3.71	
BMI (kg/m ²)	Without MS	67	31.90	5.92	0.001
	With MS	22	38.61	5.85	
WC cm	Without MS	67	92.80	11.07	0.001
	With MS	22	104.72	11.39	
Whtr	Without MS	67	0.61	0.13	0.005
	With MS	22	0.70	0.08	
WHR	Without MS	67	0.67	0.12	0.002
	With MS	22	0.76	0.11	
Systolic BP mm Hg	Without MS	67	105.85	10.50	0.001
	With MS	22	116.25	11.57	
Diastolic BP mm Hg	Without MS	67	67.36	8.24	0.001
	With MS	22	80.25	9.10	
HOMA_IR	Without MS	67	2.83	1.69	0.001
	With MS	22	4.53	1.20	
SFT cm	Without MS	67	2.12	0.57	0.001
	With MS	22	2.91	0.92	
VFT cm	Without MS	67	4.58	1.28	0.001
	With MS	22	5.92	1.73	
Liver Span cm	Without MS	67	14.13	1.64	0.001
	With MS	22	15.86	1.31	
Triglyceride [mg/dl]	Without MS	67	90.83	24.06	0.001
	With MS	22	112.95	47.25	
HDL [mg/dl]	Without MS	67	56.01	26.31	0.014
	With MS	22	41.34	17.99	

(SBP) Systolic blood pressure; (DBP) diastolic blood pressure (SFT); subcutaneous fat thickness; (VFT) visceral fat thickness; (WC) Waist circumference; (HDL) High-density lipoprotein.

Correlations between ABSI, BRI and VAI and the studied variables in obese subjects are shown in Table 5. Results showed positive significant correlations of VAI with BMI, WC/Ht, WC/Hip, SBP, DBP, SET, VFT, Liver size and HOMA-IR ($r = 0.384, 0.239, 0.268, 0.329, 0.516, 0.320, 0.254, 0.251, \text{ and } 0.278$, respectively). While, BRI had statistically significantly positive correlation with BMI, WC/Ht and HOMA-IR ($r = 0.343, 0.234, \text{ and } 0.322$, respectively). ABSI had statistically significantly positive correlation with WC/Ht only, ($r = 0.220$).

Table 5: Correlations between the studied variables in obese subjects

		BMI	WC/Ht	WC/Hip	SBP	DBP	SFT	VFT	Liver size	HOMA-IR
VAI	r	0.384**	0.239	0.268	0.329	0.516	0.320	0.254*	0.251	0.278
	P	0.002	0.024	0.012	0.004	0.000	0.004	0.023	0.022	0.008
ABSI	r	0.984	0.039	0.491	0.390	0.169	0.760	0.488	0.747	0.537
	P	0.343*	0.234	0.181	0.123	0.144	0.097	0.047	0.062	0.322*
BRI	r	0.001	0.028	0.093	0.298	0.225	0.395	0.678	0.580	0.002
	P									

**Correlation is significant at the 0.01 level (2-tailed); *correlation is significant at the 0.05 level.

The receiver operating characteristic (ROC) curve was generated to detect the predictive capabilities of BMI, WC/Ht R, WC/Hip R, VAI, ABSI, and BRI for predicting MS (Figure 1, and Figure 2).

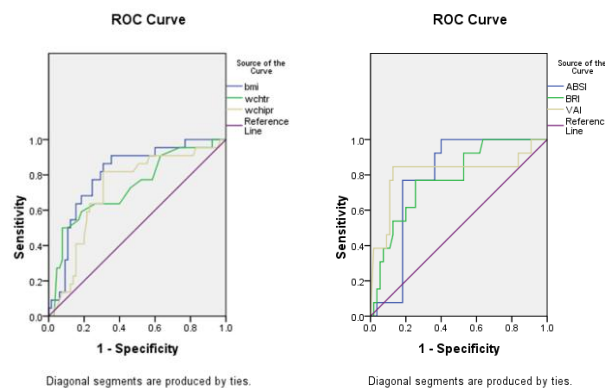


Figure 1: ROC Curves of BMI, WCHt R and WCHip R (left); ROC Curves of ABSI, BRI, and VAI (right)

The area under the ROC curve (AUC) of BMI, VAI, ABSI, BRI for predicting MS was 0.802 (0.701-0.902), 0.737 (0.633-0.841), 0.737 (0.620-0.855), 0.816 (0.698-0.934), respectively. Details are in Table 6.

Table 6: Area under the curve in obese children of all studied variables

Test Result Variables	Area	Std. Error	Sig.	Asymptotic 95% Confidence Interval	
				Lower Bound	Upper Bound
BMI	0.802	0.051	0.000	0.701	0.902
W/HtR	0.730	0.065	0.001	0.604	0.857
WHR	0.720	0.062	0.002	0.599	0.841
ABSI	0.737	0.053	0.001	0.633	0.841
BRI	0.737	0.060	0.001	0.620	0.855
VAI	0.816	0.060	0.000	0.698	0.934

Null hypothesis: true area = 0.5 & AUC: .90-1 = excellent (A), 80-.90 = good (B), .70-.80 = fair (C).

Discussion

Obesity is responsible for health burden in children and adolescents in Egypt and all over the world. BMI and WHtR are important indexes for predicting obesity and MS. However, Studies from South Africa reported that WHtR is the best predictor

of MS [19].

BMI and WHtR are limited in differentiating the lean mass from adipose tissue, and are not reflecting lipid accumulation in the circulating blood [20]. The specific mechanism causing MS has not been established, but, central obesity plays a critical role. It is hypothesized that an excess visceral adipocytes contributes to a pro inflammatory state and insulin resistance and involved with the development of MS [21], [22]. Ethnic and racial variation might need different cutoff points or use of different anthropometric measurement to diagnose obesity and MS [23].

In this study we evaluated and compared old and new anthropometric indices for detecting body adiposity .Seven anthropometric parameters: BMI, WC, WHtR, WHR, VAI, ABSI and BRI were studied. Based on our results all anthropometric parameters assessed, have been found to be significantly higher in obese subjects ($P < 0.001$) than controls which is in accordance with other studies [3].

MS cases showed a group of cardiovascular risk factors including central obesity (measured by high WC or high BMI), high systolic and diastolic pressure, high triglycerides, low HDL, high fasting glucose and high HOMA-IR. Previous studies showed similar results [3],[24].

Our results showed, that BMI and WHtR were predictive of obesity and MS. However, they did not reflect lipid accumulation in the circulating blood neither differentiating the lean mass from adipose tissue. Therefore, BMI and WHtR were not the best predictive indices of obesity and MS. These results were in accordance with those of other studies [25], [26].

In an attempt for searching of the best predictor of MS, we evaluated new anthropometric parameters of obesity namely; ABSI, BRI, and VAI. ABSI showed a significant ability to predict MS in this study, ABSI showed significant ability to predict MS. ABSI was shown to be a reliable index of fat accumulation as it encompasses waist circumference and BMI. Previous cross-sectional and prospective studies from Iran and china have reported ABSI to be a weak predictor of MS [27], [28], [29].

BRI had statistically significantly positive correlation with BMI, WHtR and HOMA-IR.

Our study showed that BRI was predictive of MS. However, this result remains controversial. One study showed its potential to identify MS and T2 DM, [30] whereas another study reported that BRI is not better than old obesity parameters in predicting MS [31].

Recently, visceral adiposity index (VAI) has shown promise as a marker of visceral fat dysfunction. The VAI is based on sex, body mass index (BMI), waist circumference (WC) and metabolic parameters

(serum triglycerides and [HDL-C] levels. Our study showed positive significant correlations of VAI with BMI, WC/ Ht, WC/Hip, SBP, DBP, SET, VFT, Liver size and HOMA-IR. The VAI showed a strong predictive ability of MS better than BMI and WHtR according to area under the curve (0.816, 0.802, 0.730, with $P = 0.000, 0.001, 0.002$, respectively). This result was in accordance with those of other studies [32], [33], [34], [28]. Yang et al., reported that VAI could be a surrogate index for obesity assessment [35]. Our study is strengthened by the fact that the VAI was established as an index of visceral fat dysfunction. Choi et al showed that the new obesity indices, ABSI and VAI have been found to be significantly associated with arterial stiffness [36]. MS in childhood predicts adult cardiovascular disease [37]. MS appears to accelerate the cardiovascular disease process [38]. Thus, the VAI is very suitable for our subjects. However, there are conflicting data in different populations and ethnicity groups, regarding MS [39]. Screening for obesity and MS should be incorporated in pediatric clinical care [40].

Limitations in the current study: This study was cross-sectional and there was limited ability to validate causality between the new markers and MS. Studied group was small, and might be insufficient to represent MS in children and adolescents.

In conclusion, the tested anthropometric parameters could predict body fat percent with relatively good power; however VAI, BMI and WHtR indices are more powerful predictors. Based on our findings, we suggest using the VAI and WHtR indices are better predictors of MS. Additional studies with larger obese group are necessary.

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