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Obesity indices may affect and reflect the blood glucose and lipid profile values

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Abstract

The aim of the present study was to observe the association between obesity indices, blood glucose, and lipid profiles as indicators for its levels. In a cross-sectional study, 491 Jordanian adults were included. Socio-demographic and anthropometric data were measured. Blood samples were collected and tested for fasting plasma glucose (FPG), insulin, and lipid profile. Obesity indices [Conicity Index (CI), Body adiposity index (BAI), Abdominal volume index (AVI), A Body Shape Index (ABSI), Body Roundness Index (BRI), and Weight-adjusted-waist index (WWI)] were calculated using standard formulas. AVI, BRI, and WWI had a higher impact on FPG and lipid profile. They explain 6.2%, 6.6%, and 4.1% of changes observed in FPG and explained 3.1%, 4.1%, and 3.5% of changes observed in total cholesterol (TC), respectively. In addition, they explain 9.9%, 9.7%, and 7.9% of changes in triglyceride (TG), 9.6%, 8.4%, and 6.0% of the variability observed in the high-density lipoprotein cholesterol (HDL), as well as 1%, 1.6%, and 1.5 of change in low-density lipoprotein cholesterol (LDL), and 7.0%, 8.6%, and 6.6% in LDL/HDL ratio; respectively (p<0.001). AVI, BRI, and WWI among obesity indices had the highest impact on blood glucose and lipid profile. The most affected tests were TG, HDL, and LDL / HDL ratio. These indices may be used as noninvasive rapid indicators for high glucose and lipid profiles.

Introduction

Over the past decade, obesity has become a major concern for health experts because of its association with chronic diseases such as Cardiovascular Disease (CVD) and Type 2 Diabetes (T2D).[1]According to the World Health Organization's definition of overweight and obesity, approximately two billion adults are affected by these conditions. Furthermore, the annual global death rate from CVD, a well-known consequence of obesity, is estimated to reach 23.6 million by 2030.[2] This concerning trend has prompted health professionals to focus on early detection of overweight and obesity, as well as strategies to prevent adverse outcomes in the general population.[3]

The most straightforward obesity indices are used widely for screening Metabolic Syndromes (MetS), such a hypertension, blood glucose, and hyperlipidemia, including Waist Circumference (WC), Body Mass Index (BMI), Waist-To-Hip Ratio (WHR), and Waist-To-Height Ratio (WHtR).[4,5] recent novel obesity indices have drawn attention in numerous research as predictors for different noncommunicable diseases, as they are simple, accurate, affordable, reliable, and easy techniques without intervention.[4,6] These obesity indices include the Abdominal Volume Index (AVI), A Body Shape Index (ABSI), Body Adiposity Index (BAI), Conicity Index (CI), Body Roundness Index (BRI), and Weight-Adjusted-Waist-Index (WWI).[7]

The BRI was correlated with MetS and was an effective indicator for its screening.[4] Also, CI was positively associated with T2D, hypertension, and dyslipidemia.[5] Many studies have confirmed the associations between ABSI, BRI, WC, BMI, and WHR and the risk of T2D and MetS.[4,5] However, there were discrepancies amongst research in the correlations between several anthropometric/obesity indices and the lipid profile, insulin, and fasting plasma glucose (FPG). Therefore, this study aimed to investigate the relationship between obesity indices, FPG, and lipid profiles and as indications of their levels.

Material and Methodology

Study population and ethical approval

in a cross-sectional study, four hundred and ninety-one adult males and females aged more than 18 were randomly selected and agreed to participate. Pregnant or lactating women, subjects with mental disorders, and subjects with incomplete anthropometric measurements and/or biochemical parameters were excluded. The Ethics Committee of Hashemite University approved the study, and all procedures were performed following the ethical standards of the Committee and with the Helsinki Declaration and its later amendments (The Institutional Board Review (IRB) committee reviewed and approved the survey protocol at The Hashemite University (No.7/13/2020/2021)). Participants who were willing and eligible provided written informed consent after a detailed explanation before participation.

Data collection, anthropometry, and biochemical measurements

An interview was conducted to collect data using a pre-designed questionnaire. The information included typical demographic data like age and gender, as well as social and lifestyle factors. Questions regarding chronic diseases and other health difficulties were also included, in addition to general health concerns. Anthropometric measurements were taken. The body weight and height were recorded to the nearest 0.1kg and 0.1cm, respectively, where they wore minimal clothing and bare feet. Anthropometric tape measuring the participant's WC while standing was used, using the RIEDER Body Measure tape (Inct. Bonus Kit, REIDHK, China). This measurement was performed on the horizontal plane midway between the lowest rib and the iliac crest. At the place in which the buttocks are at their most comprehensive, the Hip Circumference (HC) was measured over thin clothing. The measurements of both circumferences were adjusted

to the nearest 0.1 cm. The BMI was calculated according to Quetelet's formula, which is weight (kg) divided by the square of the height (m^2). WHR was calculated as WC (cm) divided by HC (cm). Based on WC, participants were divided into high or enlarged WC if their WC was ≥ 102 cm in men and ≥ 88 cm in women, and they were categorized as having average or acceptable WC if their WC was <102 cm and <88 cm, in men and women; respectively. WHR was recognized as high if WHR > 0.9 for men and WHR > 0.8 for women, which means the risk for chronic diseases is high.

After conducting face-to-face interviews, the researchers scheduled appointments to collect blood samples from participants for biochemical tests. Before drawing blood, participants were instructed to fast for 12 hours. The collected blood samples were centrifuged, separated, and stored at four °C to prepare them for analysis. Serum samples were subsequently analyzed using a compact clinical chemistry analyzer, specifically the Hitachi 902 auto-analyzer by Roche in Germany. The Roche/Hitachi 902 system employs colorimetry and absorbance measurement via the ion-selective electrode method to analyze serum samples. Additionally, the researchers calculated each participant's LDL/HDL ratio by dividing their LDL value by their HDL value. Furthermore, in this study, six obesity indices were considered and calculated: CI, BAI, AVI, ABSI, BRI, and WWI. Following are the lists of mathematical formulas that were used to calculate these obesity indices:

$$\text{CI}^{8} = \text{Waist circumference (m)}/\left(0.109 * \sqrt{\left(\frac{\text{Weight(kg)}}{\text{height(m)}}\right)}\right)$$

$$\text{BAI}^{9} = \frac{\text{Hip circumference (cm)}}{(Height\ (m))^{1.5}} - 18$$

$$\text{AVI}^{8} = (2(\text{WC (cm)})^2 + 0.7(\text{waist-hip})^2)/1000$$

$$\text{ABSI}^{10} = \text{Waist circumference (m)}/\ ((\text{Height (m)})^{0.5} * \left(\text{BMI}^{\frac{2}{3}}\right))$$

$$BRI^{11} = 364.2 - 365.5\sqrt{1 - \left(\frac{(Waist\ circumference(cm)/2\pi)^2}{(0.5*Height\ (cm))^2}\right)}$$

$$WWI^{12} = (\text{Waist circumference (cm)})/(\text{ Weight (kg) })^{0.5}$$

Statistical analysis

Frequency descriptive statistical tests were used to obtain the means and standard deviations for continuous variables and the frequencies and percentages for categorical variables to describe the sample. The association between obesity indices and biochemical markers was examined using Pearson correlation. The relationship between the biochemical tests and obesity indices was evaluated using linear regression coefficient analysis. Set to $p < 0.05$, the statistical significance was maintained. The Statistical Package for the Social Sciences (SPSS) version 25 (IBM, Chicago, IL, USA) was used for all statistical data analyses.

Results

A total of 491 adults were included in this study. As shown in Table 1, 70.1% of the participants were males, and 29.9% were females. Based on age, 40.3% of participants ranged from 20 to 34 years, 34.4% aged between 35 and 44, and 25.3% aged 45-65 years. Around half of the participants were of university education level (52.1%) and physically active (57.2%). Of the participants, 71.9% were married, and 40.7% were smokers. Almost all the participants were free of T2D, dyslipidemia, hypertension, obesity, and CVD.

Table 2 illustrates the anthropometric measurements of the participants. Participants' mean weight was 78.53±16.04 kg, while the mean BMI was 27.62 ± 5.40 kg/m^2. In addition, the participants had a mean of 96.18±14.94 cm WC, 105.44±10.66 cm HC, and 0.91±0.11 WHR. Based on BMI classification, almost two-thirds of the participants were overweight or obese

(36.9% and 27.9%, respectively). On the other hand, based on WC and WHR classification, 66.2% and 85.5% of participants were in high-risk classification, respectively.

The Pearson correlations between biochemical parameters and obesity indices are shown in Table 3. There were significantly low correlations between FPG levels and obesity indices, with R-values ranging from 0.097 (p=0.032) for BAI to 0.317 (p <0.001) for AVI. TC levels had significant weak correlations with obesity indices ranging from 0.099 (for ABSI) to 0.201 (for BRI). Regarding blood TG and obesity indices, there was a significant moderate correlation between TG levels and BRI (r=0.311, p <0.001) and AVI (r=0.423, p <0.001). While there were weak correlations with CI (r=0.283, p <0.001), ABSI (r=0.201, p <0.001), WWI (r=0.282, p <0.001) and BAI (r=0.090, p=0.046). There was a significant negative correlation between obesity indices and blood HDL levels. HDL level had a moderate inverse correlation with AVI r= -0.371 (p <0.001), while it had a negative, weak correlation with the rest of the obesity indices. On the other hand, LDL levels and LDL/HDL ratio had a significant positive weak correlation with the obesity indices (p <0.001).

The linear regression analysis results are shown in Table 4. The CI explains 3.7% of the variability observed in FPG levels, where one unit increase in it results in a 54.48±12.59 mg/dl increase in FPG level (p <0.001). While AVI explains 6.2% and BRI explains 6.6% of the change in FPG. However, an increase in AVI and BRI by one unit results in a 1.38±0.24 mg/dl and an 8.39±1.43 mg/dl increase in FPG level, respectively (p<0.001). Also, WWI increasing by one unit significantly causes a 7.05 ± 1.53 mg/dl increase in FPG level and explains 4.1% of changes observed. For TC levels, CI, BAI, and ABSI collectively explain 4.8% of the change observed at the TC level. Conversely, AVI alone explains 3.1% of the variation in TC levels, where one unit increase in AVI causes a 1.17±0.30 mg/dl increase in TC level (p<0.001). For BRI, it increased by one unit, leading to a 7.92±1.74 mg/dl increase in TC level, which explains

4.1% of the observed change (p<0.001). While WWI explains 3.5% of the change in TC levels, its increase by one unit caused the TC level to increase significantly by 7.85±1.86 mg/dl. When setting the TG level as independent, CI was found to explain significantly 8.0% of observed change, and its increase by one unit led to a 278.66 ± 42.64 mg/dl significant increase in TG levels. The AVI was found to explain 9.9% of the changes observed in the TG level, while its increase by one unit caused an increase of 6.06 ± 0.83 mg/dl in the TG level. Regarding BRI and WWI, it was found that 9.7% and 7.9% of the change observed in TG levels can be explained by them, respectively, where one unit increase in BRI causes a 35.20 ± 4.86 mg/dl increase in TG level, and one unit increase in WWI causes a 33.84 ± 5.21 mg/dl increase in TG level (p<0.001). For HDL, the CI, AVI, BRI, and WWI, their increasing by one unit resulted in a reduction in HDL level by -26.07 ± 4.23 mg/dl, -0.59 ± 0.08 mg/dl, -3.23 ± 0.48 mg/dl, and -2.90 ± 0.52 mg/dl respectively (p<0.001). In addition, the CI, AVI, BRI, and WWI were found to explain significantly 7.2%, 9.6%, 8.4%, and 6.0% of the variability observed in the HDL level, respectively (p<0.05). The obesity indices were found to have little impact on LDL levels, whereas BRI and WWI had the highest r-square values. BRI explains 1.6% of the changes in LDL level, and its increase by one unit led to a 4.15 ± 1.46 mg/dl increase in LDL level. While WWI explains 1.5% of the changes in LDL level, its increase by one unit led to a 4.16 ± 1.55 mg/dl increase in LDL level. LDL/HDL ratio increased by 0.39 ± 0.06, 0.06 ± 0.01, 0.36 ± 0.06, 2.67 ± 0.51, and 3.20 ± 0.68 as a result of one unit increase in BRI, AVI, WWI, CI and BAI; respectively (p<0.001). They explain 8.6%, 7.0%, 6.6%, 5.4%, and 4.3% of the variability observed in the LDL/HDL ratio. There is no significant data about insulin.

Discussion

Obesity induces several biochemical parameters such as lipids profile, blood pressure, inflammatory indices, and blood glucose levels, which increase the risk of non-communicable diseases such as MetS, ischemic stroke, CVD, and T2D Recently, studies have tried to find which obesity indices most closely correlate with the earlier parameters to aid in preventing chronic diseases. In the current study, the BRI was highly positively correlated with the FPG level, and the regression model of BRI explained 6.6% of the changeability detected in the FPG level.[13] Moreover, BRI was positively correlated with TG level and negatively correlated with HDL level.[14] These findings were consistent with the findings of previous studies, such as Nkwana and colleagues, who found that BRI was significantly associated with increased TG and blood glucose levels. [15] However, the BRI is a novel central obesity index estimated using height and WC.[5] Stefanescu and his team indicated that measuring central obesity, especially the BRI, could help identify who is at high risk for T2D and CVD among disease-free obese adults.[16] Moreover, they found that a unit increase in BRI was associated with a 2.43-fold increase in odds of MetS in males and a 1.89-fold increased odds in females.[16] However, Zaid and colleagues found that when identifying hypertriglyceridemia, several anthropometric/metabolic indicators are more predictive than any other type of plasma lipid.[17] While ABSI could not identify dyslipidemia, BRI's ability to predict the condition was on a level with, if not better, that of the traditional obesity indicators. Nosrati-Oskouie and colleagues found that TC showed a statistically significant ($p<0.05$) positive correlation with BMI ($r=0.207$), WC ($r=0.214$), and BRI ($r=0.237$).[18] In contrast, TG showed a statistically significant positive correlation with BRI ($r=0.242$) and a highly significant positive correlation with BMI ($r=0.311$).[14] On the other hand, LDL showed a positive correlation with WC ($r=0.25$), ABSI ($r=0.21$), and BRI ($r=0.25$) in healthy middle-aged adults.[19]

The present findings indicated no correlation between obesity indices and insulin, similar to the findings of Nkwana and colleagues, while Mameli *et al*. found a significant association between ABSI and HOMA-IR.[20] Also, contrary to the present insulin findings, Peterson and colleagues approved that the indices of insulin resistance were correlated significantly with BMI and visceral adiposity indices (WC, ABSI, and BRI) but not with the fat mass percentage. Including MetS when discussing lipid profiles is essential.[21] It has been found that BRI, CI, and AVI have a clinical approach to identifying MetS and its components, as well as the efficacy of these indices in identifying MetS affected by gender.[22]

In the present study, the AVI was positively correlated with FPG level and explained by 6.1% of the detected changeability of FPG levels. In recent studies, the AVI has been used as an essential anthropometric parameter to predict increases in FPG levels. In agreement, Zhang and colleagues concluded that AVI could identify the occurrence of T2D in Chinese women. Moreover, Wang *et al*. and Wu *et al*. have found that AVI was positively correlated with elevated blood glucose among adult males and females.[23] These prior studies showed that AVI could be a sensitive indicator of abdominal obesity-related metabolic abnormalities, including glucose levels.[4] Furthermore, Liu *et al.* used computed tomography to assess the changes in abdominal fat during a 10-year follow-up database. They proposed that an increase in abdominal fat showed increased glucose levels and the development of T2D BRI and AVI have been used as obesity indices to predict metabolic disorders in many studies.[8,24]

On the contrary, Gowda *et al.* found that AVI is not a reliable marker in diabetic patients to predict the degree of glycemic control and microalbuminuria.[8] Moreover, Endukuru and colleagues found that BRI showed a superior predictive ability to detect hyperglycemia in both genders.[22] The BRI's ability to detect other MetS components, such as central obesity, high TG,

low HDL-C, and raised BP, was equivalent to but not superior to those of the other novel anthropometric indices.[25]

In the present findings, the CI explains 3.7% of the variability observed in FPG levels, where one unit increase in it results in a 54.48 ± 12.59 mg/dl increase in FPG level.[26] In accordance, Donkor and colleagues found that CI was positively and significantly associated with FPG (r=0.21, *p*=0.005).[27] The findings of the study by Sanchez-Viveros on older Mexican adults concluded that CI had a stronger relationship with T2D than BMI and WC.[28] Additionally, Sanchez and colleagues indicated that BRI and CI were associated with dyslipidemia. Furthermore, Quaye and colleagues found that AVI and CI had larger Areas Under the Curves (AUCs) in females, while BMI remained the superior index in males.[29] While BMI and WC remained functional parameters, they did not help predict MetS and its components in the female population.[4] Moreover, CI was significant and positively correlated with obesity, muscle, and diastolic blood pressure, and also correlated with blood glucose and cholesterol level.[30]

In a large prospective study of an older Chinese population with a 10-year follow-up cohort, they have been suggested that WWI was significantly associated with an increased TG level and decreased blood glucose level, which is consistent with the current study, WWI is highly correlated with TG level. WWI explained 7.9 % of the detected changeability of TG level, as one unit increase in WWI resulted in a TG increase of 33.84± 5.21. WWI, which is a novel obesity index developed in recent years, has a good predictive ability for cardiometabolic morbidity and mortality in the Korean population.[12] Recently, Li *et al*. reported in a cohort study that a significant association exists between the highest WWI category and the increased risk of TG and glucose levels.[31] Moreover, Yu and colleagues found that increasing WWI was significantly associated with a higher incidence of newly diagnosed T2D among rural Chinese adults.[32]

In the present findings, although the LDL/HDL ratio had a significant positive weak correlation with the obesity indices (p <0.001), it increased by 0.39±0.06, 0.06±0.01, 0.36±0.06, 2.67±0.51, and 3.20±0.68 as a result of one unit increase in BRI, AVI, WWI, CI, and BAI; respectively (p<0.001). They explain 8.6%, 7.0%, 6.6%, 5.4%, and 4.3% of the variability observed in the LDL/HDL ratio. No research covered the ability of obesity indices to predict the LDL/HDL ratio.

Conversely, our research suggests that the LDL/HDL cholesterol ratio is a more effective predictor of cardiovascular and cerebrovascular metabolic-related disorders than a single lipoprotein (using LDL only or HDL only). It can simultaneously assess LDL and HDL cholesterol levels . Furthermore, the LDL/HDL cholesterol ratio has a superior predictive value compared to other lipoproteins. It can independently forecast the onset of non-Alcoholic Fatty Liver Disease (AFLD) in Chinese non-obese individuals with normal lipid profiles.[33]

Lam and colleagues (2015) studied the relationship between BMI, WC, WHR, WHtR, BAI, and CVD risk factors in the local adult population in Singapore.[34] They found that when compared to BMI, WC, and WHtR, BAI consistently had a lower correlation; however, these differences were frequently negligible and had overlapping 95% confidence ranges. In contrast to WC and WHtR, BAI did not raise the probabilities of CVD risk variables after controlling for BMI (for all but hypertension and poor HDL).[34]

The obesity indicators are affordable and easy to use. It can be applied to medical and health institutions at all levels, particularly when medical standards are lacking or large-scale data research is required.

Strengths and limitations

The current study has some strengths and limitations. To the best of our knowledge, this is the first study to use six different obesity indices to diagnose the metabolic disorder, including lipid profile and blood glucose level. On the other hand, This study had various limitations, such as the cross-sectional nature of the current research, and a causal relationship could not be achieved. The sample size was relatively small. The present study has not taken into consideration several characteristics that are linked to the progression of T2D, including dietary factors, physical activity, and genetic factors. To answer these questions, more research needs to be done

Conclusions

In conclusion, obesity indices may affect blood sugar and lipid profile levels. The highest impact was for AVI, BRI, and WWI indices. TG, HDL, and LDL / HDL ratios were the most affected tests. Studies to examine the useability of these indices as indicators for high sugar and lipid profiles are recommended and needed as they are not invasive rapid tools that will help in the early detection of T2D and CVD.

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Table 1. General characteristics (n=491).

Variables	n (%)
Gender	
Male	344 (70.1)
Female	147 (29.9)
Age (years)	
20-34	198 (40.3)
35-44	169 (34.4)
45-65	124 (25.3)
Education level	
School education level	235 (47.9)
University education level	256 (52.1)
Marital status	
Married	353 (71.9)
Single	132 (26.9)
Divorced	4 (0.8)
Widow	2 (0.4)
Total physical activity classification	
Physically active	281 (57.2)
Physically inactive	210 (42.8)
Smoking	
Yes	200 (40.7)
No	162 (33.0)
Ex-smoker	43 (8.8)
Passive smoking	86 (17.5)
Diseases history	
Diabetes mellitus	
Yes	28 (5.7)
No	463 (94.3)
Dyslipidemia	
Yes	28 (5.7)
No	463 (94.3)
Hypertension	
Yes	27 (5.5)
No	464 (94.5)
Obesity	
Yes	41 (8.4)
No	450 (91.6)
Cardiovascular diseases	
Yes	12 (2.4)
No	479 (97.6)

Table 2. Anthropometric measurements (n=491).

Variables	Mean ± SD
Height (m)	1.69 ± 0.09
Weight (kg)	78.53 ± 16.04
Waist circumference (cm)	96.18 ± 14.94
Hip circumference (cm)	105.44 ± 10.66
Body mass index (kg/m^2)	27.62 ± 5.40
Waist to Hip ratio	0.91 ± 0.11
n (%)	
Body mass index categories	
Underweight	9 (1.8)
Normal weight	164 (33.4)
Overweight	181 (36.9)
Obese	137 (27.9)
Waist Circumference categories	
High	325 (66.2)
Acceptable	166 (33.8)
Body Waist to Hip Ratio categories	
High	420 (85.5)
Acceptable	71 (14.5)

Table 3: The Pearson correlation between biochemical parameters and obesity indices (n=491).

Variables		CI	ABSI	BRI	WWI	BAI	AVI
FPG	Pearson r	0.192**	0.118**	0.257**	0.203**	0.097*	0.317**
	p-value	**<0.001**	**0.009**	**<0.001**	**<0.001**	**0.032**	**<0.001**
Insulin	Pearson r	0.063	0.059	0.010	0.021	-0.013	0.197**
	p-value	0.374	0.404	0.891	0.768	0.851	**0.005**
TC	Pearson r	0.157**	0.099*	0.201**	0.188**	0.112*	0.186**
	p-value	**<0.001**	**0.029**	**<0.001**	**<0.001**	**0.013**	**<0.001**
TG	Pearson r	0.283**	0.201**	0.311**	0.282**	0.090*	0.423**
	p-value	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.046**	**<0.001**
HDL	Pearson r	-0.269**	-0.185**	-0.289**	-0.244**	-0.139**	-0.371**
	p-value	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.002**	**<0.001**
LDL	Pearson r	0.091*	0.049	0.128**	0.121**	0.115*	0.117*
	p-value	**0.045**	0.279	**0.005**	**0.007**	**0.011**	**0.010**
LDL/HDL ratio	Pearson r	0.232**	0.146**	0.293**	0.256**	0.208**	0.322**
	p-value	**<0.001**	**0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**

CI: Conicity Index; ABSI: A Body Shape Index; BRI: Body Roundness Index; WWI: Weight-adjusted-waist index; BAI: Body adiposity index; AVI: Abdominal volume index; HDL: High-density lipoprotein cholesterol; LDL: Low-density lipoprotein cholesterol; FPG: fasting plasma glucose; TC: total cholesterol; TG: triglyceride.
**Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 4. Liner regression association between biochemical parameters and obesity indices.

Indices	β	Std. Error	t	*p*-value*	Change Statistics		
					R Square Change	% of Change	*p*-value*
Fasting plasma glucose (FPG)							
Conicity Index (CI)	54.48	12.59	4.33	<0.001	0.037	3.7	**<0.001**
Body adiposity index (BAI)	36.57	16.98	2.15	0.032	0.009	0.9	**0.032**
Abdominal volume index (AVI)	1.38	0.24	5.66	<0.001	0.062	6.2	**<0.001**
A Body Shape Index (ABSI)	567.54	215.29	2.64	0.009	0.014	1.4	**0.009**
Body Roundness Index (BRI)	8.39	1.43	5.88	<0.001	0.066	6.6	**<0.001**
Weight-adjusted-waist index (WWI)	7.05	1.53	4.59	<0.001	0.041	4.1	**<0.001**
Insulin							
Conicity Index (CI)	20.25	22.71	0.89	0.374	0.004	0.4	0.374
Body adiposity index (BAI)	-5.10	27.07	-0.19	0.851	0.000	0.0	0.851
Abdominal volume index (AVI)	0.40	0.44	0.90	0.369	0.004	0.4	0.369
A Body Shape Index (ABSI)	302.91	362.25	0.84	0.404	0.004	0.4	0.404
Body Roundness Index (BRI)	0.34	2.50	0.14	0.891	0.000	0.0	0.891
Weight-adjusted-waist index (WWI)	0.79	2.67	0.30	0.768	0.000	0.0	0.768
Total cholesterol (TC)							
Conicity Index (CI)	53.86	15.28	3.53	<0.001	0.025	2.5	**<0.001**
Body adiposity index (BAI)	50.93	20.45	2.49	0.013	0.013	1.3	**0.013**
Abdominal volume index (AVI)	1.17	0.30	3.94	<0.001	0.031	3.1	**<0.001**
A Body Shape Index (ABSI)	571.40	260.24	2.20	0.029	0.010	1.0	**0.029**
Body Roundness Index (BRI)	7.92	1.74	4.54	<0.001	0.041	4.1	**<0.001**
Weight-adjusted-waist index (WWI)	7.85	1.86	4.23	<0.001	0.035	3.5	**<0.001**
Triglycerides (TG)							
Conicity Index (CI)	278.66	42.64	6.53	<0.001	0.080	8.0	**<0.001**
Body adiposity index (BAI)	118.04	58.91	2.00	0.046	0.008	0.8	**0.046**
Abdominal volume index (AVI)	6.06	0.83	7.35	<0.001	0.099	9.9	**<0.001**
A Body Shape Index (ABSI)	3348.43	736.14	4.55	<0.001	0.041	4.1	**<0.001**
Body Roundness Index (BRI)	35.20	4.86	7.24	<0.001	0.097	9.7	**<0.001**
Weight-adjusted-waist index (WWI)	33.84	5.21	6.49	<0.001	0.079	7.9	**<0.001**
High-density lipoprotein cholesterol (HDL)							
Conicity Index (CI)	-26.07	4.23	-6.16	<0.001	0.072	7.2	**<0.001**
Body adiposity index (BAI)	-17.98	5.78	-3.11	0.002	0.019	1.9	**0.002**
Abdominal volume index (AVI)	-0.59	0.08	-7.19	<0.001	0.096	9.6	**<0.001**
A Body Shape Index (ABSI)	-302.87	72.94	-4.15	<0.001	0.034	3.4	**<0.001**
Body Roundness Index (BRI)	-3.23	0.48	-6.68	<0.001	0.084	8.4	**<0.001**
Weight-adjusted-waist index (WWI)	-2.90	0.52	-5.58	<0.001	0.060	6.0	**<0.001**
Low-density lipoprotein cholesterol (LDL)							
Conicity Index (CI)	25.59	12.71	2.01	0.045	0.008	0.8	**0.045**
Body adiposity index (BAI)	42.94	16.85	2.55	0.011	0.013	1.3	**0.011**
Abdominal volume index (AVI)	0.55	0.25	2.23	0.026	0.010	1.0	**0.026**
A Body Shape Index (ABSI)	233.65	215.41	1.08	0.279	0.002	0.2	0.279
Body Roundness Index (BRI)	4.15	1.46	2.85	0.005	0.016	1.6	**0.005**

Weight-adjusted-waist index (WWI)	4.16	1.55	2.69	0.007	0.015	1.5	**0.007**
LDL/HDL ratio							
Conicity Index (CI)	2.67	0.51	5.26	<0.001	0.054	5.4	**<0.001**
Body adiposity index (BAI)	3.20	0.68	4.71	<0.001	0.043	4.3	**<0.001**
Abdominal volume index (AVI)	0.06	0.01	6.05	<0.001	0.070	7.0	**<0.001**
A Body Shape Index (ABSI)	28.57	8.73	3.27	0.001	0.021	2.1	**0.001**
Body Roundness Index (BRI)	0.39	0.06	6.76	<0.001	0.086	8.6	**<0.001**
Weight-adjusted-waist index (WWI)	0.36	0.06	5.86	<0.001	0.066	6.6	**<0.001**

*The $p< 0.05$ level (2-tailed) is considered statistically significant.