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Research Article

Evaluation of Visceral adiposity index as a predictor of metabolic syndrome and insulin resistance among Korean adults

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Abstract

Background/Objectives: The visceral adiposity index (VAI) is an indicator that reflects the distribution of visceral fat and has been associated with increased risk of cardiometabolic disorders. This study aimed to evaluate VAI in predicting metabolic syndrome and insulin resistance among the Korean population.

Methods/Statistical analysis: This study was a retrospective cross-sectional study and was performed in 23,356 Korean adults aged >20 years. The criteria for diagnosis of metabolic syndrome were defined according to the National Cholesterol Education Program (NCEP) Adult Treatment Panel (ATP III). Insulin resistance was diagnosed via a homeostasis model assessment of insulin sensitivity (HOMA-IR) and was determined as a HOMA-IR value ≥3.0. Furthermore, anthropometric parameters including waist circumference (WC), and waist-to-height ratio (WHtR), body mass index (BMI) were also evaluated.

Findings: In both genders, the area under the curve (AUC) for predicting metabolic syndrome was higher for VAI than for other anthropometric and biochemical parameters. The AUC values for VAI were 0.888, 0.859, and 0.932 for all subjects, men, and women, respectively. The optimal cutoff of VAI for predicting metabolic syndrome, which was estimated from the ROC curve, was 1.84 for all subjects. The highest and lowest AUCs for predicting insulin resistance were observed for WHtR and VAI, respectively. The AUC values for VAI were 0.705, 0.659, and 0.778 for all subjects, men, and women, respectively. After controlling for relevant variables, VAI showed a significant correlation with metabolic syndrome and insulin resistance, regardless of anthropometric indices or biochemical metabolic syndrome risk factors.

Improvements/Applications: VAI was a stronger predictor of metabolic syndrome in the Korean population, especially in comparison to WC, BMI, and WHtR. However, the ability of VAI to predict insulin resistance was lower than that of WHtR.

Keywords: visceral adiposity index, metabolic syndrome, insulin resistance, Korean population, anthropometric parameters

1. Introduction

Excessive accumulation of visceral fat increases the risk of metabolic complications such as atherosclerosis, and subclinical inflammation, as well as insulin resistance, hypertension[1]. It is also an independent risk factor for cardiovascular disease and type 2 diabetes, leading to increased economic burden and a poor quality of life[2].

In many studies, the general use of imaging techniques such as magnetic resonance imaging (MRI) and computed tomography (CT) for direct measurements of visceral fat is challenging because of their high cost, time burden, and risk of radiation exposure[3-4]. In large-scale epidemiological studies, the usefulness of waist circumference (WC) measurements as a proxy for assessing visceral fat has been verified[5-6]. However, WC use in clinical diagnosis is limited because WC measurement alone makes it difficult to distinguish between subcutaneous and visceral fat[7]. This implies the need for an easy and precise measurement for the indirect evaluation of visceral fat accumulation.

Amato et al.[8] proposed a visceral adiposity index (VAI) to evaluate visceral adipose tissue dysfunction; the index is based on both anthropometric measures [body mass index (BMI) and WC] and biochemical indices [high-density lipoprotein (HDL) cholesterol and triglycerides (TG)]. According to their study, VAI was effectively used to assess visceral adiposity dysfunction and was independently related to cardiovascular and cerebrovascular disease risk. Additionally, they found that high VAI was associated with risk factors for metabolic syndrome such as low HDL-cholesterol, hypertension, fasting blood glucose, and TG. In Chinese subjects, VAI exhibited an outstanding ability to predict diabetes compared to BMI, WC, and waist to height ratio (WHtR); the risk of diabetes was 2.55 times higher in those with the highest VAI compared to individuals with the lowest VAI[9]. However, some studies have reported that, although VAI could be used as a screening tool to identify the risk of diabetes, its effectiveness did not exceed that of WHtR, and it was not a more powerful indicator of visceral fat changes than BMI or WC[10-11]. Disagreement among studies appears to vary according to the characteristics of the subjects, genetic susceptibility, study period, and geographic location[12].

VAI was first developed based on Caucasian subjects[8], but its adequacy as an alternative indicator of visceral fat has not yet been studied in diverse ethnic groups. Therefore, here we compared the efficacy of VAI to that of WC, BMI, and WHtR as an index predicting metabolic syndrome and insulin resistance in Korean population

2. Materials and Methods

2.1. Participants in the Research

This cross-sectional study was conducted with the approval of the institutional review board of the general hospital in the Gyeong-gi province (Approval Numbers: DMC 2019-02-005). Because the data was accessed retrospectively, the requirement for prior consent was waived. Data was obtained from a clinical data retrieval system in the health examination center of our institution. However, patient records were anonymized and de-identified prior to the analysis.

The subjects of this study were adult men and women aged 20 years or older who received a medical examination at a general hospital in Gyeong-gi province in Korea between January 2014 and December 2016. Among the

24,560 eligible subjects, the following 1204 were excluded based on the following criteria: those with a history of hypertension or diabetes; those diagnosed with either hypertension or diabetes and were taking a corresponding medication; those taking lipid-lowering drugs; and those with missing data values. Thus, 23,356 subjects (14,299 men and 9,057 women) were included in the final analysis.

2.2. Measurements

2.2.1. Anthropometry and blood pressure measurement

The height and weight of the subjects were measured using an InBody720 body composition analyzer (Biospace Co., Seoul, Korea). BMI was calculated by dividing weight (kg) by the squared of the height (m). WC (in cm) was measured horizontally between the lower part of the rib and the upper part of the iliac crest while the subject was exhaling. Hip circumference (in cm) was measured around the greater trochanter at the point of maximal protrusion. Waist to hip ratio (WHR) was calculated as WC (cm)/ hip circumference (cm), and WHtR was calculated as WC (cm)/height (cm). VAI was calculated according to the verified formula below[8].

Male VAI = (WC/[39.68 +(1.88×BMI)])×(TG/1.03)×(1.31/HDL−cholesterol)

Female VAI = (WC/[36.58 +(1.89×BMI)])×(TG/0.81)×(1.52/HDL−cholesterol)

Resting systolic and diastolic blood pressure were measured twice in a two-minute interval using a mercury sphygmomanometer (W.A. Baum Co. Inc., Copiague, NY, USA), and the mean value was calculated.

2.2.2. Diagnostic criteria and blood analysis

The criteria for diagnosis of metabolic syndrome were defined in Adult Treatment Panel (ATP III) of National Cholesterol Education Program (NCEP)[13]. Abnormalities in the components of metabolic syndrome were defined as follows: systolic blood pressure ≥130 mmHg or diastolic blood pressure ≥85 mmHg, fasting blood glucose ≥110 mg/dL, serum TG ≥150 mg/dL, serum HDL-cholesterol <40 mg/dL in men and <50 mg/dL in women. The Asia-Pacific standard was used to define an abnormal WC as follows: ≥90 cm for men and ≥80 cm for women[14]. When three or more of these five items were abnormal, the subject was diagnosed with metabolic syndrome.

Blood of the subjects was collected from the median antebrachial vein after a 12-h fasting period, and then serum was isolated from the blood and analyzed. Total cholesterol, TG, HDL- cholesterol, low-density lipoprotein cholesterol (LDL-C), fasting blood glucose, uric acid, and high-sensitivity C-reactive protein (hs-CRP) were measured using a TBA-200FR NEO device (Toshiba, Tokyo, Japan). Hemoglobin A1c (HbA1c) was measured by high performance liquid chromatography (HPLC) using a Variant II (Bio-Rad Laboratories, Hercules, CA, USA). Insulin was measured by electrochemiluminescence immunoassay (ECLIA) using a Roche Modular Analytics E170 (Roche Diagnostics, Mannheim, Germany). As an indirect measure of insulin resistance, the homeostasis model assessment of insulin sensitivity (HOMA-IR) was employed, calculated as fasting insulin concentration (μIU/mL) × fasting blood glucose (mmol/L)/22.5[15]. Insulin resistance was diagnosed as an HOMA-IR value ≥3.0[16].

2.2.3. Statistical analysis

We performed independent sample t-tests to assess differences in gender-specific anthropometric and biochemical variables, and used one-way analysis of variance (ANOVA) to determine the difference in VAI according to the metabolic syndrome risk factors. When the ANOVA results showed a significant difference, we applied the Bonferroni post-hoc test for multiple comparisons. To verify the correlations between VAI and risk factors of metabolic syndrome, a correlation analysis was performed.

In addition, areas under the receiver operating characteristic (ROC) curve were calculated to determine whether VAI, WC, BMI, and WHtR were accurate predictors of metabolic syndrome and insulin resistance. Sensitivity and

specificity were evaluated, and the point matching their largest sum was selected as the optimal cutoff. A sex-stratified binary logistic regression analysis was performed to analyze the risk of metabolic syndrome and insulin resistance based on the interquartile ranges of VAI.

Statistical analyses were performed using SPSS version 24.0 (IBM, Armonk, NY, USA), and two-sided P-values <0.05 were considered statistically significant.

3. Results

The general characteristics of the study subjects are shown in Table 1. The average age of the subjects was 45.68±11.05 and 44.87±11.61 years for men and women, respectively. The average BMIs were 24.65±2.97 kg/m^2 and 22.53±3.24 kg/m^2 for men and women, respectively. The average WHtRs were 0.48±0.04 and 0.46±0.05 for men and women, respectively. The average VAIs were 1.67±1.38 1.23±1.08 for men and women, respectively, with a significant difference between the two genders. The average systolic and diastolic blood pressure, lipid profile, glucose, HbA1c, insulin, HOMA-IR, uric acid, and hs-CRP were different between the two genders (P<0.001). The prevalence of metabolic syndrome was 11.6% in men and 6.9% in women; whereas the prevalence of insulin resistance was 5.3% in men and 2.1% in women.

Table 1: Anthropometric and biochemical characteristics of the study subjects

Variables	Men (n=14,299)	Women (n=9,057)	Total (n=23,356)	P-value
Age (years)	45.68±11.05	44.87±11.61	45.37±11.27	<.001
Height (cm)	171.43±6.38	158.77±5.94	166.52±8.76	<.001
Weight (kg)	72.54±10.29	56.71±8.08	66.40±12.23	<.001
BMI (kg/m^2)	24.65±2.97	22.53±3.24	23.83±3.25	<.001
WC (cm)	83.70±7.67	72.92±8.01	79.52±9.41	<.001
WHR	0.88±0.10	0.80±0.11	0.85±0.11	<.001
WHtR	0.48±0.04	0.46±0.05	0.47±0.05	<.001
VAI	1.67±1.38	1.23±1.08	1.50±1.29	<.001
SBP (mmHg)	112.68±13.02	104.44±14.24	109.49±14.09	<.001
DBP (mmHg)	72.92±9.97	66.66±9.85	70.49±10.38	<.001
TC (mg/dL)	195.29±34.08	189.30±33.53	192.97±33.99	<.001
TG (mg/dL)	144.65±95.06	90.52±54.49	123.67±86.41	<.001
HDL-C (mg/dL)	51.98±11.97	62.33±13.91	55.99±13.72	<.001
LDL-C (mg/dL)	122.16±30.65	112.68±30.58	118.47±30.97	<.001
Glucose (mg/dL)	92.39±20.24	86.99±14.31	90.29±18.36	<.001
HbA1c (%)	5.64±0.76	5.51±0.57	5.59±0.70	<.001
Insulin (μU/mL)	5.20±3.26	4.52±2.79	4.88±3.07	<.001
HOMA-IR	1.24±0.92	1.02±0.76	1.14±0.85	<.001
Uric acid (mg/dL)	6.05±1.28	4.22±0.95	5.34±1.46	<.001
hs-CRP (mg/dL)	0.16±0.46	0.12±0.30	0.15±0.41	<.001
MetS, n (%)	1,658 (11.6)	622 (6.9)	2,280 (9.8)	<.001
IR, n (%)	752 (5.3)	194 (2.1)	946 (4.1)	<.001

Values are presented as means ± standard deviations. Abbreviations: BMI=body mass index, WC=waist circumference, WHR=waist to hip ratio, WHtR=waist to height ratio, VAI=visceral adiposity index, SBP=systolic blood pressure, DBP=diastolic blood pressure, TC=total cholesterol, TG=triglyceride, HDL-C=high density lipoprotein cholesterol, LDL-C=low density lipoprotein cholesterol, HbA1c=hemoglobin A1c, HOMA-IR= homeostasis model assessment for insulin resistance, hs-CRP=high sensitivity C-reactive protein, MetS= metabolic syndrome, IR=insulin resistance.

Regardless of age and gender, VAI exhibited a significant correlation with all metabolic parameters except hs-CRP (all $p<0.001$). BMI, WC, WHtR, systolic and diastolic blood pressure, lipid profile, glucose, HbA1c, insulin, HOMA-IR, and uric acid were found to be significantly associated with VAI. Notably, TGs were highly correlated with VAI ($r=0.938$, $p<0.001$) (Table 2). In addition, VAI values increased significantly as the number of components of metabolic syndrome increased ($p<0.001$) (Figure 1).

Table 2: Correlations between the VAI and metabolic indicators

Metabolic indicators	VAI	
	Correlation coefficient (r)	P-value
BMI (kg/m^2)	0.275	<.001
WC (cm)	0.322	<.001
WHR	0.263	<.001
WHtR	0.333	<.001
SBP (mmHg)	0.104	<.001
DBP (mmHg)	0.115	<.001
TC (mg/dL)	0.159	<.001
TG (mg/dL)	0.938	<.001
HDL-C (mg/dL)	-0.522	<.001
LDL-C (mg/dL)	0.081	<.001
Glucose (mg/dL)	0.161	<.001
HbA1c (%)	0.150	<.001
Insulin (μU/mL)	0.350	<.001
HOMA-IR	0.348	<.001
Uric acid (mg/dL)	0.187	<.001
hs-CRP (mg/dL)	-0.002	0.919

Adjusted for age and gender. Abbreviations: See Table 1.

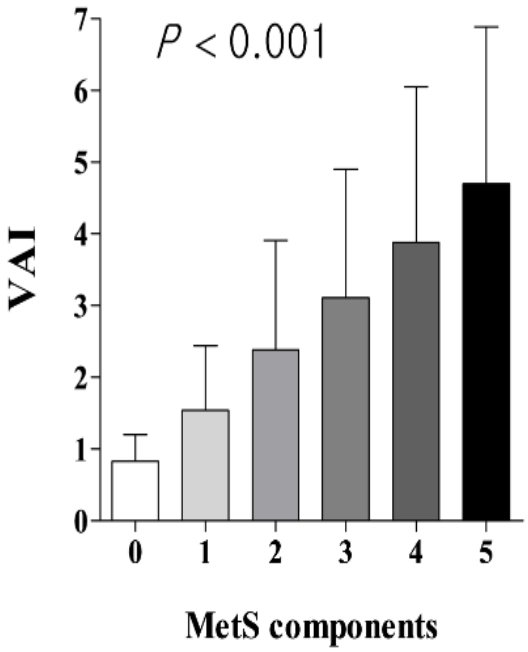

Figure 1. VAI values according to components of metabolic syndrome

VAI= visceral adiposity index, MetS=metabolic syndrome.

Table 3 shows the optimal cutoff point for each anthropometric parameter in predicting metabolic syndrome among Korean adults. In both genders, the highest AUC (area under the curve) was observed for VAI, and the lowest for BMI. The AUC values for VAI were 0.888, 0.859, and 0.932 for all subjects, men, and women, respectively. The optimal cutoff of VAI for predicting metabolic syndrome, estimated from the ROC curve, was 1.84 for all subjects.

Table 3: Optimal cutoff point of indicators for predicting metabolic syndrome

		AUC (95% CI)	Cutoff value	Sensitivity	Specificity
VAI	Men	0.859 (0.850-0.867)	1.836	0.834	0.756
	Women	0.932 (0.923-0.942)	1.840	0.846	0.879
	Total	0.888 (0.882-0.895)	1.836	0.837	0.805
WC (cm)	Men	0.851 (0.842-0.861)	89.50	0.749	0.862
	Women	0.907 (0.897-0.917)	79.50	0.865	0.855
	Total	0.851 (0.844-0.859)	86.50	0.705	0.814
BMI (kg/m^2)	Men	0.808 (0.798-0.819)	25.85	0.783	0.697
	Women	0.878 (0.867-0.890)	23.50	0.912	0.709
	Total	0.836 (0.828-0.844)	25.85	0.750	0.766
WHtR	Men	0.837 (0.828-0.847)	0.505	0.816	0.712
	Women	0.906 (0.897-0.916)	0.485	0.934	0.751
	Total	0.865 (0.858-0.872)	0.505	0.820	0.764

Abbreviations: See Table 1, AUC= area under the curve, CI=confidence interval.

Table 4 shows the optimal cutoff point for each anthropometric parameter in predicting insulin resistance among Korean adults. In both genders, the highest AUC was observed for WHtR, and the lowest for VAI. The AUC values for VAI were 0.705, 0.659, and 0.778 for all subjects, men, and women, respectively. The multivariate-adjusted odds ratios (ORs) with 95% CI (confidence interval) for the association of VAI with metabolic syndrome and insulin resistance from a sex-stratified analysis are shown in Table 5. VAI showed a significant correlation with metabolic syndrome and insulin resistance, regardless of anthropometric indices or risk factors of biochemical metabolic syndrome for all subjects. When relevant variables were controlled, the OR of VAI for metabolic syndrome was 1.77 (95% CI, 1.35–3.05) at the third quartile and 5.02 (95% CI, 3.38–9.71) at the fourth quartile, compared to the first quartile in male subjects. Furthermore, the OR of VAI for metabolic syndrome was 1.81 (95% CI, 1.50–2.94) at the third quartile and 5.84 (95% CI, 2.03–15.52) at the fourth quartile, compared to the first quartile in female subjects. We also found the association of VAI with insulin resistance similar to metabolic syndrome. The OR of VAI for insulin resistance was 2.12 (95% CI, 1.29–3.48) at the third quartile and 2.92 (95% CI, 1.82–4.71) at the fourth quartile, compared to the first quartile in male subjects (model 2 in Table 5). Finally, the OR of VAI for insulin resistance was 2.23 (95% CI, 0.90–5.49) at the third quartile and 2.92 (95% CI, 1.22–6.99) at the fourth quartile, compared to the first quartile in female subjects (model 2 in Table 5).

Table 4: Optimal cutoff point of indicators for predicting insulin resistance

		AUC (95% CI)	Cutoff value	Sensitivity	Specificity
VAI	Men	0.659 (0.640-0.678)	1.347	0.718	0.468
	Women	0.778 (0.745-0.811)	1.170	0.809	0.643
	Total	0.705 (0.689-0.721)	1.346	0.718	0.604
WC (cm)	Men	0.683 (0.663-0.702)	85.50	0.652	0.619
	Women	0.828 (0.798-0.857)	78.50	0.722	0.794
	Total	0.748 (0.734-0.763)	80.70	0.820	0.548
BMI (kg/m^2)	Men	0.644 (0.624-0.665)	26.50	0.441	0.768
	Women	0.818 (0.789-0.847)	24.50	0.747	0.773
	Total	0.713 (0.697-0.729)	24.90	0.695	0.615
WHtR	Men	0.703 (0.684-0.722)	0.505	0.629	0.666
	Women	0.836 (0.808-0.863)	0.485	0.814	0.716
	Total	0.754 (0.740-0.769)	0.485	0.797	0.580

Table 5: Adjusted odds ratios (OR) of the visceral adiposity index associated with metabolic syndrome and insulin resistance

VAI	Metabolic syndrome				Insulin resistance			
	Men		Women		Men		Women	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
1^{st} Quartile	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference

2nd Quartile	1.71 (0.97-3.01)	1.43 (0.77-2.63)	0.95 (0.84-1.91)	0.81 (0.78-1.71)	1.61 (1.15-2.26)	1.36 (0.79-2.35)	1.18 (0.91-3.59)	1.22 (0.46-3.25)
3rd Quartile	2.84 (1.93-5.62)	1.77 (1.35-3.05)	2.92 (1.58-3.43)	1.81 (1.50-2.94)	3.07 (2.26-4.17)	2.12 (1.29-3.48)	3.81 (2.04-7.13)	2.23 (0.90-5.49)
4th Quartile	7.36 (5.73-15.31)	5.02 (3.38-9.71)	9.59 (2.88-18.07)	5.84 (2.03-15.52)	5.03 (3.75-6.75)	2.92 (1.82-4.71)	4.56 (2.25-7.40)	2.92 (1.22-6.99)

Adjusted OR for anthropometric and metabolic components. Model 1 was adjusted for age, blood pressure. Model 2 was adjusted for Model 1 plus components of metabolic syndrome: total cholesterol, LDL-cholesterol, and glucose.

4. Discussion

In this study of Korean adults, we identified VAI as the strongest predictor of metabolic syndrome as compared to BMI, WC, and WHtR; however, WHtR displayed the greatest ability to predict insulin resistance. VAI implicitly reflects cardiovascular risk, and it is a gender specific indicator of visceral fat distribution and function[8]. This has led researchers to propose VAI as a useful marker for early detection of cardiovascular risks in borderline metabolic syndrome[17]. In a previous study by Elisha et al., VAI also showed a strong correlation with the area and volume of visceral fat measured by MRI, and high VAI values were correlated with high plasma insulin concentrations and low insulin sensitivity assessed using euglycemic-hyperinsulinemic clamp[11]. Ferraù et al.[18] reported that VAI exhibited a significant correlation with metabolic syndrome, TG, HDL-cholesterol, and HOMA-IR, independent of gender or age.

In the present study, VAI exhibited a significant correlation with all metabolic parameters except hs-CRP regardless of the gender or age. Furthermore, we demonstrated that VAI was related to metabolic syndrome and insulin resistance independent of other anthropometric indices or biochemical parameters of metabolic syndrome. However, such results were predictable because some of the parameters that were used to calculate VAI were identical to the risk factors used in diagnosing metabolic syndrome. Consistent with these results, VAI has been reported to be associated with risk factors of metabolic syndrome and to be the strongest indicator of hypertriglyceridemia and low HDL-C, but it has not been related to hs-CRP, which is a marker of systemic inflammatory state[11,19]. In previous studies, VAI was not superior to anthropometric parameters in relation to inflammation measured with hs-CRP[20,21]. On the other hand, VAI has been correlated with tumor necrosis factor-α and adiponectin, implying a possible association between VAI and the inflammation related to obesity and metabolic diseases[22]. Thus, we believe that VAI will be a useful indicator for assessing the risk of metabolic syndrome in Korean adults, although it may not serve as a direct diagnosis tool of cardiovascular and cerebrovascular events.

Amato et al.[8] found that VAI was associated with cardiovascular and cerebrovascular events in Caucasian subjects and proved that the sensitivity and specificity of VAI for assessing the risk of these events were higher than those of WC, BMI, HDL-C, and TG[17]. Knowles et al. reported that in Peruvian adults, the strongest predictors of metabolic syndrome risk were VAI, WC, and WHtR[23]. In fact, according to the International Diabetes Federation (IDF), a WC measurement is a prerequisite for diagnosing metabolic syndrome[24]. Some benefits of VAI over a WC measurement are that it provides more reliable information on visceral fat function and

insulin sensitivity, and that increases in VAI are highly associated with the risk of cardiovascular diseases[8]. However, one study reported that VAI may not be more effective than BMI or WC in predicting the changes in visceral fat among menopausal women on a low-calorie diet[11]. Moreover, Bozorgmanesh et al. expressed concerns that complex body measurement indices result in information loss as compared to simple anthropometric measures for predicting cardiovascular risks[25]. In this study, we found a higher prevalence of metabolic syndrome and insulin resistance in a patient subgroup with high VAI than in patients with low VAI in all subjects (Table 5). Therefore, VAI showed an outstanding ability to predict metabolic syndrome, compared to BMI, WC, and WHtR, whereas WHtR was a stronger predictor of insulin resistance.

Qing et al.[26] demonstrated that VAI was effective in predicting metabolic syndrome in Chinese patients with adult growth hormone deficiency; the optimal cutoff values for predicting metabolic syndrome were as follows: VAI, 2.29, WC, 79.65 cm; BMI, 23.46 kg/m^2; WHtR, 0.54 and WHR, 0.89. VAI was also shown to be a good detector of glucose resistance in polycystic ovarian syndrome, with an optimal cutoff of 1.82[27]. In patients with obstructive sleep apnea, the optimal cutoff for VAI in predicting metabolic syndrome was 2.282 for all subjects, 2.105 in men, and 2.511 in women[28]. In our study of Korean subjects, the optimal cutoff for VAI in predicting metabolic syndrome was 1.84; however, it remains difficult to verify the accuracy of these cutoff values, as there has been no study suggesting the optimal cutoff for VAI in predicting metabolic syndrome in the general public. Such diverse results might be due to differences in the ethnicities of the subjects, underlying conditions, gender, age, and diagnostic criteria. In particular, Asian populations tend to show higher levels of visceral fat than Caucasian populations, despite lower BMI; this suggests that further research is needed on whether VAI, an index developed for Caucasians, is appropriate to use for Asians[29].

There are several limitations to the current study. First, because this study was a retrospective cross-sectional survey, a longitudinal cohort studies may be required to confirm the causality of the positive association between many factors and VAI. Secondly, although the standard testing method for insulin resistance is the euglycemic-hyperinsulinemic clamp, this study assessed insulin resistance using HOMA-IR. Thirdly, we were unable to assess the subjects' use of medications, such as non-steroidal anti-inflammatory drugs or corticosteroid, that could have affected their plasma CRP level. Fourthly, we did not consider menopausal status and use of hormonal contraception, which could have affected the distribution of HOMA-IR[30]. Finally, this study also did not take into account the possibility of residual confounding factors such as lifestyle habits or genetic predispositions that might influence metabolic diseases. Despite the limitations of these studies, it is expected that the results could be generalized to Korean population because this study was based on a large representative sample.

5. Conclusion

VAI was a strong predictor of metabolic syndrome in Korean population, especially in comparison to WC, BMI, and WHtR. However, the ability of VAI to predict insulin resistance was lower than that of WHtR. Furthermore, the optimal cutoff value of VAI for metabolic syndrome prediction was 1.84.

6. References

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