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Deriving the cut-off of visceral adiposity index as a promising tool to assess abdominal obesity

Derivación del índice de adiposidad visceral de corte como una herramienta prometedora para evaluar la obesidad abdominal

SA. Thamilovia[1], S. Uma Mageshwari[2]

[1] Assistant Professor, Department of Food Processing Technology, PSG College of Arts and Science – Coimbatore – 641 014, India. E-mail: thamilovia1994@gmail.com

[2] Professor, Department of Food Service Management and Dietetics, Avinashilingam Institute for Home Science and Higher Education for Women – Coimbatore – 641 041, India.

Background: The visceral fat tissue is an active organ and visceral obesity present is a potent risk factor for metabolic changes in the body. Visceral Adiposity Index (VAI) is becoming a novel health assessment index and effective marker for stratifying adults for obesity phenotypes. The aim of the study is to associate and correlate the visceral adiposity index and insulin resistance among selected experimental and control adult women and to derive cut-off points among adult women between the age group of18-30 years. Methods: The target group of 300 adult women (150 obese and 150 non-obese) between the age group of 18 to 30 years were purposively selected depending on inclusion and exclusion criteria. Biochemical parameters like total cholesterol, triglycerides, low-density lipoprotein, high-density lipoprotein, fasting blood glucose and fasting insulin were estimated Visceral Adiposity Index (VAI) and Homeostasis Model Assessment of Insulin Resistance (HOMA-IR) were calculated and evaluated. Using receiver operating characteristic (ROC) analysis the cut-off value of VAI was found. Results: The VAI value was found to be higher among the experimental (Obese) compared to the control (Non-obese) which was 1% significant. A positive correlation was seen between of VAI with age, weight, BMI, WC, HC, WHtR, TC and TG with 1% significance. The R-value derived from the regression analysis was 0.940. The scatterplot between VAI and HOMA-IR indicates no strength of linear relation between VAI and IR. Conclusion: VAI is a simple and accurate means to measure the visceral adiposity as it is economical and can be used for sustainably.

Keywords: Adult Women, Visceral Adiposity Index, Insulin Resistance, HOMA-IR, ROC

RESUMEN

Antecedentes: El tejido adiposo visceral es un órgano activo y la obesidad visceral presente es un potente factor de riesgo para cambios metabólicos en el organismo. El índice de adiposidad visceral (VAI) se está convirtiendo en un nuevo índice de evaluación de la salud y un marcador eficaz para estratificar a los adultos según los fenotipos de obesidad. El objetivo del estudio es asociar y correlacionar el índice de adiposidad visceral y la resistencia a la insulina entre mujeres adultas experimentales y de control seleccionadas y derivar puntos de corte entre mujeres adultas entre el grupo de edad de 18 a 30 años. Métodos: El grupo objetivo de 300 mujeres adultas (150 obesas y 150 no obesas) entre el grupo de edad de 18 a 30 años fue seleccionado intencionalmente según los criterios de inclusión y exclusión. Se calcularon y evaluaron parámetros bioquímicos como colesterol total, triglicéridos, lipoproteínas de baja densidad, lipoproteínas de alta densidad, glucosa en sangre en ayunas e insulina en ayunas. Usando el análisis de características operativas del receptor (ROC), se encontró el valor de corte de VAI. Resultados: se encontró que el valor de VAI era mayor entre los experimentales en comparación con el control, que era 1% significativo. Una correlación positiva de VAI con

edad, peso, IMC, CC, HC, WHtR, TC y TG con un 1% de significancia. El valor R derivado del análisis de regresión fue 0,940. El diagrama de dispersión entre VAI y HOMA-IR indica que no hay fuerza de relación lineal entre VAI e IR. Conclusión: los medios precisos para medir la adiposidad visceral, como el VAI, que es económico, serán útiles para un uso sostenible.

Palabras clave: Mujeres Adultas, Índice de Adiposidad Visceral, Resistencia a la Insulina, HOMA-IR, ROC

INTRODUCTION

The visceral obesity in specific, is the high amount fat distributed in the abdominal region. Individuals with normal weight with lower BMI might be having higher risk of causing metabolic dysfunction (Sahakyan et al., 2015). The visceral fat tissue is an active organ and the visceral obesity present inside is a potent risk factor for the metabolic changes in our body. Visceral fat is particularly deleterious because of its anatomical location and the resultant increased supply of free fatty acids to the liver (Ebbert & Jensen, 2013). Even though the cause for mortality is of obesity, it is the presence of visceral obesity associated with metabolic derangements compared to general obesity is the silent killer (Arimura et al., 2011). The obesity leading to onset of complications is not only associated with obesity phenotype but also to metabolic dysfunction by inflating the cells leading to dysfunction by the distribution of visceral fat disregarding total body fat.

The worldwide prevalence of visceral obesity was found to be 41.5%. The Indian prevalence of visceral obesity was higher than the generalized obesity and in Tamil Nadu was 26.6% specifically higher among urban population of 37.4%. It was also noted that women had higher prevalence rate of 32.2% than men (Pradeepa et al., 2015). The metabolic disturbances caused due to presence of visceral fat is different for every obese individual depending upon the rate of fat distributed in the abdominal region. The visceral adipose tissue is a metabolically active organ and the intra-abdominal obesity is an independent risk factor for the metabolic alterations which is associated with the development of cardiovascular diseases (CVD) and type 2 diabetes mellitus (T2DM) in adults (Chait et al., 2020).

The visceral obesity cannot be measured using frequently used anthropometric indices. The assessment of visceral obesity requires more prominent index. The most commonly used anthropometric measurements like Body Mass Index and Waist Circumference cannot distinguish between the fat and lean tissues (Ahmad et al., 2016). However, such indexes are not comprehensive in reflecting an individual's obesity and metabolic abnormalities. Although other indices have a major role in the clinical setup, differentiating the visceral fat from subcutaneous fat methods like Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) are used commonly, but are expensive and difficult to apply (Shuster et al., 2012). Hence simple tools that can be widely used in clinical practices to bring out the metabolic changes has to be validated. Visceral Adiposity Index (VAI) is becoming novel health assessment index and effective markers for stratifying adults for obesity phenotypes (Du et al., 2015). VAI is a gender specific calculative index, which includes the anthropometric measurements and biochemical parameters which has shown to be related to adipose tissue function and express visceral fat distribution (Amato et al., 2010). VAI can aid in evaluating the manifestation and considered as a surrogate marker of visceral adipose tissue dysfunction (Nayak et al., 2020; Kumpatla et al., 2011). It reflects the severity of insulin resistance and-- exhibits a strong association with both the glucose utilization and the MRI's visceral adipose tissue.

As obese individuals differ not only in the amount of excess fat that they store but also in the regional distribution of the fat within the body which induces insulin resistance (Devi et al., 2017). Nonetheless, normal BMI individual's visceral obesity are usually neglected in clinical guidelines, hence the role to calibrate the efficient markers. The VAI standard is not available because it is ethnic specific i.e., the amount of visceral obesity present among populations differs widely, as visceral obesity is more common among South Asians (Misra & Shrivastava, 2013). The identification of high-risk individuals among obese and non-obese is essential.

METHODOLOGY

The study was carried out in Coimbatore and among adult women between the age group of 18 to 30 years. The target group of 300 adult women (150 obese and 150 non-obese) were purposively selected from Avinashilingam University Women's Clinic, Coimbatore and Karuna's Women Clinic. Due permissions were obtained from the authorities for the conduct of the study in both the selected locations and ethical clearance was procured from Institutional Human Ethics Committee of the University. The target adult women were selected depending upon the inclusion and exclusion criteria.

The participants' informed consent was obtained. Obese women aged 20 – 30 years, BMI >24.9 and willing to participate in the study were included as experimental group and overweight, normal and underweight women were excluded. Adult women of the same age group with a normal BMI range between 18.5 – 22.9 were included as the control group and underweight, overweight and obese women were excluded.

BIOCHEMICAL ESTIMATIONS

Five ml of blood samples (venous) were collected from 320 adult women (160 Experimental and 160 Control) after overnight fasting (preferably 8 hours of fasting) with the help of a well-trained technician. The collected blood sample was centrifuged for serum separation. The Total Cholesterol (TC), Triglycerides (TG), Low-Density Lipoprotein (LDL), High-Density Lipoprotein (HDL), Fasting Blood Glucose (FBG) (mg/dl) and fasting insulin (FI) (µU/ml) using standard protocols in laboratory.

VISCERAL ADIPOSITY INDEX

The VAI is an empirical, gender-specific index that includes both anthropometric measurements like Waist Circumference (WC) and Body Mass Index (BMI); biochemical parameters like Triglycerides (TG) and High-Density Lipoprotein (HDL) to calculate the visceral fat distribution in the body. VAI was first calculated by the Model of Adipose Distribution (MOAD) among healthy individuals (Amato et al., 2010).

$$\text{VAI for Women} = \frac{WC}{36.58 + (1.89 \times BMI)} \times \frac{TG}{0.81} \times \frac{1.52}{HDL}$$

The Calculation of VAI was done where

- WC – Waist Circumference (cm)
- BMI – Body Mass Index
- TG – Triglycerides (mmol)
- HDL – High-Density Lipoprotein (mmol)

INSULIN RESISTANCE

Visceral adiposity has been associated with insulin resistance and increased cardiovascular risk. The Homeostatic Model Assessment of Insulin Resistance (HOMA-IR) concept is a robust marker for defining insulin resistance. The most practical, ethical, and economical hyperinsulinemic-euglycemic clamp is the standard gold test for measuring insulin resistance. This method measures insulin resistance and beta-cell function from fasting glucose and insulin (or C-peptide) concentrations. HOMA-IR is an easy method for evaluating insulin sensitivity and correlates with the results of glucose clamp test in subjects with mild diabetes without significant hyperglycemia. For the calculation of the HOMA-IR, the fasting serum glucose (FSG) (mg/dl) and fasting insulin (FI) (µU/ml) measurements are necessary (Bhosle et al., 2016).

$$\text{HOMA-IR} = \frac{\text{fasting glucose x fasting insulin}}{}$$

The Insulin resistance was calculated where

- FBG – Fasting Blood Glucose (mg/dL)
- FI – Fasting Insulin (µIU/ml)

STATISTICAL ANALYSIS

All analyses were performed using the SPSS 21 statistical software. Numerical variables were reported as mean ± standard deviation. Comparisons were conducted between obese and non-obese groups using the t test. Comparison of prevalence data was performed by $\chi 2$ analysis. Pearson's correlation, scatter plots and linear regression were used to evaluate the possible association between the independent and the dependent variables

For each adiposity indicators logistic regression analysis was used to calculate odds ratios (ORs) and 95% confidence intervals (CIs) for experimental and control adjusting for potentially confounding variables such as age, BMI, WHR, WHtR and biochemical parameters. By using receiver operating characteristic (ROC) analysis, ROC curves of each adiposity indicators were drawn to show how well they could separate subjects into groups. Sensitivity and specificity of each adiposity indicators have been calculated at all possible cut of points to find the optimal cut off values. The optimal sensitivity and specificity were the values yielding maximum sums from the ROC curves.

RESULTS AND DISCUSSION

DETAILS ON VISCERAL ADIPOSITY INDEX

The VAI among experimental and control are shown in Table 1 and Figures 1.

Table 1
Visceral Adiposity Index and Lipid Accumulation Product

Variables	Experimental (N=160)	Control (N=160)	T-Value	P value
VAI	2.27±1.27	1.61±0.92	-5.284*	<0.001*

* Significant at 1% level

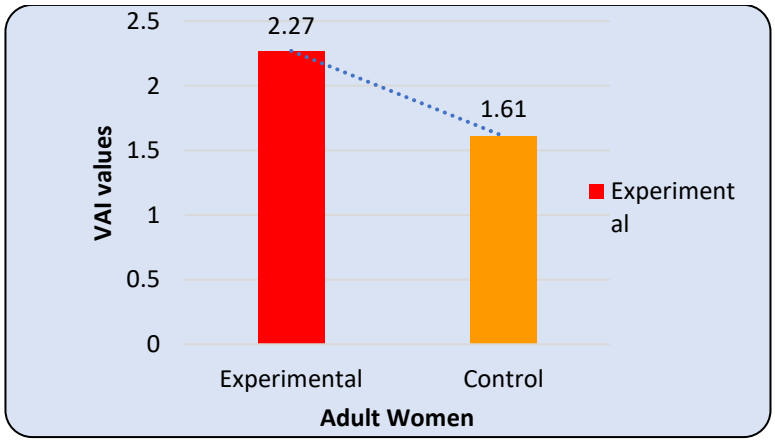


Figure 1. Visceral Adiposity Index

VAI value was higher among the experimental group (2.27±1.27) than the control group (1.61±0.92). A 1% significance was seen between the experimental and control group. A value of VAI observed in diverse studies has often been increased risk of cardiometabolic diseases (Munusamy et al., 2015).

According to Du et al (2015), lower VAI value (< 1.59) individuals were considered 'metabolically healthy' and higher VAI value (> 1.59) individuals as 'metabolically unhealthy.'

DETAILS ON INSULIN RESISTANCE

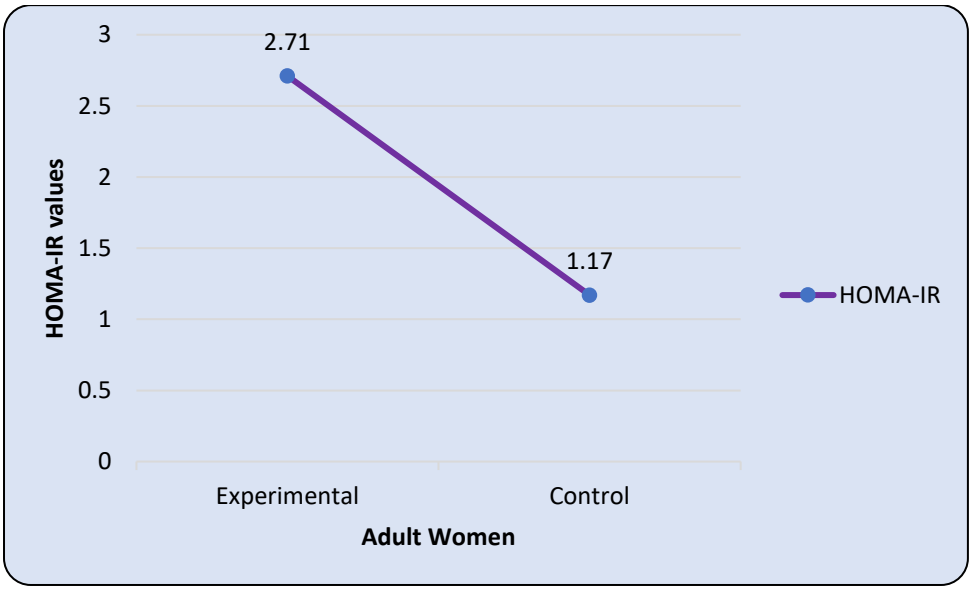
The Insulin Resistance (IR) among experimental and control women is depicted in Table 2 and Figure 2.

Table 2
Insulin Resistance

Variables	Experimental (N=160)	Control (N=160)	T-Value	P value
Insulin Resistance (HOMA-IR)	2.71±4.18	1.17±0.67	-4.707*	<0.001*

* Significant at 1% level

Figure 2. Insulin Resistance



Visceral adiposity and increased body fat are the risk factors of insulin resistance among Asian Indians (Fahed et al., 2020). The HOMA-IR method can further stratify the risk of diabetes among adults, thus identifying the high risk of non-obese and low risk of obese individuals. The mean insulin resistance (IR) value among the experimental was 2.71 when compared with control of 1.17, which was found to be at a 1% significance difference between the groups. The insulin resistance value greater than 2.5 to 3.0 was considered insulin resistant (Gutch et al., 2015).

A study among US Adults showed that the insulin resistance values increased significantly as BMI levels increased between the BMI categories. The higher levels of insulin resistance were associated with higher body fat levels, thus, indicating that high BMI and body fat percentage were strongly related to insulin

resistance. The insulin resistance among obese was 3.9 (0.14) and among non-obese was 1.6 (0.08) (Martinez et al., 2017) and which was higher than the acquired value from the study.

Another study where adults were divided as metabolically healthy and unhealthy obese had insulin resistance values of 2.26±1.64 and 2.94±2.62 respectively, whereas metabolically healthy and unhealthy non-obese had 1.34±1.30 and 1.74±1.78 respectively (Liao et al., 2021).

ASSOCIATION OF VAI WITH INSULIN RESISTANCE

CORRELATION ANALYSIS OF VAI

The correlation analysis of VAI with other indices like anthropometric and biochemical values of selected experimental and control adult women is shown in Table 3.

Table 3

Correlation of VAI with Anthropometry and Biochemical Values

Variables	VAI	
	r	p
Age	0.161	0.004*
Weight	0.228	<0.001*
Body Mass Index	0.245	<0.001*
Waist Circumference	0.255	<0.001*
Hip Circumference	0.208	<0.001*
Waist Hip Ratio	0.137	0.014*
Waist Height Ratio	0.249	<0.001*
Total Cholesterol	0.206	<0.001*
Triglycerides	0.835	<0.001*
High Density Lipoprotein	-0.636	<0.001*
Low Density Lipoprotein	0.078	0.164 ^{NS}
Fasting Blood Glucose	0.120	0.032**
Fasting Insulin	0.070	0.209 ^{NS}
Insulin Resistance	0.072	0.213 ^{NS}
LAP	0.127	0.023**

* Significant at 1% level, ** Significant at 5% level, ^{NS} Not Significant

A positive correlation of VAI with age, weight, BMI, WC, HC, WHtR, TC and TG with 1% significance was noted. A negative correlation (r= -.636, p=<0.001) was noted with HDL, which indicates that there will be a decrease in VAI if HDL increases.

Waist Hip Ratio (r = 0.137, p=0.014), Fasting Blood Glucose (r = 0.120, p=0.032) and LAP (r = 0.127, p=0.023) showed a 5% significant difference. There was no correlation between VAI with LDL, fasting insulin and insulin resistance. This study points out that VAI and insulin resistance were not correlated among the general adult women population, but in studies conducted earlier, there was a strong relationship seen between visceral adiposity and insulin resistance. Hence H_0 of hypothesis 1 was accepted. VAI had the strongest correlation with FBG, TG, TC, HDL and BP, as supported by (Goldani et al., 2015).

Likewise, a similar result was found in which VAI was not correlated with IR (r = 0.132, p = 0.119) among healthy adult women (control). Still, it showed a significant positive correlation with insulin resistance (r = 0.299, p = 0.003) among prediabetic adult women population and stated that the higher level of VAI among adults was due to significantly higher BMI, WC, TG and lower HDL (Morshed et al., 2021).

On the contrary, a significant positive correlation was found between VAI and insulin resistance (Pathak et al., 2018; Munusamy et al., 2015). VAI was also correlated positively with cardiometabolic risk among women (Agrawal et al., 2019).

REGRESSION ANALYSIS OF VAI

The regression analysis was statistically analyzed for VAI and other experimental and control confounders, as shown in Table 4- a, b & c and Figure 3.

Table 4-a

Regression Analysis of VAI

Modal Summary			
R	R Square	Adjusted R Square	Std. Error of the Estimate
0.940	0.884	0.879	0.401

Table 4-b

ANOVA					
Model	Sum of Squares	Df	Mean Square	F	P value
Regression	375.617	13	28.894	179.291	<0.001*
Residual	49.313	306	0.161		
Total	424.930	319			

* Significant at 1% level

Table 4-c

Coefficients			
Variables	Standardized Coefficients	T	P value
Age	0.026	1.014	0.311 ^{NS}
WC	0.201	2.962	0.003**
BMI	-0.232	-4.629	<0.001
WHR	-0.043	-1.242	0.215 ^{NS}
WHtR	0.074	0.933	0.001*
TC	0.175	5.083	<0.001*
TG	0.693	29.160	<0.001*
HDL	-0.432	-18.644	<0.001*
LDL	-0.243	-7.639	<0.001*
FBS	0.007	0.257	0.798 ^{NS}
FI	-0.039	-0.193	0.847 ^{NS}
IR	0.025	0.126	0.900 ^{NS}
LAP	0.018	0.583	0.560 ^{NS}

* Significant at 1% level, ** Significant at 5% level, ^{NS} Not Significant

Dependent Variable: VAI

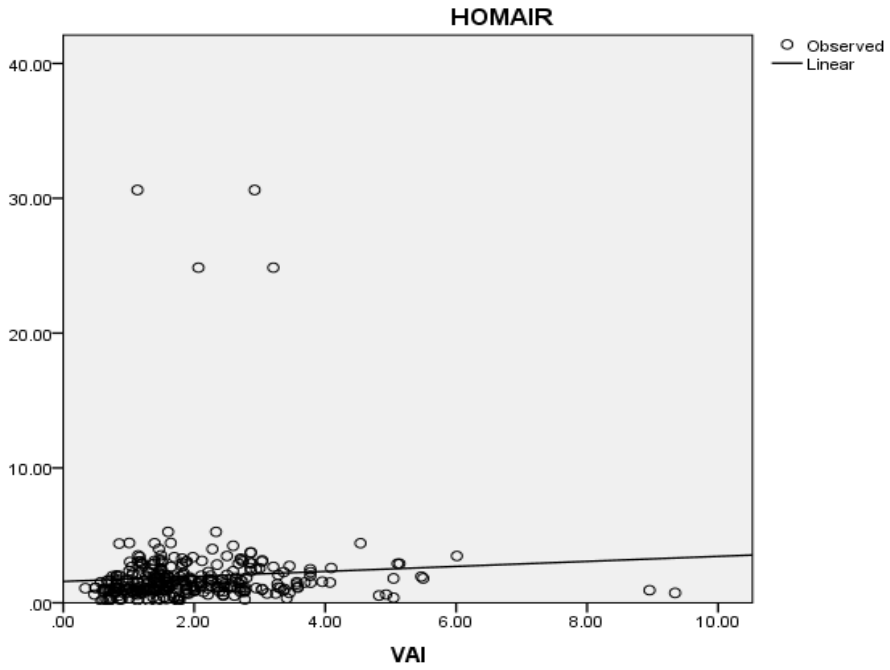


Figure 3. Linear Graph of VAI and IR

The R-value derived from the regression analysis was 0.940 and the degree of determination R square value was 0.884 for VAI. The adjusted R square value (0.879) shows the extent to which BMI, WHtR, TC, TG, HDL and LDL influences the value of VAI. The results show that the VAI was determined to the extent of 88% by all the other confounders.

The ANOVA shows that the significant value was less than 0.05 ($p=<0.001$), which means independent variables significantly predicted the dependent variable VAI at a 95% confidence level. It indicates that the regression model for VAI was significant.

The multiple regression results for VAI were predicted by the WC, BMI, WHtR, TC, TG, HDL and LDL. In the analysis, mentioned variables have a P-value less than 0.05. Those variables are statistically significant with VAI. Hence, this proves a relation among the study's significant variables (BMI, WHtR, TC, TG, HDL and LDL on VAI).

Figure 13 shows the scatterplot linear graph between VAI and IR. The picture elicits the cluster towards the lower left, indicating a horizontal line with the slope. The r-value (0.025) indicates no strength of linear relation between VAI and IR, depicted in the scatterplot graph with minimal outliers. The outliers were not removed since the cut-off value must be derived using the ROC curve.

DERIVING THE CUT-OFF VALUE OF VISCERAL ADIPOSITY INDICES

The ROC area under the curve (ROC-AUC) of WHR, WHtR, VAI, and IR with the area under the curve, cut-off value, sensitivity, 1-specificity, odds ratio, 95% confidence interval and youden index is depicted in Table 5 and Figure 4.

Table 5. ROC Characteristics of WC, WHR, WHtR, VAI and LAP

Characteristics	VAI
Area Under Curve (AUC)	0.716
Lower Limit	0.636
Upper Limit	0.751
Cut-off Value	1.70
Sensitivity (%)	61.4
1- Specificity (%)	58.8
Odds Ratio (95% Confidence Interval)	1.711 (1.363-2.148)
Youden's Index	0.202

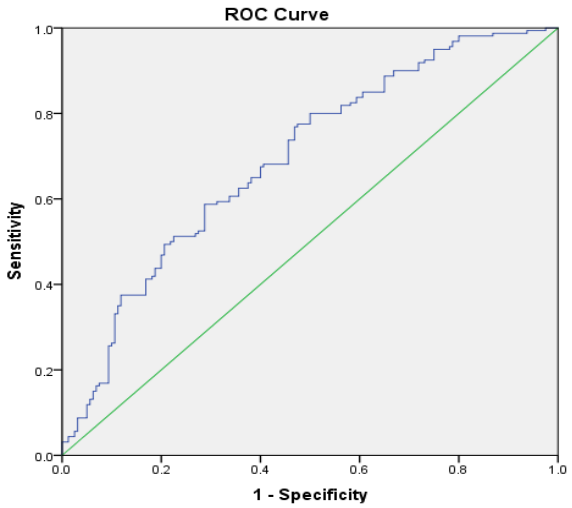


Figure 4. ROC Curve of VAI

The VAI had the AUC value of 0.716 (0.636-0.751 95%CI), and the cut-off was calculated to be 1.70 for adult women. A similar cut-off was found by (Agrawal et al., 2019).

VISCERAL ADIPOSITY BY DERIVED VAI CUT-OFF VALUE

The derived cut-off value of VAI was 1.70, which was used to evaluate the visceral adiposity among adult women. Table 6 shows the prevalence of visceral adiposity among the experimental and control group.

Table 6
Visceral Adiposity using Derived VAI Cut-off Value

Variables	Experimental (N=160)		Control (N=160)	
VAI Cut-off Value	<1.70	>1.70	<1.70	>1.70
Number (N=160)	64	96	106	54
Percent	40	59	66.3	33.7
Mean ± SD	1.29±0.28	2.91±1.26	1.12±0.35	2.58±0.91
P value	0.0012*	0.0929 NS	0.0012*	0.0929 NS

* Significant at 1% level, NS Not Significant

The prevalence of visceral adiposity among the experimental and control groups was 59 per cent and 33.7 per cent, respectively. The mean of greater visceral adiposity cut-off value (>1.70) among the

experimental group was higher (2.91±1.26) than among the control group (2.58±0.91), which was not statistically significant ($p<0.05$).

The VAI value for normal body weight women (control group) was higher than the derived cut-off value. The experimental group having visceral adiposity was relatable, but nearly 34% of adult women had visceral adiposity among the control group. It indicates the presence of invisible fat within the normal BMI adult, indicating metabolically unhealthy. It provides a health indication among the general population using visceral adiposity indices.

DISCUSSION

The study signifies the importance of measuring the visceral adiposity among the population to prevent metabolic disturbances and onset of communicable diseases. In this present study, the derived cut-off value of VAI was 1.70 which was gender and ethnic specific which was re-introduced among selected age group which resulted in the prevalence of visceral adiposity among the adult women population which was found out to be 59%.

Visceral adiposity index (VAI) is a novel sex specific index for visceral adipose function (Dong et al., 2017). A study in Chennai found the VAI cut-off value to be 2.69 which was higher than the value derived from this study, with a sensitivity of 70.1% and specificity of 74.35%, and AUC of 0.81 with 0.74 to 0.87 95% CI (Munusamy et al., 2015). In a study carried out by Joshi et al, (2018) among young PCOS girls, the cut-off value for PCOS was found to be 2.73, has a sensitivity of 0.76 and specificity of 0.699 and could predict the risk of metabolic syndrome (AOR: 7.757, 95% CI: 2.041-29.48) compared to the literature reference cut-off among the Caucasian population of 1.67 which was similar to the derived value of the study.

The higher VAI values were found with increased risk of developing cardiovascular disorder in future[23]. The cutoff value of VAI in predicting IR among obese with and without metabolic syndrome (MetS) was found to be 2.31. The study found that MetS was present in al-most half of overweight and obese individuals, and the cutoff values of VAI in predicting the presence of MetS and IR were 2.205 and 2.31, respectively (Pekgor et al., 2019).

Even though the prevalence of obesity among adults is considerably lesser than the normal adults (a considerable prevalence of underweight also observed proving double burden of malnutrition), India is the capital of diabetes and many other metabolic disorders. India is a land full of diversity and varying ethnicities. The reasons behind be, were the genetic build-up and the predisposition of the high amount of fat within the body.

The real task will be observing visceral adiposity by differentiating the subcutaneous and visceral fat responsible for metabolic dysfunction. So accurate means to measure the visceral adiposity, which is economical, will be useful for sustainable use. This study signifies the importance of deriving the cut-off value of visceral adiposity index among different age groups and conditions to involve so that prevention can be initiated at early stage

RECOMMENDATION

A larger sample size is recommended to calculate and validate Visceral Adiposity Index among various age groups. Moreover, relation between VAI assessments with other indicators should be compared to find the predictability of the index.

CONCLUSION

The derived cut-off value for a given population might not suit other countries. India has a broad genetic pool from the population of north and south, and an estimate to derive the cut-off values to represent will be sustainably beneficial and clinical potential. Visceral adiposity fat has been found to play a role in our body's metabolic, endocrine, and immune functions. Visceral adiposity increases the risk of metabolic and cardiovascular disorders and, hence, is important as an anthropometric tool. The visceral adiposity index might

be used as valuable and surrogate indexes of visceral tissue dysfunction since they are cost-effective and non-invasive tools that can be performed easily and utilized for a screening assessment. It can also be used as a criterion to assess the risk of NCDs among population studies and in clinical practices if the cut-off values are validated.

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