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Abdominal volume index is a better predictor of visceral fat in patients with type 2 diabetes: a cross-sectional study in Ho municipality, Ghana

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ABSTRACT

Background: Visceral obesity is associated with increased risk of metabolic disorders and cardiovascular disease, hence, diagnosing visceral fat is indispensable in clinical practice. However, the diagnostic capacity of waist–hip ratio (WHR), conicity index (CI), and abdominal volume index (AVI) to predict visceral obesity in patients with type 2 diabetes remains unclear. This study was designed to evaluate the performance of WHR, CI, and AVI in predicting visceral fat among patients with type 2 diabetes in Ho municipality.

Methods: A hospital-based cross-sectional survey involved 221 patients with type 2 diabetes. A questionnaire was designed to collect data on demography and other relevant variables. Anthropometric measurements were obtained using standard methods. Visceral fat was measured using bioelectrical impedance analysis (BIA). The diagnostic performance of WHR, CI, and AVI in predicting visceral fat was evaluated based on receiver operating characteristics (ROC) curve analyses. Pearson correlation analysis was used to determine the relationship between adiposity indices and visceral fat.

Results: Among men, the optimal threshold for AVI, >15.56, demonstrated the highest sensitivity, 87.5% and specificity, 80.71% compared to CI and WHR while among women, the optimal cutoff value for AVI, >18.49, produced the highest sensitivity, 77.05% and specificity, 85.29%. Likewise, AVI showed a better discriminatory ability in the diagnosis of visceral fat (AUC: 0.89; $p < 0.001$) compared to CI (AUC: 0.68; $p < 0.003$), and WHR (AUC: 0.73; $p < 0.001$) in men and AUC: 0.89; $p < 0.001$ compared to CI (AUC: 0.62; $p < 0.023$), and WHR (AUC: 0.59; $p < 0.066$) in women. Similarly, the strongest positive correlation was observed between visceral fat and AVI after adjustment for age (male $r = 0.787$, $p < 0.01$; female $r = 0.770$, $p < 0.01$).

Conclusion: AVI appeared to have outperformed CI and WHR in the diagnosis of visceral fat. Therefore, it could be a better predictive tool for visceral obesity among patients with type 2 diabetes in low-resource settings.

1. Introduction

Obesity is an unhealthy accumulation of body fat that can be detrimental to health [1]. Statistics released by the WHO indicate that 13.1% of the global population was obese and 38.9% overweight in 2016 [2]. However, current estimates show that between 20% and 50% of Africans living in urban communities are overweight or obese [3]. In Ghana, a study conducted in Accra revealed an overall prevalence of 23.4% and 14.1% for overweight and obesity, respectively [1]. Visceral obesity reflects an increased accumulation of adipose tissue in the abdominal viscera. The main factors contributing to visceral obesity include insulin resistance, hypertension, dyslipidemia, and type 2 diabetes [4,5], with a high risk of cardiovascular morbidity [6].

Globally, the prevalence of visceral obesity is estimated at 41.5%, with a slightly higher prevalence (49.6%) reported in Africa [7]. In Ghana, central obesity was reported among 19.4–19.9% of commercial drivers in Accra and Kumasi [8]

Computed tomography (CT), magnetic resonance imaging (MRI), and bioelectrical impedance analysis (BIA) provide valid and reliable estimates of visceral fat [9]. However, these methods require specialized skills and expensive equipment to be operationalized. Furthermore, exposure to the radiation associated with MRI and CT methods imposes restrictions on the frequency of their use [9]. Therefore, it would be desirable to develop simple, easy to perform but valid anthropometric indicators of visceral obesity. In this

regard, the waist-to-hip ratio (WHR), conicity index (CI), and abdominal volume index (AVI) have been proposed to offer good alternative measurements of visceral fat [10]. WHR is calculated by dividing the value of waist circumference (WC) by hip circumference (HC). Values greater than the established threshold for men, 0.95, and women, 0.85 reflect android, central, or the abdominal type of body fat distribution [11]. The CI equation was developed as an indicator of obesity and body fat distribution taking into account the individual's weight, height, and WC [12]. Furthermore, depending on whether fat accumulation in the abdominal area is greater or less, the model predicts the sort of body shape that would be consistent with a double cone sharing the same base or a cylinder [13]. The AVI equation, which incorporates WC and HC, was devised to quantify the overall abdominal volume using a mathematical connection. Measures of waist and hip circumference are believed to account for intra-abdominal fat and adipose tissue volumes by using this equation [14].

In Ghana, visceral obesity is a growing problem particularly among patients with type 2 diabetes [15–17]. This is in spite of national efforts such as establishment of diabetic clinics and training of specialized health-care workers dedicated to the management of diabetes in primary and secondary health-care settings. Meanwhile, most health professionals continue to rely on simple anthropometric methods, such as BMI, WC, and HC in the evaluation of adiposity due to unavailability of the more precise methods of determining visceral adiposity. Although basic anthropometric indices have a wide range of clinical uses, their ability to distinguish between visceral fat levels in patients with type 2 diabetes remains scarce in the literature. Therefore, we designed the current study to explore the capacity of WHR, CI, and AVI to predict visceral fat among patients with type 2 diabetes in the Ho municipality of the Volta Region, Ghana.

2. Materials and methods

2.1. Study design, population, and sampling technique

A hospital-based cross-sectional study was carried out at the Ho Municipal Hospital, where patients with type 2 diabetes receiving care at the diabetic clinic were conveniently enrolled between January 2019 and October 2020. Adult patients who satisfied the inclusion criteria of being 20 years or older, fasted overnight between 10 and 12 hours, not suffering from any diabetes-related complications including kidney disease, coronary artery disease, and cancers etc., capable of completing anthropometric measures, and consenting to participate in this study were included.

2.2. Ethical consideration

Ethical approval was sought from the Research Ethics Committee of the University of Health and Allied Sciences (UHAS-REC A.10 [15] 20–21). The study was approved by the authorities of the Ho Municipal Hospital.

2.3. Sample size determination

The Raosoft Online sample size calculator was used to calculate a minimum recommended sample size of 197 from a total population of 400 patients with type 2 diabetes, at 95% confidence interval and 5% error margin, with a response distribution of 50%. However, we included a total of 221 patients with type 2 diabetes for this study.

2.4. Data Collection

2.4.1. Demographic data and anthropometric assessment

We designed a semi-structured questionnaire to obtain information on demographic profile (age and gender). Height was measured on a stadiometer with individuals lightly dressed, without shoes, standing erect, back straight, heels together with feet slightly spread. Other anthropometric indices, including weight and visceral fat, were measured using a BIA body composition device (Omron BF-511; Omron Healthcare Co., Ltd., Kiyoto, Japan). The device uses eight electrodes in a tetrapolar arrangement that requires participant to step barefoot onto the scale, holding the display unit with both hands and extending the arms parallel to the floor, while standing upright. A low level, imperceptible electrical current is introduced into the body, the flow of which is affected by the amount of water in the body. The device measures the impedance of the current as it moves through different types of tissue. Before mounting the scale, information on participant's age, height (cm), and gender parameters were entered into the device.

Waist circumference (WC) was measured as the midway between the lower border of the rib cage and iliac crest, in the midaxillary line, with patients standing and breathing normally. Hip circumference (HC) was measured in centimeters as the maximal circumference over the buttock at the level of the widest diameter around the gluteal protuberance. The waist-to-hip ratio (WHR) was defined as WC (cm) divided by HC (cm). Other relevant anthropometric parameters include conicity index (CI) and abdominal volume index (AVI). CI was calculated using the following formula:

$$\frac{\text{waist circumference (in meters)}}{0.109} \times \frac{1}{\sqrt{\frac{\text{weight (in kilogram)}}{\text{height (in meters)}}}} \quad [18],$$

while AVI was calculated using the equation:

$$\frac{2\,\text{cm}\,(\text{waist})^2 + 0.7\,(\text{waist circumference} - \text{hip circumference})^2}{1000} \quad [18].$$

2.4.2. Definition of central obesity based on visceral fat and WHR algorithms

Since CI and AVI do not yet have set cutoff values for the classification of central obesity, central obesity was characterized using visceral fat and WHR algorithms. For visceral fat, central obesity was defined as visceral fat levels greater than 9 [19], while for WHR, central obesity was defined as WHR greater than 0.90 for men and 0.85 for women [20].

2.5. Statistical analysis

Data collected were entered into Microsoft Office Excel 2016 spreadsheet, cleaned and exported to Statistical Package for Social Sciences version 26.00 (SPSS Inc, Chicago, USA (http://www.spss.com) for analysis. The normality test was performed on all continuous variables. Continuous variables were expressed as means ± standard deviations while categorical variables were expressed as frequencies and proportions. Comparisons between groups of continuous and categorical variables were performed by means of unpaired student's t-test and Fisher's exact chi square test analysis, respectively. Spearman correlation analysis was used to determine the relationship between adiposity indices and visceral fat. The receiver operating characteristic curve (ROC) analysis was used to determine the discriminatory abilities to predict visceral fat. MedCalc version 12.3.2 for windows (MedCalc software bvba, Acacialaan 22, B-8400 Ostend, Belgium), (www.medcalc.org) was used for the analysis. In all cases, a p-value of <0.05 was considered statistically significant.

3. Results

Of a total of 221 recruited participants, 129 (58.37%) were females. The average age was 50.95 ± 8.84 years, with a significantly higher average age among the female participants (52.13 ± 8.37 years) compared to their male counterparts (49.30 ± 9.26 years); (p = 0.0188). The average WC, HC, and AVI were significantly higher among female participants compared to their male peers, while height, WHR and CI were found to be averagely higher among men compared to women. According to the visceral fat and WHR algorithms, the prevalence of central obesity was 45.70% and 73.76%, respectively. Based on WHR, central obesity was preponderant among women (82.95%) than men (60.87%) (p < 0.0001). However, central obesity according to visceral fat levels was comparable for both gender (p = 0.587). See Table 1.

Data were presented as mean ± standard deviation and frequency with the corresponding proportion in parentheses. WC-Waist Circumference, HC-Hip circumference, WHR - Waist-to-Hip Ratio, AVI-Abdominal Volume Index * measurement based on bioelectrical impedance analysis

The optimal diagnostic cutoff values of >15.56, >1.58 and >0.92 were determined for AVI, CI, and WHR, respectively, to classify the level of visceral fat in men. However, optimal cutoffs of >18.49, >1.61, and >0.93 were determined for AVI, CI, and WHR, respectively, in women. The maximum J statistic was highest for AVI in predicting visceral fat (males = 0.68 and females = 0.62). See Table 2 below.

WHR - Weight-to-Hip Ratio, CI – Conicity Index, AVI – Abdominal Volume Index

The area under the ROC curve (AUC) for AVI, CI, and WHR to predict visceral fat was 0.89, 0.68, and 0.73, respectively, for men while those for women was 0.89, 0.62, and 0.59 , respectively. Except for WHR among females, all AUC values varied significantly from the reference line (p < 0.05) (Figure 1).
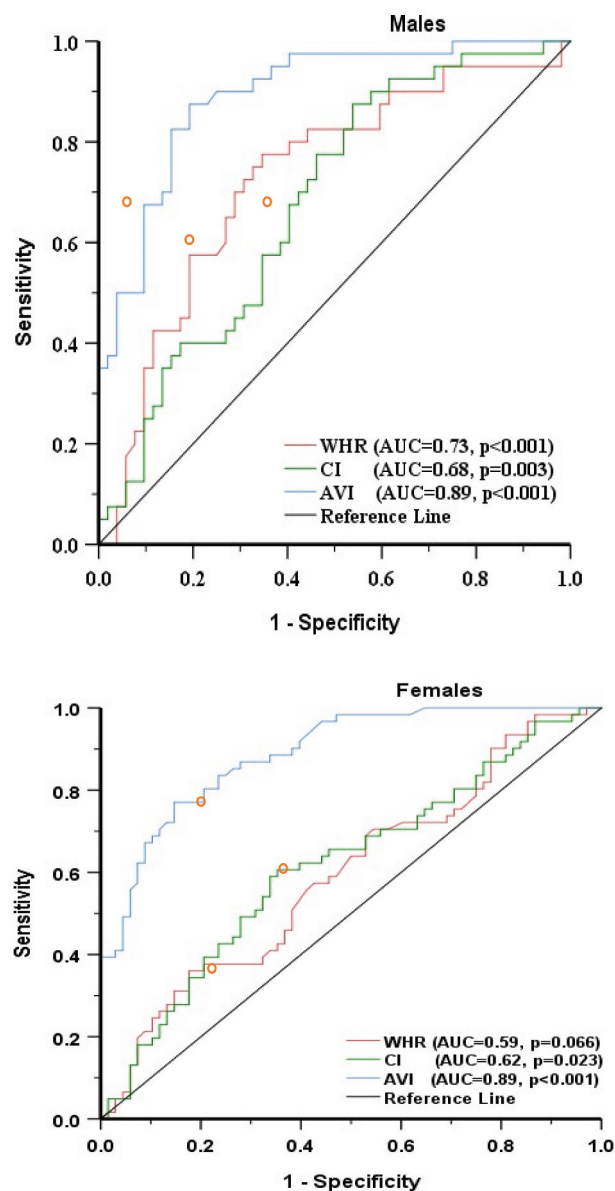
Except for CI among men, visceral fat was generally well correlated with all diagnostic indices used in the study in both male and female participants (p < 0.05). However, after adjusting for age, there was no longer a significant relationship between visceral fat and WHR in both male and females, or CI in females. Although there was no significant correlation between CI and visceral fat levels (0.136;

Table 1. Demographic, anthropometric characteristics, and the prevalence of central obesity among the study participants stratified by gender.

Parameter	Total (221)	Male (92)	Female (129)	p-value
Age	50.95 ± 8.84	49.30 ± 9.26	52.13 ± 8.37	**0.0188**
Weight(kg)	74.16 ± 15.86	74.18 ± 15.38	74.14 ± 16.26	0.9878
Height(cm)	163.29 ± 10.01	171.20 ± 8.42	157.64 ± 6.68	**<0.0001**
WC (cm)	92.63 ± 13.17	89.93 ± 12.36	94.57 ± 13.44	**0.0096**
HC (cm)	101.77 ± 14.33	97.00 ± 13.45	105.18 ± 14.01	**<0.0001**
Visceral Fat*	9.32 ± 4.04	9.18 ± 5.07	9.42 ± 3.12	0.6724
WHR	0.91 ± 0.08	0.93 ± 0.1	0.90 ± 0.05	**0.0016**
Conicity Index	1.62 ± 0.13	1.64 ± 0.12	1.59 ± 0.13	**0.0047**
AVI	17.60 ± 4.99	16.55 ± 4.56	18.35 ± 5.16	**0.0079**
Visceral Fat*				
Obese	101(45.70)	40(43.48)	61(47.29)	0.587
Non-Obese	120(54.30)	52(56.52)	68(52.71)	
WHR				
Obese	163(73.76)	56(60.87)	107(82.95)	**<0.0001**
Non-Obese	58(26.24)	36(39.13)	22(17.05)	

Table 2. Optimal cutoff point for WHR, CI, and AVI in classifying visceral fat stratified by gender categories.

Method	Optimal cutoff	Sensitivity	Specificity	Youden J
Male				
AVI	>15.56	87.5	80.71	0.6827
CI	>1.58	87.5	46.15	0.3365
WHR	>0.92	77.5	65.38	0.4288
Female				
AVI	>18.49	77.05	85.29	0.6234
CI	>1.61	60.66	64.71	0.2536
WHR	>0.93	36.07	82.35	0.1842

Figure 1. Receiver Operator Characteristic curves of WHR, CI, and AVI in determining visceral fat. WHR - Weight-to-Hip Ratio, CI – Conicity Index, AVI – Abdominal Volume Index, AUC – Area under the curve.

Table 3. Bivariate and age-adjusted correlation between diagnostic anthropometric indices; age, WHR, CI, and visceral fat.

Male Female	Age	Visceral Fat	WHR	CI	AVI
Bivariate correlation					
AGE	1	0.166	−0.028	0.357a	0.200
Visceral Fat	.294**	1	0.742**	0.136	0.793**
WHR	0.184*	0.216*	1	0.209*	0.361a
CI	0.212*	0.195*	0.463**	1	0.625**
AVI	0.149	0.772**	0.359**	−0.005	1
Age Adjusted Correlation					
Visceral Fat	-	1	0.000	0.328**	0.787**
WHR	-	0.172	1	0.235*	0.144
CI	-	0.142	0.441**	1	0.733**
AVI	-	.770**	0.342**	0.614**	1

aCorrelation is significant at 0.01 level, * Correlation is significant at 0.05 level WHR-Waist to Hip Ratio, CI – Conicity Index, AVI – Abdominal Volume Index

4. Discussion

Until now, computed tomography (CT), magnetic resonance impedance (MRI), and bioelectric impedance analysis (BIA) techniques are known to provide valid and reliable estimates of visceral fat in the diagnosis of central obesity [9]. Because these methods are skill-intensive and expensive to implement, it is critical to develop alternative diagnostic techniques, particularly for resource-constrained settings. To our knowledge, however, this is the first study to investigate the performance of AVI, CI, and WHR in predicting central obesity using visceral fat determined by BIA as the reference standard among patients with type 2 diabetes in Ho in the Volta Region of Ghana.

The diagnostic capacities of the three adiposity indices evaluated in this study revealed AVI as the highest performing predictive index of visceral fat, regardless of gender. Thus, among men, the optimal threshold value for AVI, >15.56, demonstrated the highest sensitivity, 87.5% and specificity, 80.71% compared to CI and WHR while among women, the cutoff value for AVI, >18.49 produced the highest sensitivity, 77.05% and specificity, 85.29% (Table 2). Sensitivity and specificity values provide indications of the suitability of a diagnostic tool, and therefore are regarded as important indicators of test accuracy [21]. A highly sensitive test leads to a positive finding in an individual with a disease, while a highly specific test leads to a negative finding in an individual without a disease [22]. There is, however, an inverse relationship between sensitivity and specificity such that as sensitivity increases, specificity tends to decrease, and vice versa [23] but both must be considered to provide a holistic picture of a diagnostic test [24].

Although our findings are significant and important additions to the literature, it is imperative to mention that we were unable to draw direct comparisons between our results and those of previous studies. This is because most studies focused on investigating the usefulness of visceral adiposity measurements to predict metabolic syndrome [25,26] and cardiovascular risk factors

p > 0.05), after adjusting for age in men (0.328; p > 0.05), a positive correlation was observed between them. After adjusting for age, a significantly strong positive linear relationship between AVI and visceral fat was observed, regardless of gender. See Table 3.

[27,28], with a few studies reporting moderate-to-high predictive ability of AVI [29,30]. However, a recent study found that body roundness index (BRI) was a better predictor of visceral fat area among Chinese patients with type 2 diabetes, with sensitivity and specificity scores similar to the results of this study [31]. The apparent lack of related works in the literature, however, underscores the novelty of the current findings.

AVI estimates total abdominal volume between the pubic symphysis and xiphoid appendix, and this theoretically includes intra-abdominal fat and adipose tissue volumes [14]. WC and HC are simple adiposity indices incorporated into the formula for calculating AVI. When HC value supersedes WC, the effect of the latter is blighted, hence the value of AVI tends to increase [32]. The phenomenon of higher AVI values is often associated with women due to their higher HC compared to men (Table 1). This could explain the disparity in the gender cutoff values and related performance indices of AVI observed in this study, which is consistent with the findings of Quaye, et al. [30].

Again, we found that AVI demonstrated a better discriminatory capacity in the diagnosis of visceral fat (AUC: 0.89; p < 0.001) compared to CI (AUC: 0.68; p < 0.003) and WHR (AUC: 0.73; p < 0.001) among men and AUC: 0.89; p < 0.001 compared to CI (AUC: 0.62; p < 0.023), and WHR (AUC: 0.59; p < 0.066) among women (Figure 1). Although not a direct comparison, Perona, et al. [29] reported that AVI had a substantial AUC value greater than 0.8 in predicting metabolic syndrome in a Spanish sample. This finding is similar to the high discriminatory ability of AVI observed in this study. Furthermore, the Youden index, which measures the overall diagnostic performance was highest for AVI in both men, 0.6827, and women, 0.6234 in the diagnosis of visceral fat (Table 2). Hence, based on our findings, it suggests that AVI could be a reliable predictor of central obesity and a convenient substitute to the BIA method of determining visceral fat in this study cohort.

In the bivariate analysis based on Pearson's correlation analysis, we found that visceral fat in general correlated well with all adiposity indices measured in this study, and in both genders, except for CI in men. However, the strongest positive correlation was observed between visceral fat and AVI (male r = 0.793, p < 0.01; female r = 0.772, p < 0.01), even after adjustment for age (male r = 0.787, p < 0.01; female r = 0.770, p < 0.01) (Table 3). The finding that correlation was positive and strongest between visceral fat and AVI suggest appreciable level of agreement between the two adiposity indices in the diagnosis of visceral fat. This appears to agree with the published findings of Liu, et al. [31] where BRI, an adiposity index, demonstrated similar strong relationship with visceral fat area.

This study has a limitation worth mentioning for the interpretation of our findings. It is a hospital-based study, hence the results cannot be generalized to the entire population in Ho municipality. However, the findings provide valuable initial estimates for future research on developing country-specific thresholds for alternative measures in the diagnosis of visceral fat.

5. Conclusion

AVI appeared to have outperformed CI and WHR in diagnosing visceral fat levels. Hence, AVI could be a better predictive tool for visceral obesity among patients with type 2 diabetes in low-resource settings.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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