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Triglycerides and waist to height ratio are more accurate than visceral adiposity and body adiposity index to predict impaired fasting glucose

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ABSTRACT

Aims: To evaluate the clinical accuracy of novel indices visceral adiposity index (VAI) and body adiposity index (BAI) to identify patients with impaired fasting glucose (IFG) and compare with its individual components and other obesity indicators.

Methods: A cross-sectional study was conducted in Mexican population. Body mass index (BMI), waist circumference, hip circumference, triglycerides (TG), High density lipoprotein cholesterol (HDL-C), VAI, BAI, waist to hip ratio (WHR) and waist to height ratio (WHtR) were determined. We plotted a receiver operating characteristic curves to assess the abilities to discriminate subjects with IFG from those with normal glucose tolerance (NGT) of the measurements. A binary logistic regression analysis was performed to determine the strength of association with IFG.

Results: A total of 280 individuals were included, from which 144 (51.3%) have IFG; the mean age was 47.14 years and 164 (55.5%) were females. Compared with NGT subjects, the participants with IFG had significantly higher levels of BMI, WHtR, VAI, BAI and TG. The measurements with highest area under the curve were TG, (0.631, 95% confidence interval [CI] 0.566–0.697) VAI (0.628, 95% CI 0.563–0.693) and WHtR (0.622, 95% CI 0.557–0.688) and in the adjusted binary logistic regression model, were found to be independently associated with IFG, Odds Ratio of 2.665, (95% CI 1.567–4.533) 2.567 (95% CI 1.527–4.317) and 2.171 (95% CI 1.102–4.276) respectively.

Conclusions: Our data provide evidence that TG, VAI and WHtR could be considered potential tools for the risk assessment of type 2 diabetes mellitus (T2DM) in this population.

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1. Introduction

Diabetes has become a worldwide public health problem, increasing incidence of type 2 diabetes mellitus (T2DM) and its macrovascular and microvascular complications are associated with increased mortality and morbidity and health-system costs in the world [1–3].

In Mexico, the results of The Mexican National Health Survey (ENSA) in 2016 showed that the prevalence of diabetes was 9.4% in adults, thus Mexican population appear to have a high propensity toward developing T2DM [4]. Furthermore, has been reported that in Mexico, T2DM is the cause of at least one third of all deaths of individuals between 35 and 74 years of age [5].

T2DM is a multifactorial metabolic disease associated with several conditions, including physical inactivity, genetic predisposition, poor nutrition, and obesity. Many studies have firmly confirmed the pivotal role of obesity in the development of T2DM [6,7]. However, obesity is heterogeneous and not every obese patient develops chronic complications. In this regard, central and visceral adiposity have been found to be associated with an increased risk of T2DM [8].

The most widely used method of measuring obesity is BMI; however, the BMI does not consider body fat distribution and is unable to differentiate between lean and fat mass [9–11]. Hence, other measures of adiposity, like waist circumference (WC), WHR and WHtR have been developed. Nevertheless WC does not help in distinguishing between subcutaneous and visceral (both omental and mesenteric) fat mass. Other simple indices that combine anthropometric measure(s) and biochemical factor(s) are now available, such as the body adiposity index (BAI) [12], that may be provide a direct estimate of percentage body adiposity (%BF), and the visceral adiposity index (VAI) [13], that was associated with visceral fat tissue [14,15] and could be used as a surrogate marker of adipose tissue dysfunction [16]; additionally, VAI has shown a strong association with insulin resistance [17,18] and has shown better predictive power for incident diabetes events than its individual components (WC, BMI, TG and HDL-C) [19] However, only a few studies have examined the association between the VAI and the risk for type 2 diabetes and compared it to various body fatness indexes, and they came to inconsistent conclusions [20–22].

On the other hand, impaired fasting glucose (IFG), defined as a fasting plasma glucose concentration >100 mg/dl) and <126 mg/dl is an intermediate condition in the transition between normal blood glucose levels and T2DM, individuals with IFG have a high-risk for diabetes development [23]. If VAI and BAI are better predictors of impaired glucose metabolism compared with simple anthropometric measures of adiposity BMI, WHtR or WHR in Mexican population is unclear.

Therefore, the aim of this study was to assess the clinical accuracy of VAI and BAI to identify patients with IFG and to compare the predictive ability with its individual components (WC, BMI, TG and HDL-C) and other body fatness indices, i.e., WHR and WHtR.

2. Subjects, materials and methods

2.1. Study design and population

This cross-sectional study included non-smoker, overweight and obese, otherwise healthy ambulatory adults who did not exercise regularly and which were recruited by a simple random sampling approach, from a target population of two General Hospitals in Mexico City. Pregnant and lactating women were excluded. The glucose status (NGT vs IFG) was identified at moment of evaluation, so subjects with IFG do not have any pharmacological treatment

2.2. Data collection

Anthropometric measurements were conducted at the time of interview including weight, height, WC and blood pressure. Body weight and height were measured by standard methods. BMI was calculated as the weight in kilograms divided by the square of the height in meters. WC was measured at 1 cm above the umbilicus level at minimal respiration. WHR was calculated by dividing the WC (cm) by the hip circumference (cm), while the WHtR was obtained by dividing WC (cm) by the height (cm).

The BAI was calculated using the following formula: (Hip circumference/Height $^{1.5}$ –18)

The VAI was calculated using the following sex-specific equation, where TG and HDL-C levels are expressed in mmol/l:

VAI = (WC(cm)/(39.68+(1.88*BMI)))*(TG/1.03)*(1.31/HDL) for males and VAI = (WC(cm)/(36.58+(1.89*BMI)))*(TG/0.81)*(1.52/HDL) for females.

Blood samples were collected in the morning after at least 8 h of overnight fasting. Fasting plasma glucose (FPG) levels were measured by an enzymatic colorimetric kit (quantILab Ref 0018259140 ©). HDL-C and TG were assessed enzymatically using an automatic biochemistry analyzer (Hitachi Inc) and commercial reagents.

2.3. Statistical analysis

The Statistical Packages for Social Sciences SPSS version 21 was used for data analysis. Normality of distribution for quantitative data was assessed by the Kolmogorov-Smirnov test. Baseline characteristics for continuous variables were presented as mean ± Standard Deviation (SD) for parametric distribution and median and interquartile range for non-parametric distribution; rates and proportions were calculated for categorical data. Differences between groups (IFG vs NGT) were detected by the Mann–Whitney or unpaired t-test for continuous variables and by the Chi-squared-test for categorical variables.

Receiver-operating characteristic (ROC) curve analyses were performed to determine appropriate cut-off points of HDL-C, TG, BMI, WC, WHR, WHtR, BAI and VAI for identifying individuals with IFG; respective cut-off values were

determined by calculating Youden index. Area under the curve (AUC) was compared using the method of Hanley and McNeil [24].

A binary logistic regression model was performed to assess the risk association between the different measurements and IFG and odds ratio with 95% confidence interval (CI) were computed to assess the strength of association. Previously cut points of ROC analyses were used to classify participants to as being either at "high" or "low" level of each variable in regression models. Only the variables with a p value of the AUC < 0.05 were included in the regression analysis.

3. Results

3.1. Demographic and clinical characteristics

A total of 280 patients were included; the basic characteristics of the study population are shown in Table 1. Briefly, 55.5% (n = 164) of the subjects were females, the mean age of the study population was 47.14 years, and 51.3% (n = 144) have IFG.

When the characteristics of the studied subjects were classified according to glucose status (Table 2), it was found that age, BMI, WHtR, VAI, BAI and TGC were significantly higher in the group of IFG than in group of NGT.

3.2. Assess of accuracy of obesity indices

We then assessed the possible diagnostic accuracy of BMI, WC, HC, WHR, WHtR, BAI and VAI for the presence or absence IFG by means of ROC curve analysis.

Table 1 – Characteristics of population.

Variables	
Age	45.68 ± 11.89
Female (%)	55.5
IFG (%)	51.3
Anthropometric measures	
Height (cm)	160 [154.5–168]
Weight (kg)	79.45 ± 12.37
WC (cm)	97.88 ± 11.06
HC (cm)	105.28 ± 9.62
Anthropometric indices	
BMI	29.68 [27.25–32.83]
WHR	0.93 ± 0.73
WHtR	0.60 [0.55–0.64]
BAI	32.9 [28.33–37.38]
VAI	2.44 [1.64–3.58]
Laboratory measures	
TG (mg/dl)	150 [119–200]
HDL-C (mg/dl)	44.25 [38–52.5]

Abbreviations: IFG = Impaired Fasting Glucose, WC = Waist Circumference, HC = Hip Circumference, BMI = Body Mass Index, WHR = Waist Hip Ratio, WHtR = Waist Height Ratio, BAI = Body adiposity index, VAI = Visceral Adiposity index, TG = Triglycerides, HDL-C = HDL-Cholesterol. Data are presented as means ± standard deviation, median and interquartile range or frequencies.

According to the results of ROC analysis (Table 3), the largest AUC was observed for TG, followed by VAI and WHtR ($p < 0.01$); BAI and BMI presented a lower AUC compared with TG, VAI and WHtR. The p value for AUC of the other measurements was >0.05. Globally, WHtR had better specificity, but TG and VAI had better sensitivity. However, we do not found significant differences in the AUCs for VAI, WHtR and TGC.

3.3. Associations of obesity indicators with IFG

Because BMI or TG levels are components of VAI and therefore, not appropriate for prediction models already incorporating these indexes, two predictive models were fitted: model 1 include VAI, BAI, and WHtR, and model 2 include BMI, BAI, WHtR and TG; both models were adjusted for gender and age, for this last, a dichotomic variable was created, through the division of patients into quartiles and then separated those within the highest quartile of age from the remainder.

Tables 4 and 5 present the predictive performances of combinations of VAI, BAI, TG and WHtR. Both VAI and WHtR showed an independent association with IFG in model 1. In model 2, TG showed association with IFG and WHtR kept its association. Controlling for gender and age did not appreciably alter the OR compared to the unadjusted model. Neither BAI (in 2 models) nor BMI (in model 2) showed association with IFG.

4. Discussion

T2DM has become a major health problem worldwide, especially in Mexico. Identification of high risk populations is important for early intervention. Although individuals with IFG have an enhanced risk of conversion to diabetes, only a fraction become diabetic within a certain timeframe [25].

Therefore, identification of additional risk factors associated with carbohydrate metabolism disorders could provide potential predictions tools for the development of T2DM.

In the present study, we compared the ability of various common anthropometric indices, including novels BAI and VAI, and its components to discriminate between two different glucose tolerance statuses, IFG vs NGT and, by means of a logistic regression analysis, we evaluated the strength of the association with IFG.

Central obesity is mainly related to visceral fat accumulation. Both, subcutaneous and visceral fat had been studied as independent compartments and associated to cardiometabolic comorbidities [26]. The VAI and BAI are a recently developed parameters used to get a better assess of fat mass and the degree of visceral adiposity.

Previous studies have shown that VAI increased in different stages of glucose intolerance [21]. Kumpatla et al. reported that a cut-off value of VAI 2.3 gave sensitivity of 61.2% and specificity of 59.7% to detect glucose intolerance [27]. In other study VAI showed strong correlation with fasting insulin and insulin sensitivity [28]. In cross-sectional studies VAI is associated with adiponectin values, IFG and diabetes risk [20,29]. Nevertheless, in these studies the ability of VAI to identify type 2 diabetes risk was not found to be superior to easily

Table 2 – Characteristics of IFG patients and NGT controls.

Variable	IFG N = 110	NGT N = 102	P value
Age	49.94 ± 10.05	41.17 ± 12.05	<0.01
Female	93 (64.6%)	71 (52.2%)	<0.05
Weight (kg)	79.19 ± 12.22	79.72 ± 12.56	>0.05
Height (cm)	159 [155–166]	163 [154–170]	<0.05
WC (cm)	99.11 ± 10.83	96.58 ± 11.20	>0.05
HC (cm)	105.69 ± 9.67	104.84 ± 9.59	>0.05
BMI (kg/m^2)	30.37 [27.63–33.75]	29.33 [26.91–32.04]	<0.05
WHR	0.93±0.070	0.92 ± 0.75	>0.05
WHtR	0.61 [0.56–0.66]	0.58 [0.54–0.63]	<0.01
BAI	34.36 [29.18–38.51]	32.33 [27.56–36.78]	<0.05
VAI	2.79 [1.82–3.91]	2.21 [1.52–3.0]	<0.01
TGC (mg/dl)	167 [124.25–233.5]	143 [113–170]	<0.01
HDL-C (mg/dl)	44 [38–52.85]	44.55 [37.8–52.5]	>0.05

Abbreviations: IFG = Impaired Fasting Glucose, NGT = Normal Glucose Tolerance, WC = Waist Circumference, HC = Hip Circumference, BMI = Body Mass Index, WHR = Waist Hip Ratio, WHtR = Waist Height Ratio, BAI = Body adiposity index, VAI = Visceral Adiposity index, TG = Triglycerides, HDL-C = HDL-Cholesterol. P value from unpaired t or Mann–Whitney tests for mean or median differences, respectively.

Table 3 – Curve ROC analysis.

Variable	Cutoff Point	Sens.	Spec.	Area under ROC curve	SE	95% CI	P value
BMI	29.65	58.3%	57.4%	0.569	0.34	0.502–0.636	<0.05
WC	96.5	54.9%	52.9%	0.561	0.34	0.494–0.628	>0.05
HC	104.5	51.4%	54.4%	0.527	0.35	0.459–0.594	>0.05
TG	147.5	63.9%	53.7%	0.631	0.33	0.566–0.697	<0.01
HDL-C	43.95	52.8	47.1%	0.494	0.35	0.426–0.561	>0.05
WHR	0.92	55.6%	50.7%	0.548	0.34	0.481–0.616	>0.05
WHtR	0.6	60.4%	62.5%	0.622	0.34	0.557–0.688	<0.01
VAI	2.3	63.9%	57.4%	0.628	0.33	0.563–0.693	<0.01
BAI	32.53	56.9%	54.4%	0.580	0.34	0.513–0.647	<0.05

Abbreviations: Sens. = sensitivity, Spec. = specificity, SE = standard error, 95% CI = 95% confidence interval, BMI = Body Mass Index, WC = Waist Circumference, HC = Hip Circumference, TG = Triglycerides, HDL-C = HDL-Cholesterol, WHR = Waist Hip Ratio, WHtR = Waist Height Ratio, VAI = Visceral Adiposity index, BAI = Body adiposity index.

Table 4 – Binary logistic regression Model 1.

Measurements	OR	Wald statistic	P value	95% CI	
				Lower	Upper
VAI	2.567	12.653	<0.01	1.527	4.317
BAI	0.696	0.817	>0.05	0.317	1.528
WHtR	2.094	5.893	<0.05	1.153	3.803

Abbreviations: OR = Odds Ratio, 95% CI = 95% confidence interval, VAI = Visceral Adiposity index, BAI = Body adiposity index, WHtR = Waist Height Ratio.

Table 5 – Binary logistic regression Model 2.

Measurements	OR	Wald statistic	P value	95% CI	
				Lower	Upper
BMI	1.299	0.626	>0.05	0.680	2.482
WHtR	2.171	5.021	<0.05	1.102	4.276
TG	2.665	13.074	<0.01	1.567	4.533
BAI	0.666	0.961	>0.05	0.295	1.502

Abbreviations: OR = Odds Ratio, 95% CI = 95% confidence interval, VAI = Visceral Adiposity index, BAI = Body adiposity index, WHtR = Waist Height Ratio.

measurable anthropometric markers, such as BMI, WC and WHtR. Furthermore, in cohort studies VAI has been associated with increased risk for T2DM, and although has been reported that VAI is better than WC, WHtR and BMI [30]. this observation has not been corroborated in following studies [19,31,32]. In addition, Yang et al shown that VAI is not superior to triglyceride levels to predict T2DM risk [21].

On the other hand, even though has been suggested that BAI may function as a measure of overall adiposity [33], validation studies of the BAI have shown that tends to overestimate adiposity at lower %BF and underestimate adiposity at higher BF [34]. Alvim et al. in a study that evaluated two populations (general and Amerindian) in Brazil, reported that BAI was better risk predictor for T2DM than BMI and WC in the Amerindian population and was the index with highest odds ratio (6.32, CI 95% 1.41–28.28) for T2DM in men from the general population [35]. However, BAI was not more strongly associated with diabetes incidence than BMI, WC and WHtR in two large prospective studies in both sexes [36,37].

Our present results indicate that although the VAI and WHtR could be alternative risk factors to predict T2DM, both showed similar discriminating abilities compared to TG. This conclusion is supported by our observations of that the differences in the AUCs between VAI, WHtR compared with TG were not statistically significant. Furthermore, we found that associations with IFG risk were relatively similar for VAI, WHtR and TG. BAI does not showed association with IFG risk.

Current studies show that both VAI and WHtR are similarly predictors of incidence of T2DM, nevertheless WHtR is easier to obtain. Furthermore, we found that the ability of the VAI and WHtR to identify subjects with IFG was not superior to TG, and given the simplicity of WC and Height measurement and TG assessment, we suggest that the WHtR and TG would be useful tools for the evaluation of the risk for T2DM.

Although obesity and adiposity indices are well-established predictors of diabetes, as has been reported in other studies [27,30] our ROC analysis shows only a low to moderate predictive ability of these measurements to discriminate tolerance glucose status. This finding could be explained by the fact that the indexes evaluated do not necessarily define visceral fat dysfunction, which is characterized by chronic subclinical inflammation, with greater association with glucose alterations. Additionally, other conditions as ectopic fat accumulation, particularly hepatic fat, dysfunctional endothelial or vitamin D deficiency had been associated with alterations of glucose homeostasis and its implications could be evaluated in future studies.

The study findings have some limitations; the cross-sectional design of the study does not allow safe conclusions to be drawn on the causality of VAI, WHtR and TG in terms of future progression to T2DM.

In conclusion, our data provide evidence that obesity and adiposity are important risk factors for IFG among mexican population. TG, VAI and WHtR show similar prediction performance for IFG and could be used for the risk assessment of T2DM in this population.

Author contributions

Cesar Ivan Elizalde-Barrera led this study, is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. All authors contributed to interpretation, analysis and discussion of data; reviewed the manuscript and approved the final version.

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Declaration of Competing Interest

We declare that we have no conflicts of interest

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.diabres.2019.05.019.

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