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# Anthropometric Predictors for Multiple Risk Factor Aggregation in Adults from Maracaibo City

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## Abstract

**Context and Objective:** There are several anthropometric measures that are useful for diagnosis obesity and also are related to the development of different cardiovascular risk factors. The purpose of this study was to determine the predictive ability of various anthropometric parameters for the multiple risk factors aggregation (MRFA) in the adult population of the city of Maracaibo-Venezuela.

**Participants and Methods:** This was a cross-sectional study undertaken with 1902 adult individuals of both genders. Waist circumference (WC), body mass index (BMI) and waist-height index ratio (WHtR) were determined. MRFA was defined as the presence ≥2 components of metabolic syndrome (MS) except for high waist circumference. The Receiver Operating Characteristic (ROC) curve was plotted to determine the area under the curve (AUC) for each anthropometric parameter.

**Results:** There were 52.2% women in this study. All studied anthropometric variables were associated with MRFA ($p$<0.0001). According to ROC curves, the best AUC for a MRFA parameter was for WHtR [Men: 0.725 (0693-0757) and Women: 0.760 (0729-0791)]. However when analyzing Odds Ratios, WC is the only one that exhibits association after adjustment [OR 2.6 (1.44-2.95); $p$<0.01].

**Conclusion:** Waist circumference provides greater predictive ability of MRFA compared to other parameters.

**Keywords:** Cardiovascular risk factor; Waist circumference; Body mass index; Waist-height index ratio; Obesity; Prediction; ROC Curves

**Abbreviations:** AUC: Area Under the Curve; BMI: Body Mass Index; HBP: High Blood Pressure; HDL-C: High Density Lipoprotein-Cholesterol; MRFA: Multiple Risk Factor Aggregation; MS: Metabolic Syndrome; OR: Odds Ratio; ROC: Receiver Operating Characteristic; SD: Standard Deviation; T2DM: Type 2 Diabetes Mellitus; TAG: Triacylglycerides; WC: Waist Circumference; WHO: World Health Organization; WHtR: Waist-to-Height Ratio

## Introduction

Anthropometric parameters such as weight, length, skinfolds, perimeters and body diameters, are widely used in the medical field for clinical nutrition assessment, with the aim of assessing the growth, development, and determination of the individual body composition for diagnosis and prognosis for diverse pathological conditions such as low birth weight, malnutrition, and especially obesity [1].

In this sense, there are several anthropometric measures such as waist circumference (WC), body mass index (BMI), waist-hip ratio, waist-to-height ratio (WHtR), among others; which also serve as diagnostic methods for obesity [2,3]. They have also been linked to the development or progression of various cardiovascular risk factors such as dyslipidemia, high blood pressure (HBP), diabetes mellitus type 2 (T2DM) and metabolic syndrome (MS) [4,5].

Within these anthropometric measurements, BMI is the most widely used in clinical practice for the detection of obesity in the adult population, given its easy implementation, safety and minimal cost, but various reports have raised serious disadvantages due to their low ability to distinguish between lean and fat mass in an individual [6,7]. For these reasons, together with the great variability of body composition depending on gender, age group, ethnicity and socio-cultural habits [8]; the selection of the best anthropometric parameter able to predict morbidity and mortality from cardiometabolic diseases has been very controversial.

Therefore, the main purpose of this study was to determine the predictive ability of various anthropometric parameters for the multiple risk factors aggregation in the adult population of the city of Maracaibo-Venezuela.

# Research Design and Methods

## Subject Selection

The Maracaibo City Metabolic Syndrome Prevalence Study (MMSPS) [9] was a cross-sectional research study undertaken in the city of Maracaibo-Venezuela, the second largest city in the country with 2.500.000 inhabitants, with the purpose of identifying and analyzing MS and cardiovascular risk factors in our adult population. A total of 2,230 subjects were enrolled through a multi-stage random sampling, out of which 1,902 were selected after the exclusion of individuals without serum insulin levels determination, and those with a previous diagnosis of Type 2 Diabetes Mellitus (T2DM). The study was approved by the Bioethics Committee of the Endocrine and Metabolic Diseases Research Center – University of Zulia, and all participants signed a written consent before being interrogated and physically examined by a trained team.

## Clinical and Biochemical Evaluation

Assessment of blood pressure was done using a calibrated mercury sphygmomanometer, with patients previously rested (during at least 15 minutes) in a sitting position with both feet touching the floor, the arm was positioned at heart level; a proper sized cuff was used for the procedure. The WHO classification for Obesity is based upon the BMI [10] [weight/height$^2$] expressed in kg/m$^2$. Height was obtained using a calibrated rod, millimeters and centimeters, with the patient barefooted and his/her back facing the wall. Weight was recorded using a digital scale (Tanita, TBF-310 GS Body Composition Analyzer, Tokyo – Japan) with the patient using light clothing and no shoes. WC was assessed using calibrated measuring tapes in accordance the USA National Institutes of Health protocol [11]. WHtR was determined from waist circumference (cm) divided by height (cm). An antecubital blood sample was taken following an overnight fasting of 8-12 hours in order to measure the following: fasting blood glucose, total cholesterol, triacylglycerides (TAG) and High Density Lipoprotein-Cholesterol (HDL-C) with an enzymatic colorimetric technique and a computerized analyzer (Human, Magdeburg, Germany).

## Definitions

Multiple Risk Factor Aggregation (MRFA) was defined as ≥2 of the following: impaired fasting glucose (≥100mg/dL or presence of diagnosis of T2DM), HBP (Systolic Blood Pressure ≥130mmHg and/or Diastolic Blood Pressure ≥85mmHg; or history of antihypertensive usage), high TAG (≥150mg/dL or presence of treatment for this disorder), and low HDL-C (<40mg/dL in males and <50mg/dL in females or presence of treatment for this disorder).

## Statistical Analysis

Normal distribution of continuous variables was evaluated by using Geary's test. For normally distributed variables, the results were expressed as arithmetic mean ± SD (standard deviation). Variables without a normal distribution were logarithmically transformed, and normal distribution later corroborated. Differences between arithmetic mean were assessed using Student's *t*-test (when two groups were compared). Qualitative variables were expressed as absolute and relative frequencies. The Receiver Operating Characteristic (ROC) curves were constructed to expect presence of 2 or more metabolic components for MS, with the exception of WC. ROC Curves were plotted for each gender using R Project software for Statistical Computing. Cut-off points were selected using The Youden Index, the distance of the point closest to (0.1) on the ROC curve and the comparison of Area Under Curve (AUC) was calculated with DeLong's test. Two logistic regression models were calculated for MRFA (Dependent Variable), the first adjusted for: gender, age groups, ethnic groups, socioeconomic status and anthropometric parameters definitions. The second one adjusted for: gender, age groups, ethnic groups, socioeconomic status and amount of abnormal anthropometric parameter. Statistical analysis was done using the Statistical Package for the Social Sciences (SPSS) v19 for Windows (IBM Inc. Chicago, IL).

# Results

## General characteristics of the Population

A total of 1,902 subjects were studied (52.2% females). The arithmetic mean of age was 38.7±15.0 years, being the age group 20-29yrs the biggest one with 26.9% of the sample. The majority of the population was considered as mixed race (76.9%), classified as Middle Class socioeconomic status (40.2%), where 37% displayed HBP, 24.1% showed dysglycemia, 26.1% hypertriacylglyceridemia, 56.5% has Low HDL-C levels, and 43.3% of the subjects had 2 or more risk factors (Table 1).

## Overall Anthropometric Evaluation

Table 2 shows the results between subjects with or without MFRA according to gender, rendering significant differences between all variables. It's noteworthy to point out that all measurements were higher in those with positive MFRA than in those individuals whom had no risk aggregation, being grossly observed in WC with differences over 10 cm between such groups.

| | Females (n=992) | | Males (n=910) | | Total (n=1902) | |
|---|---|---|---|---|---|---|
| | **n** | **%** | **n** | **%** | **n** | **%** |
| **Age Groups (years)** | | | | | | |
| 18-20 | 87 | 8.8 | 70 | 7.7 | 157 | 8.3 |
| 20-29 | 218 | 22.0 | 294 | 32.3 | 512 | 26.9 |
| 30-39 | 176 | 17.7 | 178 | 19.6 | 354 | 18.6 |
| 40-49 | 230 | 23.2 | 164 | 18.0 | 394 | 20.7 |
| 50-59 | 170 | 17.1 | 136 | 14.9 | 306 | 16.1 |
| ≥60 | 111 | 11.2 | 68 | 7.5 | 179 | 9.4 |
| **Ethnic groups** | | | | | | |
| Mixed | 757 | 76.3 | 706 | 77.6 | 1463 | 76.9 |
| Hispanic White | 162 | 16.3 | 138 | 15.2 | 300 | 15.8 |
| Afro-Venezuelan | 24 | 2.4 | 31 | 3.4 | 55 | 2.9 |
| Amerindian | 39 | 3.9 | 34 | 3.7 | 73 | 3.8 |
| Others | 10 | 1.0 | 1 | 0.1 | 11 | 0.6 |
| **Socioeconomic Status** | | | | | | |
| Stratum I: High Class | 17 | 1.7 | 19 | 2.1 | 36 | 1.9 |
| Stratum II: Upper middle Class | 172 | 17.3 | 175 | 19.2 | 347 | 18.2 |
| Stratum III: Middle Class | 379 | 38.2 | 385 | 42.3 | 764 | 40.2 |
| Stratum IV: Working Class | 373 | 37.6 | 301 | 33.1 | 674 | 35.4 |
| Stratum V: Lower-Extreme Poverty | 51 | 5.1 | 30 | 3.3 | 81 | 4.3 |
| **High Blood Pressure¶** | 324 | 32.7 | 379 | 41.6 | 703 | 37.0 |
| **Impaired Fasting Glucose‡** | 216 | 21.8 | 243 | 26.7 | 459 | 24.1 |
| **High Triacylglyceridesψ** | 206 | 20.8 | 290 | 31.9 | 496 | 26.1 |
| **Low HDL-C¥** | 624 | 62.9 | 451 | 49.6 | 1075 | 56.5 |
| **Elevated Waist Circumference§** | 779 | 78.5 | 638 | 70.1 | 1417 | 74.5 |
| **Multiple Risk Factor Aggregation†** | 395 | 39.8 | 429 | 47.1 | 824 | 43.3 |
| **TOTAL** | **992** | **52.2** | **910** | **47.8** | **1902** | **100** |

¶ Systolic Blood Pressure ≥130mmHg and/or Diastolic Blood Pressure ≥85mmHg or history of antihypertensive usage
‡ ≥100mg/dL or presence of diagnosis of type 2 diabetes
ψ ≥150mg/dL or presence of treatment for this disorder
¥ <40mg/dL in males and <50mg/dL in females or presence of treatment for this disorder
§ ≥90cm in males and ≥80cm in females
† Defined as ≥2 of the following: High Blood Pressure, Impaired Fasting Glucose, High Triacylglycerides, Low HDL-C
**Table 1:** General characteristics of the general population according to gender. The Maracaibo City Metabolic Syndrome Prevalence Study, 2014

| | Females (n=992) | | | Males (n=910) | | |
|---|---|---|---|---|---|---|
| | **Without MRFA** | **With MRFA** | | **Without MRFA** | **With MRFA** | |
| | **Mean±SD** | **Mean±SD** | ***p**** | **Mean±SD** | **Mean±SD** | ***p**** |
| **Body Mass Index (Kg/m²)** | 26.1±5.5 | 30.3±6.5 | $1.9x10^{-24}$ | 26.7±5.3 | 30.9±6.5 | $6.1x10^{-25}$ |
| **Waist-to-Height Ratio** | 0.55±0.08 | 0.62±0.09 | $3.2x10^{-34}$ | 0.54±0.08 | 0.62±0.09 | $2.0x10^{-43}$ |
| **Waist Circumference (cm)** | 86.7±12.4 | 96.8±13.4 | $7.9x10^{-32}$ | 92.2±13.1 | 105.0±16.1 | $1.3x10^{-35}$ |

(*) *t*-Student test (After logarithmic transformation)
MRFA=Multiple Risk Factor Aggregation; SD=Standard Deviation
**Table 2:** Anthropometric parameters by gender and presence of Multiple risk factor aggregation. The Maracaibo City Metabolic Syndrome Prevalence Study, 2014

## ROC curves for Anthropometric variables

ROC curves were plotted for both genders to determine the BMI and WHtR cut-off values for MRFA in each gender (Figure 1). Based on the cut-off predicted value for WC, the results were 90.25cm for women and 95.15 for men. For WHtR, the cut-off points were similar for both genders with 0.56 for women and for men. The BMI cut-off point for females was 26.7 kg/m$^2$, and for males 27.5 kg/m$^2$. Table 3 shows the cut-off points for each anthropometric parameter with their respecting predicted values, as well as AUC comparisons according to gender.

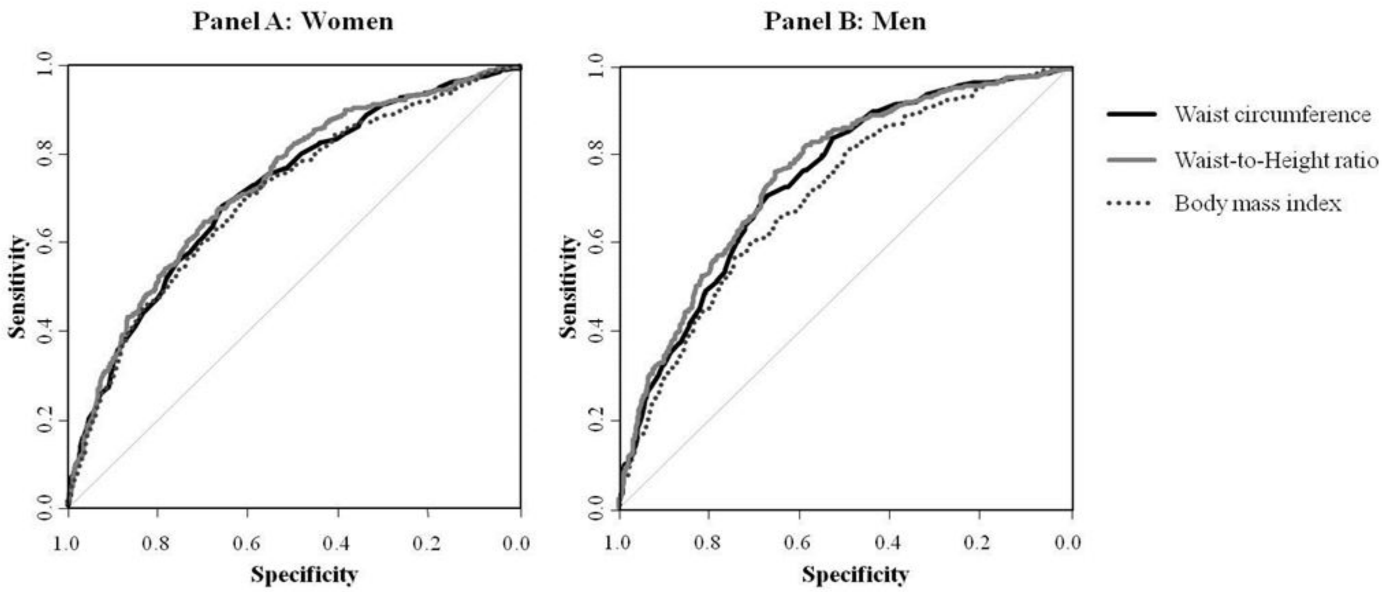


**Figure 1:** ROC curves constructed to determine Waist Circumference, Body Mass Index and Waist-to-Height ratio cut-off points for the detection of multiple risk factor aggregation. The Maracaibo City Metabolic Syndrome Prevalence Study, 2014

| | Anthropometric Parameters | | | *DeLong's test (p)** | | |
|---|---|---|---|---|---|---|
| | **Waist Circumference (A)** | **Waist-to-Height Ratio (B)** | **Body Mass Index (C)** | **A vs B** | **A vs C** | **B vs C** |
| **Females** | | | | | | |
| Cutoffs point | 90.25 cm | 0.56 | 26.7 kg/m$^2$ | | | |
| AUC (CI 95%) | 0.716 (0.684-0.748) | 0.725 (0.693-0.757) | 0.700 (0.667-0.733) | 0.073 | 0.100 | 0.009 |
| Sensivity (%) | 68.4 | 70.1 | 69.6 | | | |
| Specificity (%) | 65.8 | 62.5 | 61.5 | | | |
| Youden Index | 0.34 | 0.33 | 0.31 | | | |
| Distance to ROC | 0.465 | 0.479 | 0.492 | | | |
| **Males** | | | | | | |
| Cutoffs point | 95.15 cm | 0.56 | 27.5 kg/m$^2$ | | | |
| AUC (CI 95%) | 0.746 (0.715-0.778) | 0.760 (0.729-0.791) | 0.712 (0.679-0.745) | 0.601 | 1.99x10$^{-7}$ | 2.98x10$^{-6}$ |
| Sensivity (%) | 71.1 | 71.1 | 68.5 | | | |
| Specificity (%) | 67.4 | 68.6 | 60.7 | | | |
| Youden Index | 0.39 | 0.40 | 0.29 | | | |
| Distance to ROC | 0.435 | 0.426 | 0.503 | | | |

*Differences between AUC

**Table 3:** Optimal cut-off values, area under curve, sensitivity, specificity, Youden Index and Distance to ROC of anthropometric parameters by gender. The Maracaibo City Metabolic Syndrome Prevalence Study, 2014

### Anthropometric variables and MFRA

Anthropometric variables were categorized according to cut-off point and association was calculated, demonstrating that all 3 variables were associated with MFRA (Table 4). During the multivariable analysis, BMI and WHtR loss their association, while WC maintained it (Table 5). Moreover, an increasing pattern is observed when MFRA numbers of variables are grouped, that goes from 22.1% in the healthy group to 62.5% in the group with 3-factors MRFA (Figure 2). In a final multivariable analysis, a similar trend is shown with progressive increase in the value of the OR for MRFA as the number of anthropometric alterations are added, going from OR: 1.48 with 1 anthropometric variable to OR: 3.93 with 3-factors MRFA; $p<0.00001$, Figure 3.

## Discussion

Several studies have reported that body composition assessed by BMI is a good predictor of cardiometabolic risk [12]. However, most research studies in this field have shown that the measurements body fat distribution is more important; therefore its accuracy makes central obesity markers the best predictors in morbidity and mortality for cardiovascular disease compared to BMI [13,14]. Based on different findings worldwide, an ongoing debate has developed concerning which of these anthropometric parameters provides clinicians with a better understanding of potential cardiometabolic risks in their patients. In this regard, our findings

| | Without MRFA | | With MRFA | | | |
|---|---|---|---|---|---|---|
| | n | % | n | % | $\chi^2$ *(p)* | Z Test p |
| **Body Mass Index‡** | | | | | **163.66 (<0.0001)** | |
| Normal | 651 | 60.4 | 254 | 30.8 | | <0.05 |
| Elevated | 427 | 39.6 | 570 | 69.2 | | <0.05 |
| **Waist-to-Height Ratioψ** | | | | | **233.79 (0.00001)** | |
| Normal | 639 | 59.3 | 199 | 24.2 | | <0.05 |
| Elevated | 439 | 40.7 | 625 | 75.8 | | <0.05 |
| **Waist Circumference¶** | | | | | **246.13 (<0.00001)** | |
| Normal | 717 | 66.5 | 249 | 30.2 | | <0.05 |
| Elevated | 361 | 33.5 | 575 | 69.8 | | <0.05 |
| **TOTAL** | 1078 | 100.0 | 824 | 100.0 | | |

MRFA=Multiple Risk Factor Aggregation
‡ ≥26.7 kg/m² in females and ≥27.5 kg/m² in males
ψ ≥0.56 in both genders
¶ >90cm in females and >95cm in males
**Table 4:** Association between anthropometric parameters classification and multiple risk factor aggregation. The Maracaibo City Metabolic Syndrome Prevalence Study, 2014

| | Crude Odds Ratio (CI 95%[a]) | $p^b$ | Adjusted Odds Ratio[c] (CI 95%) | $p^b$ |
|---|---|---|---|---|
| **Gender** | | | | |
| Female | 1.00 | - | 1.00 | - |
| Male | 1.35 (1.12 – 1.62) | < 0.01 | 1.73 (1.40 – 2.13) | < 0.01 |
| **Age Groups (years)** | | | | |
| <20 | 1.00 | - | 1.00 | - |
| 20-29 | 1.13 (0.72 – 1.76) | 0.60 | 0.73 (0.46 – 1.17) | 0.19 |
| 30-39 | 2.39 (1.52 – 3.74) | < 0.01 | 1.30 (0.81 – 2.09) | 0.29 |
| 40-49 | 5.58 (3.59 – 8.68) | < 0.01 | 2.96 (1.85 – 4.75) | < 0.01 |
| 50-59 | 7.04 (4.46 – 11.12) | < 0.01 | 3.68 (2.26 – 5.99) | < 0.01 |
| ≥60 | 10.47 (6.29 – 17.48) | < 0.01 | 5.59 (3.23 – 9.68) | < 0.01 |
| **Ethnic groups** | | | | |
| Mixed | 1.00 | - | 1.00 | - |
| Hispanic White | 1.16 (0.90 – 1.49) | 0.24 | 1.04 (0.78 – 1.39) | 0.78 |
| Afro-Venezuelan | 1.38 (0.80 – 2.36) | 0.25 | 1.46 (0.80 – 2.67) | 0.22 |
| Amerindian | 0.57 (0.34 – 0.95) | 0.03 | 0.66 (0.35 – 1.22) | 0.18 |
| Others | 1.11 (0.34 – 3.64) | 0.87 | 1.27 (0.30 – 5.33) | 0.74 |
| **Body Mass Index‡** | | | | |
| Normal | 1.00 | - | 1.00 | - |
| Elevated | 3.42 (2.82 – 4.14) | < 0.01 | 1.33 (0.99 – 1.78) | 0.06 |
| **Waist-to-Height Ratioψ** | | | | |
| Normal | 1.00 | - | 1.00 | - |
| Elevated | 4.57 (3.74 – 5.59) | < 0.01 | 1.43 (0.99 – 2.04) | 0.05 |
| **Waist Circumference¶** | | | | |
| Normal | 1.00 | - | 1.00 | - |
| Elevated | 4.59 (3.77 – 5.58) | < 0.01 | 2.06 (1.44 – 2.95) | < 0.01 |

a Confidence Interval (95%), b Significance Level
c Ajusted for: Gender, Age groups, Ethnic Groups, Socioeconomic Status and anthropometric parameters definitions
‡ ≥26.7 kg/m² in females and ≥27.5 kg/m² in males
ψ ≥0.56 in both genders
¶ >90cm in females and >95cm in males
**Table 5:** Multivariable analysis of anthropometric parameters classification for multiple risk factor aggregation. The Maracaibo City Metabolic Syndrome Prevalence Study, 2014

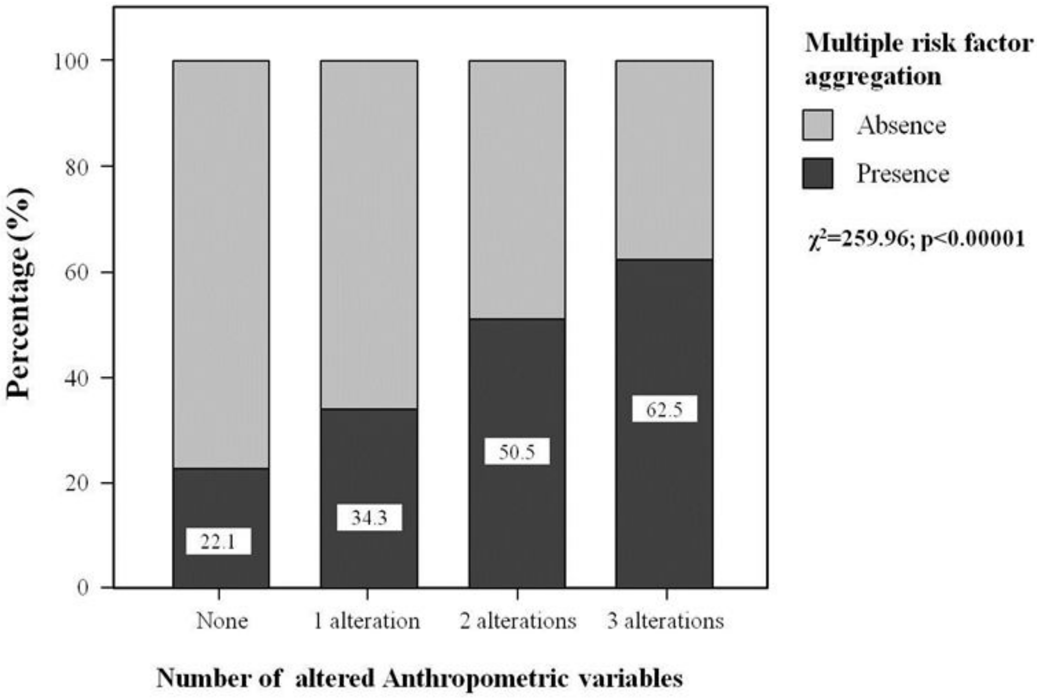


**Figure 2:** Distribution of the subjects with Multiple Risk Factor Aggregation according to the number of alterations present. The Maracaibo City Metabolic Syndrome Prevalence Study, 2014

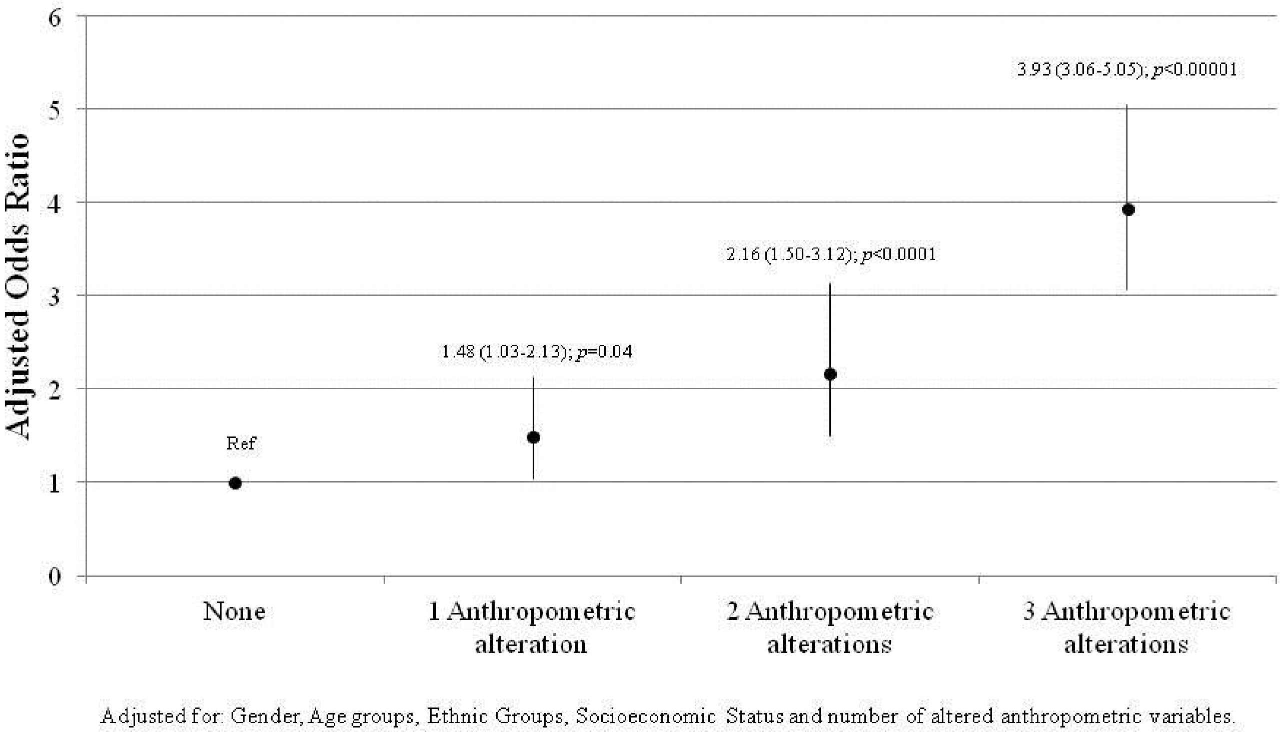


**Figure 3:** Odds Ratios adjusted according to number of altered anthropometric parameters and MRFA. The Maracaibo City Metabolic Syndrome Prevalence Study, 2014

show that various anthropometric parameters exhibit varying degrees of predictive capacity for MRFA in both men and women (at or above 0.70 AUC). This confirms that anthropometric alterations are linked to obesity, regardless of the index or measure that is used, are closely related to dyslipidemia, hypertension, dysglycemia, among other metabolic disorders [15-17]. Such variables a series of risk factors that predispose from childhood to major chronic diseases with a significance epidemiological importance worldwide [18,19].

During the assessment of anthropometric parameters individually by gender, it shows that WHtR in women is more predictable than BMI, and WC was better for predicting MRFA. These findings differ from those reported by Mora-Garcia et al. [20] in the female population of the city of Cartagena (Colombia), publishing that WHtR was the only parameter associated with MS (ergo MRAF). However, several meta-analysis have shown that WHtR is a diagnostic tool and important cardiometabolic risk predictor parameter not only in adults but also in individuals, including young adults and teenagers [21-23]. Moreover, in men both WC and WHtR show a higher similar predictive capacity over BMI, results that differ from those shown by Liu et al. [24] in adults from Liaoning Province in China, reporting that the 3 variables show no difference in their behavior. Nevertheless, Bener et al. [25] published their evaluation of anthropometric variables and MS prediction in the Qatari population, suggesting that WC was the measurement with higher predictive power for MS, followed by the waist-hip-ration and WHtR.

Once cut-off points were obtained applying ROC curve analysis, the association between anthropometric parameters showed a similar development evidenced by the curves plots, with an increased risk of MRFA for those exhibiting abdominal obesity and high WHtR. This demonstrates the importance of body fat distribution and its influence on the appearance of several metabolic disorders associated with the accumulation of dysfunctional adipocytes capable of synthesizing a large number of proinflammatory molecules, a condition known as "adiposopathy" and which forms the basis for different molecular metabolic diseases such as dyslipidemia, T2DM and MS [26,27].

It is important to highlight the relationship shown in this study between abdominal circumference and MRFA, because it differs from previous reports where the predictive capacity of abdominal obesity for MS was shown, without considering the autocorrelation generated by not exclude it from assessment of the outcome [20,25,28]. Likewise, cut-off points for each parameter show the importance of their adjustment to the characteristics of each region; in the case of WC the values have been previously detailed by our research team [29]. For WHtR the cut-off points are slightly higher than those shown in most reports worldwide [30,31], whereas BMI cutoffs are lower than those used for the diagnosis of obesity (WHO), which has already been suggested by Nieto et al. [32] in our population. Therefore, beyond recommending a specific parameter in detecting risk factors such as Peruvians [33], our main finding is that there is a high association between MRFA and the presence of a higher number of altered anthropometric parameters, results that were evidence in both univariate and multivariate context. This demonstrates the importance of determining the highest amount of anthropometric measurements in clinical practice, as a key strategy to improve diagnostic capacity of individual indexes.

Among our limitations is the cross-sectional nature of the study, making it impossible to establish a causal relation for each anthropometric parameter. Nevertheless, few locally studies have evaluated the role of anthropometric measurements and their impact on the determination of the main cardiometabolic abnormalities that affect Latin America and the Caribbean [34]. Furthermore, this study is the first analysis of a series of reports where anthropometric indexes isolated with adiposity indexes are compared, combining anthropometric and metabolic variables.

We can conclude that WC provides greater predictive ability of MRFA compared to other parameters. Further studies are needed to properly understand the influence of WC in the clustering of metabolic variables and how ethnicity might influence such predictive power.

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