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Predictive capacity of obesity indicators for metabolic syndrome in adult quilombolas (inhabitants of black communities)

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Abstract *The objective of this study was to evaluate the predictive capacity of different obesity indicators (OIs) for metabolic syndrome (MetS) in adult quilombolas (inhabitants of black communities). A cross-sectional study involving a representative sample of 850 adult quilombolas (18 to 92 years) living in the geographic micro-region of Guanambi, Bahia, Brazil, was conducted. Receiver operating characteristic (ROC) curves were constructed between OI [body fat percentage (BF%), body adiposity index (BAI), and body mass index (BMI)] and MetS. The balance between sensitivity and specificity defined the best predictive cutoff points of OI for MetS. The three OIs were predictors of MetS (significant area under ROC curve > 0.5). Among women, BF% showed a significantly greater area under the ROC curve (0.69, 95% CI: 0.65; 0.73) than the other OIs. Among men, the areas for BF%% and BMI were the same (0.81, 95% CI: 0.76; 0.85) and were greater than that of BAI. The best OI cutoff points to identify the presence of MetS in women and men were, respectively: 24.97 and 25.36 kg/m² for BMI, 34.30 and 26.14% for BAI, and 37.7 and 23.8% for BF%. The OIs tested are valid tools to screen for MetS in adult quilombolas when specific cutoff points for the population studied are used.*

Key words *Group with African Continental ancestry, Metabolic syndrome X, Obesity, ROC curve, Cross-sectional studies*

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Introduction

Metabolic syndrome (MetS) is defined as the simultaneous presence of atherogenic dyslipidemia (hypertriglyceridemia and/or low high-density lipoprotein [HDL] cholesterol), high blood pressure, hyperglycemia, and excess abdominal fat[1]. Despite the demonstration of a high prevalence in the world[1] and in Brazil[2], MetS is still insufficiently diagnosed in some regions and populations[3], particularly those characterized by socioeconomic vulnerability because of the high cost and technological requirements for its diagnosis. This highly negative epidemiological profile requires efforts to implement efficient programs for the early detection of MetS and minimization of its deleterious and disabling effects[3,4].

Ethnic-racial investigation in health permits to identify population groups that are more susceptible to certain risks and diseases[5-7], as demonstrated for the prevalence of MetS[3,8-11].

The importance of obesity in the etiology of MetS has been recognized[3,4]. Within this context, obesity indicators (OIs) emerge as screening tools for MetS because of their favorable benefit-cost relationship, especially in situations of limited resources and restricted access to health services.

Studies have shown variations in the screening capacity of different general OIs for MetS according to population profile[12-17]. In addition, studies involving different population groups have identified differences in the predictive capacity of OIs according to ethnic-racial characteristics[18-20]. These findings highlight the importance of accuracy analysis of MetS screening in specific population groups. However, we found no studies that simultaneously evaluated the three main general OIs (body fat by bioimpedance, body adiposity index (BAI], and body mass index (BMI)] in quilombolas.

Nosological characteristics of the population with African ancestry have been recognized, including genetic (hereditary diseases), clinical (a higher frequency and severity of metabolic and cardiovascular diseases), and social factors (poor life conditions and racism)[21]. In this respect, being black increases the probability of manifesting chronic diseases[6,22-24], prejudice results in unfavorable inequities for black and brown people[24,25], and social inequalities increase the likelihood of manifestation of metabolic disorders in in populations with African ancestry[3,5,7,22,24,26]. Although we understand that sociocultural factors reinforce the genetic determination of manifestation of metabolic disorders in blacks, specific information about the health conditions of this population group is still limited.

An important part of the Brazilian population with African ancestry' lives in quilombos, self-attributed ethnic-racial communities of African ancestry linked to land and resistant to historical oppression[27,28]. Many of these communities still fight for equal rights, land tenure regularization, full citizenship, and public health equity[5,29]. Detailed information about the healthcare conditions of quilombolas is still lacking[29,30], as are actions designed to combat the situation of socioeconomic vulnerability and difficult access to health services[5,31,32].

Despite the limited number of studies, a high prevalence of MetS among quilombolas has been reported[33-36]. Furthermore, anthropometric studies have shown high rates of overweight and obesity in this population[37,38]. However, we found no studies involving the quilombo population that investigated the accuracy of OIs and established cutoff points for the identification of individuals at increased risk and their immediate referral to specialized health services for diagnostic confirmation and treatment of MetS.

Considering the importance of simple, low-cost methods that permit the screening of a large number of subjects for metabolic disorders in a specific ethnic-racial population segment for which health information is limited, the objective of the present study was to evaluate the predictive capacity of different OIs for MetS in adult quilombolas.

Materials and methods

This analysis used data from the cross-sectional population-based study entitled "Epidemiological Profile of Quilombolas from Bahia". The study was approved by the Ethics Committee on Research Involving Humans of Universidade do Estado da Bahia (CEP/UNEB) and was conducted between February and November 2016.

The geographic micro-region of Guanambi/Bahia, which comprises 18 municipalities and a territorial area of 22,668.688 km^2 [39], with 42 contemporaneous quilombos[40] certified until 2016 and distributed across 10 municipalities[41], was the empirical field studied. Because of the lack of official data on the number of quilombo inhabitants of this micro-region, the population was estimated considering 80 families per quilombo[42], with two adults (≥ 18 years) per family, totaling 6,720 adults.

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For sample size calculation, we adopted correction for a finite population, a prevalence of the unknown outcome of 50%, 95% confidence interval, a sampling error of five percentage points, correction of 1.5 times for a single-stage cluster (quilombo), and additions of 30% for refusals and 20% for losses and confounding[43], resulting in a minimum sample of 818 subjects.

Sampling was performed in two steps: random sampling of the quilombos (cluster), followed by census sampling. First, the quilombos were selected by drawing lots. Fourteen of the selected units allowed visits for the study through their respective resident associations (local organizations that represent the interests of quilombolas). According to the information of the 14 resident associations, 1,025 adults lived in these quilombos during the period of data collection. All adults were eligible, were informed about the objective and procedures of the study, and were invited, ensuring equal chance of participation. The data were collected in a joint effort on weekends and holidays. A total of 850 quilombolas attended the activities and agreed voluntarily to participate by signing the individual free informed consent form or by providing a fingerprint. These subjects composed the final sample; 17.07% of the invited adults did not attend the activities and were characterized as refusals.

The data were collected by interview, blood collection, blood pressure measurement, and anthropometric assessment. These procedures were performed by teams consisting of health professionals and/or researchers according to their skills after training in their respective function.

Subjects with cognitive impairment or compromised independent communication, bedridden and amputated subjects, subjects using a plaster cast, pregnant women and women breastfeeding for less than 6 months were excluded from this analysis since they did not participate in the interviews, anthropometric measurements or tests, or had not responded to some questions regarding this analysis at the time of the interview. Losses were defined when the subject did not undergo a measurement or test or when he/she did not answer a question in the interview.

The anthropometric measurements (body weight, height, and hip and waist circumference) were obtained in duplicate in a closed room on a single occasion by the same evaluator certified by the International Society for the Advancement of Kinanthropometry (ISAK). The measurements were made according to ISAK recommendations[44], with the subjects barefoot and wearing minimal clothing. In the case of discrepancy, a third measurement was obtained and the median was used for analysis.

Body weight was measured with a digital scale (Omron hbf-514c, capacity of 150 kg) to the nearest 100 g. Height was measured with a portable metal stadiometer (Sanny Caprice) to the nearest 0.1 mm. Waist and hip circumferences were obtained with a steel measuring tape (Sanny sn-4010, 2 m long and 0.5 cm wide) to the nearest 0.1 mm. The intra-evaluator technical error of measurement[45] was 0.20% for body weight, 0.12% for height, 0.39% for waist circumference and 0.20% for hip circumference, indicating an adequate level of the measurements.

Body fat percentage was determined by bioimpedance using a validated scale (Omron hbf-514c, capacity of 150 kg and precision of 0.1%)[46]. The measurements were made in duplicate in the morning before breakfast and a third measurement was obtained in the case of discrepancy, using the median for analysis. The subjects were asked not to consume alcoholic beverages or caffein and not to perform intense physical activity during the 24 hours prior to the measurements. The participants were also instructed to remove metal objects and to rest for 5 minutes before the tests.

Blood samples (15 ml), properly separated and identified, were collected after a minimum fast of 8 hours by puncture of the median antecubital vein using a vacuum system, according to the protocol of the Brazilian Society for Clinical Pathology and Laboratory Medicine[47]. The samples were stored in a refrigerated thermal box and transported to the certified laboratory where the material was centrifuged and analyzed. Glucose, HDL and triglycerides were determined by automated colorimetric enzymatic methods (Cobas Mira Plus, Roche®).

Blood pressure was measured in triplicate with a validated semi-automated sphygmomanometer (Omron HEM-742INT)[48] after a 10-minute rest, with the subject sitting, feet on the floor, left arm at the height of the heart, and palm of the hand facing upwards[49]. The arithmetic mean of the three measurements was used for analysis.

The Joint Interim Statement[1] was used for the definition of MetS (dependent variable), which proposes the simultaneous presence of at least three of the following factors: 1) elevated triglycerides when ≥ 150 mg/dL or use of medications to treat hypertriglyceridemia; 2) increased fasting glucose when ≥ 100 mg/dL or use of diabetes medications; 3) reduced HDL when < 40 mg/dL (men) and < 50 mg/dL (women) or use of medications to treat low HDL; 4) high blood pressure (systolic ≥ 130 mmHg and/or diastolic ≥ 85 mmHg) or use of antihypertensive medications; 5) increased waist circumference when > 90 cm for men or > 80 cm for women (the cutoffs suggested for Latin America were adopted)[3].

The OIs (independent variables) analyzed were: body fat percentage (BF%) estimated by bioimpedance; BAI [waist circumference (cm)/ height $(m)^{1.5}$ – 18][50], and BMI [body weight (kg)/ $height^2$ (m)]

For statistical analysis, the Kolmogorov-Smirnov test was first applied, which indicated the absence of a normal distribution for all continuous variables ($p<0.05$). Thus, the Mann-Whitney U test was used for comparison of the median results. Descriptive statistics were also used for description of the variables.

To evaluate the accuracy of the OIs in predicting MetS, receiver operating characteristic (ROC) curves were constructed to compare sensitivity versus specificity[51]. An area under the ROC curve > 0.5, including the 95% confidence interval, defined statistical significance for MetS screening. The balance between sensitivity and specificity determined the best cutoff points of each OI to discriminate MetS. Positive predictive (PPV) and negative predictive values (NPV) of the best OI cutoffs to identify MetS were also determined. The Z test was applied to compare the areas under the ROC curves of the different OIs.

The general results or results stratified by sex are reported. The Statistical Package for the Social Sciences for Windows (SPSS), version 22, was used for descriptive and association analyses. The screening ability of the OIs was evaluated using the MedCalc 12.1.4 program.

Results

The age of the sample ranged from 18 to 92 years (median of 41 years in women and of 49 years in men). There was a predominance of women (61.2%, 95%CI: 57.9;64.5) and the prevalence of MetS was 25.8% (95%CI: 22.8;28.7). The other results are shown in Table 1. The variable with the largest number of losses was BF% (21 women; 15 men).

Association analysis stratified by sex between the outcome (MetS) and each predictor (BF%, BAI, and BMI) showed a significant association ($p < 0.001$) in all cases.

Figure 1 shows the area under the ROC curves between MetS and BF%, BAI and BMI according to sex. The areas under the ROC curves between MetS and the three OIs were significant (> 0.5) in both sexes (Figure 1; Table 2). Thus, the indicators exhibited satisfactory capacity to discriminate the presence of MetS in male and female adult quilombolas.

Among women, the greatest area under the ROC curve was observed for BF% (0.69; 95%CI: 0.65;0.73). Among men, the best areas under the ROC curve were found for BF% and BMI (0.81 for both; 95%CI: 0.76;0.85) (Table 2). In women, the Z test indicated a significantly greater area under the ROC curve ($p < 0.05$) of BF% with MetS compared to the other OIs. In men, the curves of BF% and BMI with MetS were greater ($p < 0.05$) than the BAI curve. Therefore, BF% in women and BF% and BMI in men had the highest discriminatory power for MetS in adult quilombolas.

The best OI cutoff points for predicting MetS and their respective characteristics are shown in Table 2. Among women, the best cutoff for BF% (37.7%) showed the highest sensitivity, i.e., it is the best OI to detect subjects with MetS when BF% is higher than this value. The best cutoff point for BAI (71.0%) exhibited the highest specificity and is therefore the best OI to define the absence of MetS in individuals with a BAI lower than this value. The BAI cutoff produced the highest proportion of true positive results (PPV = 45.6%), while the BF% cutoff was associated with the highest proportion of true negative results (NPV = 87.5%).

In the group of men (Table 2), the best cutoff point for BAI (26.1%) had the highest sensitivity (79.4%), while the BF% cutoff (23.8%) exhibited the highest specificity (74.8%). The BF% cutoff produced the highest proportion of true positive results (PPV = 46.1%), while the BMI cutoff (25.4 kg/m^2) was associated with the highest proportion of true negative results (NPV = 92.6%).

Discussion

The present results demonstrate the capacity of all OIs analyzed to predict MetS in adult quilombolas. To our knowledge, this is the first study to investigate OIs as screening tools of MetS in a quilombo population, a fact impairing comparison of the results with other studies.

Metabolic syndrome is an important health risk factor that is still under-notified in some populations[3]. In this respect, an increased risk for metabolic disorders has been observed in the population with African ancestry[3,5,6,22-24,26,52]

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Table 1. Characteristics of adult quilombolas stratified by sex. Bahia, Brazil (2016).

Variable	n	Median (range)	n	Female (range)	n	Male (range)	p-value
Age (years)	850	45.0 (18.0-92.0)	520	41.0 (18.0-92.0)	330	49.0 (18.0-90.0)	<0.001
Height (m)	837	1.61 (1.36-1.96)	513	1.56 (1.36-1.77)	324	1.67 (1.43-1.96)	<0.001
Body weight (kg)	837	65.8 (38.8-112.2)	512	64.3 (38.8-112.2)	325	67.9 (39.7-110.8)	<0.001
Hip circumference (cm)	835	97.5 (77.0-132.0)	511	99.0 (77.0-132.0)	324	95.1 (79.5-120.0)	<0.001
Waist circumference (cm)	835	85.6 (58.7-126.6)	511	87.0 (58.7-124.5)	324	84.3 (63.5-126.6)	0.004
DBP (mmHg)	825	75.7 (46.3-140.7)	504	74.7 (47.7-129.7)	321	76.7 (46.3-140-7)	<0.001
SBP (mmHg)	825	127.0 (90.0-238.0)	504	123.5 (90.0-225.0)	321	132.3 (91.3-238.0)	0.225
Glucose (mg/dL)	835	87.0 (47.0-342.0)	512	87.0 (47.0-305.0)	325	88.0 (55.0-342.0)	0.323
HDL (mg/dL)	835	59.0 (20.0-112.0)	513	60.0 (20.0-109.0)	327	58.0 (20.0-112.0)	0.342
Triglycerides (mg/dL)	835	83.0 (20.0-719.0)	513	82.0 (20.0-719.0)	327	84.0 (32.0-535.0)	0.631
BF%	814	32.1 (5.0-56.2)	499	38.8 (14.0-56.2)	315	20.6 (5.0-39.4)	<0.001
BAI (%)	835	29.9 (16.3-53.3)	511	32.8 (16.3-53.3)	324	25.8 (16.8-40.7)	<0.001
BMI (kg/m2)	836	25.2 (15.9-45.4)	512	26.2 (16.9-45.4)	324	24.2 (15.9-38.7)	<0.001

n: number of subjects; DBP: diastolic blood pressure; SBP: systolic blood pressure; BF%: body fat percentage estimated by bioimpedance; BAI: body adiposity index, in % fat; BMI: body mass index.

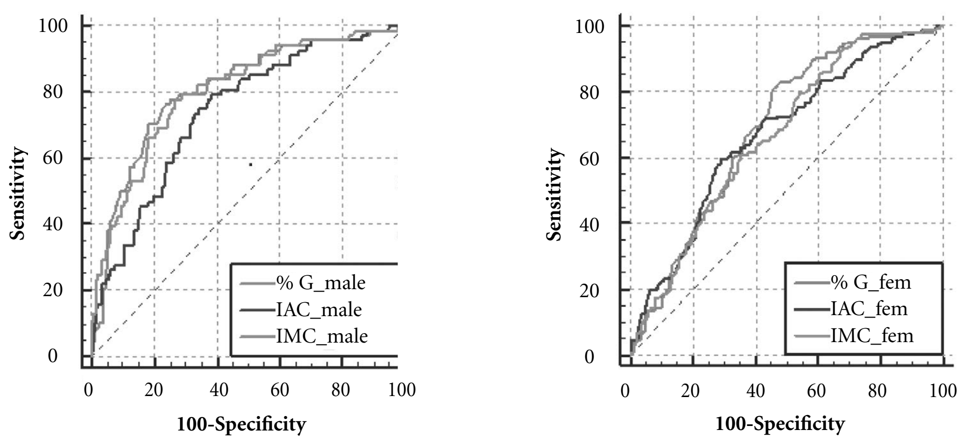

Figure 1. ROC curves stratified by sex comparing the predictive capacity of general obesity indicators for metabolic syndrome in adult quilombolas. Bahia, Brazil (2016). BF%: body fat percentage estimated by bioimpedance; BAI: body adiposity index; BMI: body mass index.

and quilombo inhabitants encounter difficulties in the use of health services[5,31,32]. Furthermore, obesity has been shown to be an important predictor of MetS[3,4]. Thus, this study is relevant by demonstrating that OIs are reliable to discriminate adult quilombolas who are more susceptible to MetS, favoring its diagnosis already in the first phase of clinical practice and early therapeutic intervention. These results agree with the understanding that general body fat accumulation predisposes to a higher risk of illness and population death[53,54]. In addition, studies involving

Table 2. Diagnostic properties of obesity indicators to screen for the presence of metabolic syndrome in adult quilombolas according to sex. Bahia, Brazil (2016).

	n	ROC curve (95%CI)	Cutoff	Sensitivity (95%CI)	Specificity (95%CI)	PPV (95%CI)	NPV (95%CI)
Women							
BF%	498	0.69 (0.65;0.73)	>37.7	81.5 (74.2;87.4)	53.7 (48.3;59.0)	42.2 (36.4;48.2)	87.5 (82.3;91.6)
BAI	510	0.67 (0.63;0.71)	> 34.30	59.1 (50.7;67.0)	70.9 (65.9;75.5)	45.6 (38.4;52.9)	80.8 (76.0;84.9)
BMI	511	0.66 (0.62;0.70)	> 24.97	78.5 (71.1;84.8)	46.4 (41.2;51.7)	37.6 (32.2;43.3)	84.0 (78.2;88.8)
Men							
BF%	314	0.81 (0.76;0.85)	> 23.8	77.9 (66.2;87.1)	74.8 (68.9;80.1)	46.1 (36.8;55.6)	92.5 (87.9;95.7)
BAI	323	0.74 (0.69;0.79)	> 26.14	79.4 (67.9;88.3)	62.4 (56.1;68.3)	36.0 (28.3;44.2)	91.9 (86.8;95.5)
BMI	324	0.807 (0.76;0.85)	> 25.36	77.9 (66.2;87.1)	73.8 (68.0;79.1)	44.2 (35.1;53.5)	92.6 (88.2;95.8)

BF%: body fat percentage estimated by bioimpedance; BAI: body adiposity index, in %; BMI: body mass index, in kg/m2; 95%CI: 95% confidence interval; PPV: positive predictive value; NPV: negative predictive value.

different adult populations have also shown the MetS screening capacity of BF%[16], BAI[13-15] and BMI[12,14-17]. However, to our knowledge, this is the first study to evaluate the capacity of the three main general OIs to screen for MetS in the same study of adults.

Among the OIs investigated, BF% estimated by bioimpedance exhibited the highest accuracy to discriminate MetS in adult quilombolas of both sexes. It should be noted that this technique is more accurate for the analysis of body composition than anthropometric indicators (BMI and/or BAI)[53] and that adipose tissue is highly detrimental to insulin and inflammatory functions regularly associated with MetS[1,3].

On the other hand, some studies have indicated BMI as the best predictor of MetS compared to BF%[16] and BAI[14,15]. These differences in OIs with the best predictive capacity obtained in this study on black quilombolas and in the cited studies involving Asian populations[15,16] and populations of Amerindian ancestry[14] might be explained in part by the differences in fat distribution pattern and body proportionality among ethnic-racial groups[19,55]. Another possible explanation for these divergences is the difference in the criteria adopted for the establishment of MetS in this study (Joint Interim Statement)[1] and in the other studies (National Cholesterol Education Program's Adult Treatment Panel[16]; *International Diabetes Federation*[15]), a factor known to influence the estimation of its prevalence[2,3].

High sensitivity is a fundamental characteristic for the selection of a screening test in health since it minimizes the number of false-negative results[51]. Except for BAI in women (59%), the other OIs exhibited sensitivity of approximately 80% in both sexes. This value shows good capacity to identify adult quilombolas who will truly have MetS and consequently a low probability of false-negative results in provisional diagnostic tests replacing the gold standard. These values are similar to[16] or better[12,13,17] than those found in the literature.

Analysis of diagnostic accuracy through the construction of ROC curves is recommended for the determination of the best cutoff points that can discriminate health problems in tests alternative to the gold standard[51]. In the present study, the best BF% cutoff to screen for MetS in men was lower than the 25% suggested for the prognosis of obesity[56], but similar to the 24% proposed for MetS screening in Chinese individuals[16]. Among women, the BF% cutoff was much higher than the 30% determining obesity[56] and the 31.4% discriminating MetS in a Chinese study[16].

For BAI, the best cutoff point to discriminate MetS in male quilombolas was higher than the 25% defining obesity[56], but lower than the 27.1% discriminating MetS in the rural Chinese popu-

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lation[13]. Among women, the cutoff was higher than the 30% predicting obesity[56] and the 32.1% discriminating MetS in rural Chinese women[13].

The differences between cutoff points for the discrimination of health risk corroborate the finding of an ethnic-racial influence on the predictive capacity of OIs[18-20], highlighting the importance to establish specific cutoff points for different population groups. In addition, the better BF% and BAI cutoff points confirm the observation that, even in the presence of increased adiposity, some subjects are protected from its deleterious health effects[57]. In the quilombo population, MetS generally tends to manifest in the presence of excessive body fat accumulation, at levels that are markedly higher than those defined for the categorization of obesity.

The BMI cutoff points, in both sexes, were close to the 25 kg/m^2 recommended by the World Health Organization (WHO) as a discriminator of overweight[58]. However, these cutoffs differ from those reported in the literature for the prediction of MetS. A population study involving adults from the Brazilian capital identified 26.8 kg/m^2 for women and 26.0 kg/m^2 for men as the best cutoffs to discriminate MetS[17], values higher than those found for quilombolas. International studies reported lower cutoff points for Chinese women (23.9 kg/m^2)[16] and higher values for Chinese men (27.5 kg/m^2)[16] and for Qatari women (31.0 kg/m^2) and men (29.0 kg/m^2)[12] compared to those defined in this study.

This study shows that the general cutoff points for detecting overweight and obesity derived from surveys that mainly involve Caucasian populations[1,3,58,59] or for MetS screening in other ethnic-racial profiles[12,13,16,17] are limited when applied to the black quilombo population. The use of these cutoffs can lead to the over or underestimation of the chance of having MetS.

In contrast to the other studies that investigated the capacity of OIs to detect MetS[12-17], this analysis reports PPV and NPV. The evaluation of the quality of screening tests should also take into consideration the probability of identifying individuals with the health problem studied when the result is positive or individuals without the problem when the result is negative[60]. This study found a PPV of OI ranging from 36 to 45%, i.e., four to five in each 10 subjects identified as having MetS by OI are very likely to be diagnosed with MetS. In contrast, the NPV ranged from 81 to 93%, suggesting good probability that the participants screened as without MetS indeed do not have the condition.

Some limitations of the present study should be mentioned, such as the lack of a cutoff point for the estimation of visceral obesity based on a specific waist measure for the black population[3], a fact that may influence the identification of MetS and the predictive power of the indicators. Furthermore, methodological difficulties in establishing the ethnic-racial background limit the interpretation of its influence in studies on OIs[61]. In this study, ethnic-racial self-definition was adopted, an approach that can exhibit differences or similarities that are difficult to reproduce.

The strengths of this study are related to the establishment of practical and inexpensive clinical criteria for MetS screening in a specific ethnic-racial population. In addition, the survey was carried out using a representative sample of the rural black population from a geographic micro-region in a northeastern state, and laboratory analysis and face-to-face measurements were performed.

Conclusion

The results demonstrated good accuracy of the three OIs studied for MetS screening in adult quilombolas, which can be applied in clinical practice using their best cutoff points for provisional replacement of more complex and expensive tests. In this respect, the OIs exhibited good capacity to identify affected patients (sensitivity), to discriminate false-negative results (NPV), and to indicate the syndrome based on the best cutoffs. It should be noted that validation of OIs as predictors of health risks, such as MetS, does not replace the clinical diagnosis. However, this strategy permits to increase the number of individuals attended at a lower cost and with good accuracy and to define priorities for the referral of those that are more likely to have the health problems investigated.

Finally, it is important to emphasize that the best predictive results of MetS in adult quilombolas will be obtained by the combined use of OIs, increasing the capacity of identifying true positive and true negative results, i.e., better defining those subjects that truly will or will not have MetS.

Collaborations

RFF Mussi: design, study design, analysis and interpretation of results. RFF Mussi and EL Petróski: essay writing and critical review. All authors have approved the final version of the manuscript and declare that they are responsible for all aspects of the manuscript, ensuring its accuracy and integrity.

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