Different Measurements of the Sagittal Abdominal Diameter and Waist Perimeter in the Prediction of HOMA-IR

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Summary

Background: The correlation between the increase in visceral fat and insulin resistance makes the sagittal abdominal diameter and the waist perimeter as potential tools for the prediction of insulin resistance.

Objectives: To assess the reproducibility of different measurements of the sagittal abdominal diameter and the waist perimeter and analyze the discriminating power of the measurements when predicting insulin resistance.

Methods: A total of 190 adult males were studied. The sagittal abdominal diameter (smallest girth, larger abdominal diameter, umbilical level and midpoint between the iliac crests) and the waist perimeter (umbilical level, smallest girth, immediately above the iliac crest and midpoint between the iliac crest and the last rib) were measured at four different sites. Insulin resistance was assessed by the homeostasis model of assessment-insulin resistance (HOMA-IR) index.

Results: All measurements presented an intraclass correlation of 0.986-0.999. The sagittal abdominal diameter measured at the smallest girth (r=0.482 and AUC=0.739±0.049) and the waist perimeter measured at the midpoint between the last rib and the iliac crest (r=0.464 and AUC=0.746±0.05) presented the highest correlations with the HOMA-IR and the best discriminating power for HOMA-IR according to the ROC analysis (p<0.001).

Conclusions: The sagittal abdominal diameter and waist perimeter showed to be highly reproducible and the sagittal abdominal diameter (smallest girth) and waist perimeter (midpoint between the iliac crest and the last rib) presented the best performance when predicting HOMA-IR. Further studies in other groups of the Brazilian population must be carried out to allow the use of these indicators of insulin resistance in the population as a whole, following standardized procedures. (Arq Bras Cardiol 2009; 93(5) : 473-479)

Key Words: Obesity; insulin resistance; abdominal circunference; abdominal fat; antropometry.

Introduction

The insulin resistance represents an important association between obesity and the morbidities that occur concomitantly to the increase in visceral adiposity. The more resistant to insulin the individual is, the higher the risk for the development of type 2 diabetes and cardiovascular disease. Due to the fact that it is at the physiopathological basis of several cardiometabolic risk conditions, the early identification of insulin resistance implies in a higher degree of attention to these patients[1].

The available laboratory methods used for the assessment of insulin resistance are still little applicable to clinical practice, due not only to the high cost of some techniques, but also to the poor standardization of insulin assays used by the laboratories[2,3]. The strong correlation between the increase in visceral fat and the increase in insulin resistance points out the anthropometric indicators of abdominal obesity extension as possible indicators of insulin resistance[4,5]. The sagittal abdominal diameter and the waist perimeter have been studied in this sense, mainly due to the high correlation of these measurements with visceral fat[6], together with their easy applicability and low cost.

The waist perimeter (WP) is a classic anthropometric measurement, in addition to being the best known and more often used indicator of abdominal adiposity. It is present in the proposals made by the European Group for the Study of Insulin Resistance[7], by the International Diabetes Federation[8] and the National Cholesterol Education Program-NCEP-ATPIII[9] for the diagnosis of metabolic syndrome or insulin resistance syndrome. The sagittal abdominal diameter (SAD), although less well-known among professionals and less often reported in the literature, is being increasingly acknowledged in the scientific community, mainly after the studies by Henry Kahn, one of the pioneers in working with SAD as an anthropometric measurement capable of predicting the risk of cardiovascular mortality and morbidity[10,11]. However, the absence of an international standardization regarding the anatomic site used for the measurement of the WP and the SAD can make

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it difficult to compare the results of different studies and the use of these measurements in clinical practice.

Considering that, the present study aimed at evaluating the reproducibility of the SAD and the WP; comparing different anatomic sites used for the measurement of the WP and the SAD; and evaluating the efficacy of all these anthropometric measurements in predicting insulin resistance.

Methods

This was a cross-sectional study, which evaluated adult males (20-59 years) connected to the Federal University of Vicosa (UFV). The data were collected at the Health Division of the UFV, state of Minas Gerais, Brazil. The study protocol was approved by the Ethics Committee in Research with Human Subjects of UFV and all the volunteers signed the Free and Informed Consent Form.

The exclusion criteria were: fasting glucose > 99mg/dl, LDL-C levels ≥ 160mg/dl, triglycerides ≥ 150mg/dl, previous history of cardiovascular event, presence of arterial hypertension and use of medications that affected the carbohydrate and lipid metabolism. A total of 190 individuals were assessed, of which 138 met the study inclusion criteria and had the fasting insulinemia measured.

Anthropometric assessment

The anthropometric assessment was carried out by a single trained examiner. Weight and height were measured according to the techniques proposed by Jellife[12]. The body mass index (BMI) was calculated according to the formula: BMI = weight/(height)^2, expressed in kg/m^2. Individuals with a BMI ≥ 25 kg/m^2 were considered as being overweight[13].

The WP was measured with a flexible and inelastic measuring tape, whereas taking the necessary care not to compress tissues. The WP was measured at four different anatomic sites: at the umbilical level[14], the smallest girth between the thorax and the hip[15], immediately above the iliac crests[16], and the midpoint between the iliac crest and the last rib[13]. The measurement was carried out at the end-expiratory position.

The SAD was measured with an abdominal caliper (Holtain Kahn Abdominal Caliper®), with a movable arm and 0.1-cm subdivision. During the assessment, the volunteer was lying in the supine position on a solid examination table, with flexed knees. The measurement was obtained at four different anatomic sites: smallest girth between the thorax and the hip[17], the largest abdominal diameter[18], at the umbilical level[19] and midpoint between the iliac crests[20]. The measurements were obtained to the closest millimeter, when the movable arm of the caliper touched the abdomen slightly, without compression, after normal expiratory movement. The SAD and the WP were measured in duplicate and the respective means were calculated. When the difference was > 1 cm between the two measurements, a third measurement was obtained and the two closest values were used.

Biochemical analyses

Blood samples were collected after a 12-hour overnight fast. The plasma levels of triglycerides, total cholesterol, HDL and glucose were carried out by the enzymatic colorimetric assay, using laboratory kits (Enzymatic Triglycerides K037, Cholesterol Mono reagent K083, HDL Direct K071 and Glucose Mono reagent K082 by Bioclin®). LDL-C was calculated using Friedwald's formula[21]. Plasma insulin levels were measured by ELISA, using ultra-sensitive kits (Human insulin ELISA - Linco Research®) with intra-assay and inter-assay coefficients of variation of 5.96 ± 1.17 μU/ml and 10.3 ± 0.9 μU/ml, respectively.

The homeostasis model assessment – insulin resistance (HOMA-IR) index was used to evaluate insulin resistance, calculated using the formula[22]:

$$\text{HOMA} - \text{IR} = \frac{\text{IJ } (\mu\text{U/ml}) \text{ x GJ(mmol/l)}}{22{,}5}$$

, where IJ corresponds to fasting insulinemia and GJ to fasting glycemia. The cutoff for the analyses was the 75th percentile of the HOMA-IR index.

Statistical analyses

The statistical analyses were carried out with the software SPSS, version 12.0. The level of significance established was < 5%. The intra-individual reproducibility of the measurements was assessed by the intraclass correlation coeficient (ICC). Only the two first measurements were used for this calculation.

The Kolmogorov-Smirnov test was used to evaluate the normality of the distribution of the variables. The analysis of variance (ANOVA) was used to compare the four measurements of the WP and the SAD with normal distribution. In situations where the difference was statistically significant, Tukey's post-hoc test was used to identify which groups differed among them. For the variables that did not pass the normality test, Kruskall-Wallis test and Dunn's post-hoc test were used. To evaluate the behavior of the anthropometric variables regarding the HOMA-IR index, Spearman's correlation was used.

ROC (Receiver Operating Characteristic) curves were constructed to evaluate the efficacy of the anthropometric indicators in predicting insulin resistance regarding the reference test, in this case, the HOMA-IR index. The areas under the curve (AUC) were calculated to evaluate the discriminating power of the different measurements of the WP and the SAD, according to Hanley and McNeil[23]. To compare the curves, the Z test was applied, using the software *MedCalc* version 9.3.

Results

The characteristics related to age, nutritional profile, and blood pressure levels of the participants are shown in Table 1. Table 2 shows the comparison between the means of the different measurements of WP and SAD. In the entire sample, as well as in the sample stratified according to excess body weight, the WP measured at the smallest girth between the thorax and the hip was the lowest among all measurements. In the group with BMI < 25 kg/m^2, the WP measured at the midpoint between the last rib and the iliac crest presented the lowest mean regarding the WP measured immediately above the iliac crests. For the SAD, the measurement taken at the largest abdominal girth was higher than the other three measurements in the entire sample. At the stratification by BMI, measurements taken at the midpoint between the iliac crests and the umbilical level were lower than the largest abdominal girth, whereas the SAD measured at the natural waist did not differ from the others. The assessment of reproducibility of WP and the SAD identified very high and statistically significant intra-class coefficients of correlation for both measurements in all anatomic sites studied, demonstrating the high reproducibility of the measurements (Table 3).

The correlations between the HOMA-IR values and the different measurements of the WP and SAD were moderate. Among the four measurements of WP and SAD, stronger correlations were identified for the WP, measured at the midpoint between the last rib and the iliac crest and for the SAD, the measurement taken at the level of the smallest girth between the thorax and the hip (Table 4).

Table 5 presents the areas under the curves (AUC), their respective standard-errors and the confidence intervals (CI) for the ROC curves constructed for the four measurements of WP (Figure 1) and SAD (Figure 2). The Z test did not identify statistical difference between the areas under the curve for the WP and for SAD. However, according to the correlation analyses, the ROC analysis showed that the WP measured at midpoint between the last rib and the iliac crest and the SAD measured at the level of the natural waist presented the AUC with the highest absolute values.

Discussion

The results of the present study demonstrated that, regardless of the nutritional status, the SAD measured at the

Table 1 – **Characterization of the individuals according to age, anthropometric profile and blood pressure levels**

Variables	Mean ± SD or Median (Min - Max)
Age (years)	38.36 ± 10.68
Anthropometry	
Weight (kg)	73.27 ± 10.15
Height (cm)	173.38 ± 6.92
BMI (kg/m²)	24.37 ± 3.08
Biochemical Profile	
Fasting glucose (mg/dl)	83.3 ± 7.0
Fasting insulinemia (µU/ml)	5.45 ± 1.48
HOMA-IR	1.06 (0.52-2.43)
Total Cholesterol (mg/dl)	162.61 ± 29.43
HDL-C (mg/dl)	43.5 (23.0-110.0)
LDL-C (mg/dl)	102.22 ± 26.88
Triglycerides (mg/dl)	77.21 ± 28.72
Blood Pressure levels	
Systolic arterial pressure (mmHg)	120.0 (100-160)
Diastolic arterial pressure (mmHg)	80.0 (60-100)

SD – standard deviation, BMI – body mass index. Values are presented as means or medians according to distribution of variables in the normality curve.

Table 2 – **Comparison between different anatomic sites in the measurement of the waist perimeter and sagittal abdominal diameter according to the presence and absence of excess body weight in all individuals**

Measurements	BMI < 25.0 kg/m² (n = 93)	BMI ≥ 25.0 kg/m² (n = 97)	All (n = 190)
Waist perimeter (cm)			
Smallest girth between the thorax and hip	79.8 ± 6.3 †[a]	91.5 ± 5.9 †[a]	86.2 ± 9.1 †[a]
Midpoint between the last rib and iliac crest	82.4 ± 7.1 [b]	94.9 ± 6.5 [b]	89.3 ± 10.0 [b]
Umbilical level	83.6 ± 7.4 [bc]	95.8 ± 6.6 [b]	90.4 ± 10.0 [b]
Immediately above the iliac crests	85.2 ± 6.6 [c]	96.2 ± 6.1 [b]	91.3 ± 9.1 [b]
Sagittal abdominal diameter (cm)			
Smallest girth between the thorax and hip	18.1*[ab]	21.6 ± 2.0 *[ab]	19.9 ± 2.6 †[a]
Midpoint between the iliac crests	17.9 [a]	21.4 ± 1.8 [a]	19.8 ± 2.5 [a]
Umbilical level	17.9 [a]	21.3 ± 2.1 [a]	19.7 ± 2.6 [a]
Largest abdominal diameter	18.8 [b]	22.3 ± 2.0 [b]	20.7 ± 2.6 [b]

ANOVA and Tukey's post-hoc test for variables presented as means± SD; Kruskall-Wallis Test and Dunn's post-hoc test for variables presented as medians; $p < 0.01$; † $p < 0.001$. Comparisons performed inside the column among the four different measurements of the waist perimeter and sagittal abdominal diameter. Same letters indicate absence of statistical significance among the values and different letters indicate statistically significant difference.*

largest abdominal girth and the WP measured at the smallest girth between the thorax and the hip differed from the other anatomic sites considered for these measurements. Such finding demonstrates that both are not equivalent to the other sites, suggesting that the comparison between the results of different studies must be carried out carefully. In agreement with it, two other studies demonstrated that the WP measured at the smallest girth was the only anatomic site that differed from the others for the male sex[24,25]. As for the SAD, to the best of our knowledge, there have been no studies in the literature that performed such comparisons.

For the WP, when considering the nutritional status, the group with BMI < 25 kg/m^2 showed the best discrimination among the other sites, which was not true for the group with excess weight. It is noteworthy the fact that, in individuals with excess weight, there is a higher uniformity among the measurements taken at sites that are easier to delimitate, such as the umbilical level. For the SAD, there was less distinction between the means in the groups with and without excess weight.

The sites that are based on the identification of anatomic points, such as the iliac crests and the last rib, need palpation of bone structures and higher expertise on the part of the examiner. Thus, in very obese individuals, the identification of the midpoints might be impaired, depending on the accumulation of adipose tissue at that site.

Regarding the smallest girth between the thorax and the hip, the umbilical level and the largest abdominal diameter, they are easier to identify, although some individuals with pronounced abdominal obesity can have several waists along the abdomen, which can make it more difficult to identify the smallest girth location.

As for the reproducibility, even in the presence of different degrees of difficulty in determining the several anatomic points, the four measurements of the SAD and the WP presented high precision in the analysis of intra-class correlation, which was also demonstrated in other studies[20,24,26-28]. The reliability of an anthropometric measurement is related to its precision, which depends on measurement errors resulting from the imperfections in the measurement tools and the capacity of the examiner to perform the measurement. For the SAD, it is mandatory that the caliper be exactly on the sagittal plane at the moment of the measurement, which can be monitored through the location of the air bubble in the upper part of its arm, reflecting the importance of using appropriate equipment; for the WP, the measuring tape must be positioned perpendicularly to the body axis, with these two aspects being crucial for the reliability of the measurements.

Another point in the present study that raises questions refers to the anatomic site used for the measurement of the SAD and the WP that best correlates with and/or discriminates insulin resistance. In this study, for the SAD, the lowest girth between the thorax and the hip and for the WP, the midpoint between the iliac crest and the last rib were the anatomic points that presented the best correlations, and at the ROC analysis, they also obtained the highest AUC, reflecting a better discriminating power in the assessment of insulin resistance. Although the AUC presented similar values from the statistical point of view, it is believed that, from the biological point of view, the anatomic site that presents the higher AUC is an indicator of the quality of the curve and of the discriminating power of the test in question[29].

For the SAD, the most often used anatomic site has been the midpoint between the iliac crests[20,30]. Such recommendation originated from studies carried out since the end of the 80s, in which estimates of the visceral adipose tissue volume, carried out by computed tomography, better correlated with the sagittal views at the level of lumbar vertebrae L4 and L5, which coincide with the midpoint between the iliac crests[31,32]. However, these studies were carried out with small number of individuals. Recent studies have questioned the use of the L4-L5 and proposed other sites for the estimate of the visceral adipose tissue[33-35]. The study by Shen et al[35] carried out with men (n = 283) of different ethnicities, the scans evaluated 15 cm above the L4-L5 presented a higher correlation with

Table 3 – Reproducibility of the Waist Perimeter and Sagittal Abdominal Diameter measured at four different anatomic sites

Measurements	ICC	CI (95%)
Waist perimeter		
Smallest girth between the thorax and hip	0.994*	0.992 – 0.995
Midpoint between the last rib and iliac crest	0.998*	0.997 – 0.998
Umbilical level	0.998*	0.997 – 0.999
Immediately above the iliac crests	0.999*	0.998 – 0.999
Sagittal abdominal diameter		
Smallest girth between the thorax and hip	0.994*	0.992 – 0.995
Midpoint between the iliac crests	0.992*	0.989 – 0.994
Umbilical level	0.993*	0.991 – 0.995
Largest abdominal diameter	0.986*	0.981 – 0.989

*N – 190. ICC – intraclass correlation coefficient, CI – confidence interval. *p < 0.001.*

Table 4 – Correlations between the four different measurements of the waist perimeter and sagittal abdominal diameter with the HOMA-IR

Measurements	HOMA-IR
Waist perimeter	
Smallest girth between the thorax and hip	0.434*
Midpoint between the last rib and iliac crest	0.464*
Umbilical level	0.455*
Immediately above the iliac crests	0.453*
Sagittal abdominal diameter	
Smallest girth between the thorax and hip	0.482*
Midpoint between the iliac crests	0.458*
Umbilical level	0.477*
Largest abdominal diameter	0.458*

*N – 138. Spearman's correlation coefficient. *p < 0.001.*

the fasting insulinemic levels, when compared to the other locations (- 5cm, L4-L5, +5 cm and +10 cm). In the consensus published by Klein et al[36], the authors mention that the site of assessment of the intra-abdominal fat influences its association with the cardiometabolic risk and that the scans performed at the level of the L1-L2 vertebrae are better than those obtained at L4-L5 for this type of assessment[36].

It is possible that the SAD, measured at the smallest girth between the thorax and the hip, presented a better association with the insulin resistance, when compared to the other sites used in the study, due to the distribution of the visceral adipose tissue in the abdominal region. The visceral adipose tissue can be divided in intra-peritoneal and extra-peritoneal adipose tissues, which present metabolic differences between them. The first, located in the upper portion of the abdomen, is more metabolically active, favoring a direct exposition of the liver, through the portal circulation, to high concentrations of fatty acids or other byproducts of their metabolism, which increases the risk of metabolic complications, such as insulin resistance. As for the extra-peritoneal adipose tissue, located in the lower portion of the abdomen (a place that coincides with the midpoint between the iliac crests), acts mainly as mechanical pads for the protection of organs such as the kidneys, rectum, uterus and bladder[31,37].

For the WP, similarly to our study, some studies evaluated this measurement at the midpoint between the iliac crest and the last rib, and identified a good performance for the prediction of insulin resistance. Ybarra et al[38] studied 78 healthy men and found an area under the ROC curve of 0.929 for the WP measured at the midpoint between the iliac crest and the last rib, according to the HOMA-IR. Such finding, in accordance, although much higher than the one found by the present study (0.746), might be due to higher insulinemic (17.0 ±1.3 μU/ml) as well as HOMA-IR (4.08 ± 0.34) levels in this sample. Moreover, the frequency of excess weight (85.1 *vs.* 44.9%) and WP mean (106.2 ± 2.0 *vs.* 87.2 ± 9.2 cm) were higher than the ones in the present study, which certainly explains the high AUC.

The study by Shen et al[35], carried out with 283 men with metabolic characteristics that were similar to those in the present study, the WP measured at the midpoint between the iliac crest and the last rib was the indicator that best correlated with the fasting insulinemic levels, when compared to the indicators of generalized obesity. Willis et al[25] compared the WP measured at the smallest girth and at the umbilical level in 134 men aged 45 to 60 years and found that the smallest girth was the one that best positively correlated with fasting

Table 5 – Area under the ROC curve for the different measurements of the waist perimeter and sagittal abdominal diameter as predictors of insulin resistance

Variables	Area ± SE (95%CI)
Waist perimeter	
Smallest girth between the thorax and hip	0.736 ± 0.050 (0.638 - 0.834)*
Midpoint between the last rib and iliac crest	0.746 ± 0.049 (0.649 - 0.842)*
Umbilical level	0.738 ± 0.049 (0.641 - 0.835)*
Immediately above the iliac crests	0.728 ± 0.049 (0.632 - 0.824)*
Sagittal abdominal diameter	
Smallest girth between the thorax and hip	0.739 ± 0.049 (0.643 - 0.834)*
Midpoint between the iliac crests	0.716 ± 0.051 (0.617 - 0.816)*
Umbilical level	0.726 ± 0.050 (0. 628 - 0.823)*
Largest abdominal diameter	0.726 ± 0.050 (0.628 - 0.823)*

*N – 138. * p < 0.001. SE – standard-error. CI – confidence interval.*

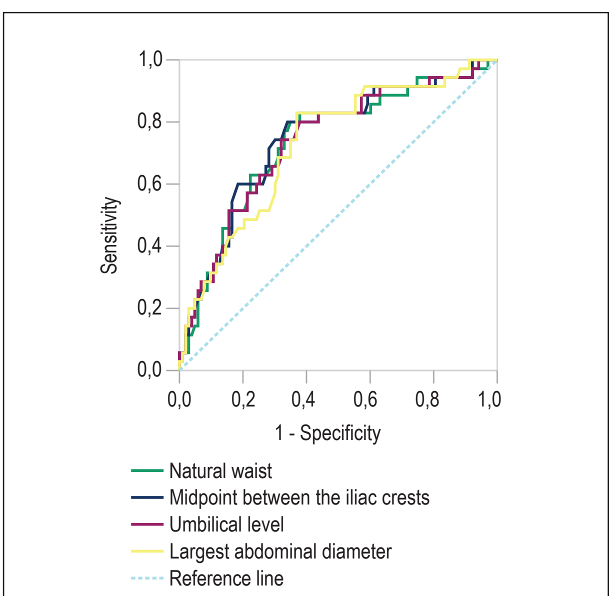

Figure 1 - ROC curves comparing the efficacy of four different measurements of the waist perimeter in the prediction of insulin resistance in men.

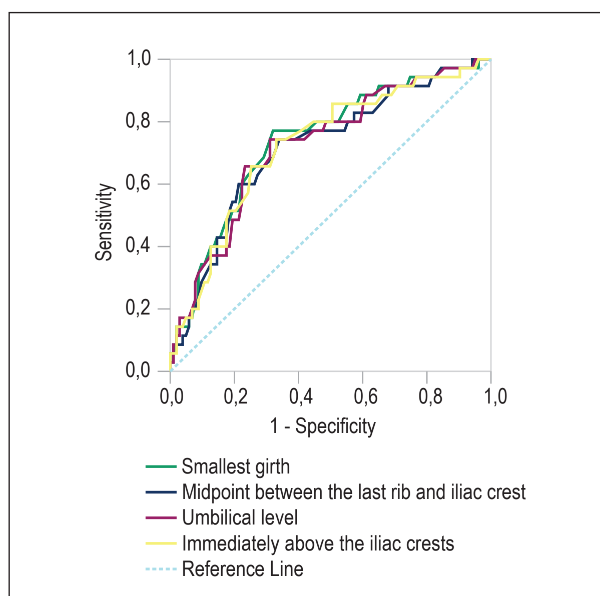

Figure 2 - ROC curves comparing the efficacy of four different measurements of the sagittal abdominal diameter in the prediction of insulin resistance in men.

insulinemia and insulin resistance. Unfortunately, these authors did not evaluate the WP at the midpoint between the iliac crest and the last rib, as in the present study.

In general, we deplore the scarcity of studies comparing the several anatomic points used for the measurement of WP and the SAD in the prediction of insulin resistance.

Corroborating our results, of which the WP and the SAD are good anthropometric indicators of insulin resistance, Pouliot et al[6], in a sample that consisted of 81 adult men, reported that the WP and the SAD are the best anthropometric indicators related to cardiometabolic risk factors, such as increased fasting insulinemic levels.

Although the HOMA-IR is not the most accurate method for the identification of insulin resistance, that is, the gold-standard method as the clamp technique, it represents an adequate method for population-based studies. Several validation studies have demonstrated strong correlations between the two methods[39,40]. Moreover, the present study used an assay for insulin that presents no crossover reaction with pro-insulin, which guarantees higher reliability of our plasma insulin measurements.

Another important point refers to the inclusion of individuals that are metabolically healthy regarding the variables related to insulin resistance, which resulted, although not on purpose, in a sample that consisted of individuals with low insulinemic levels and, consequently, low levels of HOMA-IR. Furthermore, most of the volunteers (72.5%) practiced regular physical activities (data not presented), a factor known to exercise a positive influence on insulin sensitivity, which might also have contributed to the HOMA-IR levels.

However, it is important to mention that, even if this sample consists only of healthy individuals with low levels of HOMA-IR, moderate correlations between the waist perimeter, the sagittal abdominal diameter and HOMA-IR were identified, demonstrating the association between these variables. Additionally, in general, our sample consisted of an *n* that was higher than or similar to the ones evaluated by most of the aforementioned studies, which ensures that our findings have reliability and statistical power.

Conclusion

In conclusion, the waist perimeter and the sagittal abdominal diameter are highly reproducible anthropometric measures and the anatomic sites tested here for the sagittal abdominal diameter and the waist perimeter are not the same between them. Among the studied sites, the smallest girth between the thorax and the hip for the sagittal abdominal diameter and the midpoint between the iliac crest and the last rib for the waist perimeter are the sites of choice for predicting insulin resistance. Therefore, we suggest the inclusion of these two measures, measured at these anatomic sites, in clinical practice to evaluate insulin resistance. The choice between the two shall be based on the available infra-structure and the examiner's capacity to perform such measurement. Both are relatively inexpensive; however, the measurement of the sagittal abdominal diameter requires the presence of an abdominal caliper and an examining table so that the patient can lie in the supine position.

Further studies are suggested to evaluate the behavior of several anatomic sites tested here, such as the waist perimeter and the sagittal abdominal diameter in the prediction of insulin resistance in women, in other ethnic groups and at different age ranges, such as adolescents and the elderly, allowing the use of these indicators of insulin resistance in the population as a whole, either in population screening procedures or even in clinical practice, in a standardized way.

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Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

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