

Circumference measured at different sites of the trunk and cardiometabolic risk factors

Circunferências medidas em diferentes locais do tronco e fatores de risco cardiometabólico

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Abstract – The objectives of this study were to compare waist and abdominal circumference and to analyze their association with cardiometabolic risk factors in employees of a university in Bahia. Fifty-five men and 71 women (36.4 ± 11.2 years) were submitted to anthropometric assessment and measurement of systolic and diastolic blood pressure, blood glucose, triglycerides, total cholesterol, and HDL and LDL fractions. Despite strong correlations ($P < 0.01$) between the different measures ($r > 0.93$), waist circumference was significantly lower than abdominal circumference in the two genders, with the mean difference being greater in women (8.6 ± 4.1 vs 3.8 ± 4.2 cm; $P < 0.01$). Waist circumference was significantly associated with two and four risk factors in men and women, respectively. On the other hand, abdominal circumference was significantly associated with one risk factor in men and with five factors in women. No significant differences ($P > 0.05$) between correlation coefficients were observed in cases in which the two circumference measures were significantly associated with one risk factor. These results suggest that the site of measurement has substantial influence on circumference measured in the lower region of the trunk, particularly in women. However, there is no clear evidence of the superiority of a single measure in terms of the association with traditional cardiometabolic risk factors in the Brazilian sample studied. Further investigations are needed to compare the predictive capacity of different circumference measures for the development of risk factors and cardiovascular diseases in different populations.

Key words: Anthropometry; Central obesity; Risk factors.

Resumo – Os objetivos deste estudo foram comparar medidas de circunferências da cintura e abdominal e analisar suas relações com fatores de risco cardiometabólico em servidores de uma universidade da Bahia. Para tanto, cinquenta e cinco homens e setenta e uma mulheres ($36,4 \pm 11,2$ anos) foram submetidos à avaliação antropométrica bem como medidas das pressões arteriais sistólica e diastólica, glicemia, triglicérides, colesterol total e frações HDL e LDL. Apesar das fortes correlações ($P < 0.01$) entre as diferentes medidas ($r > 0,93$), a circunferência da cintura foi significativamente menor que a circunferência abdominal em ambos os sexos, sendo a diferença média entre locais maior em mulheres ($8,6 \pm 4,1$ vs $3,8 \pm 4,2$ cm; $P < 0,01$). A circunferência da cintura foi significativamente relacionada a dois e quatro fatores de risco em homens e mulheres, respectivamente. Por outro lado, a circunferência abdominal foi significativamente relacionada a um fator em homens e cinco em mulheres. Não foram observadas diferenças significativas ($P > 0,05$) entre coeficientes de correlação nos casos em que ambas as circunferências se relacionaram significativamente a um fator de risco. Esses resultados sugerem que o local de mensuração tem influência substancial sobre a circunferência tomada na região inferior do tronco, particularmente, em mulheres, porém, não evidenciam clara superioridade de uma das medidas quanto às relações com fatores de risco cardiometabólico tradicionais em amostra brasileira. Estudos devem ser conduzidos, buscando comparar a capacidade preditiva de diferentes medidas de circunferência para o desenvolvimento de fatores de risco e doenças cardiovasculares em diferentes populações.

Palavras-chave: Antropometria; Obesidade central; Fatores de risco.

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INTRODUCTION

Although controversy exists regarding the superiority of a single anthropometric measure for the prediction of cardiovascular risk^{1,2}, circumference measures obtained in the lower region of the trunk are frequently adopted in epidemiological studies as indicators of central adiposity³⁻⁵ and are part of the criteria used worldwide for the diagnosis of metabolic syndrome⁶⁻⁸. One important aspect of circumference measures is the site of measurement, considering the wide variation in the protocols reported in the literature. Different bony and external anatomical landmarks, including minimal waist and umbilicus, are adopted for this purpose^{6,9-11}. External landmarks are widely used due to their practicality since they require less exposure of the body surface, less time, and less experience for their localization than bony landmarks^{9,12,13}. In view of divergences in the terminology used for the designation of the same site, in the present study waist circumference (WC) was used for measures obtained at the minimal waist, and abdominal circumference (AC) for measures obtained at the umbilicus.

Despite high correlations, significant differences between circumference measures obtained at different sites have been reported^{9,11,14}, with WC and AC providing lower and higher values for the two genders, respectively. However, data regarding the preference of one measurement protocol over the other are limited.

In a review, Ross et al.¹² argued that the site of measurement does not exert a substantial influence on the association between circumference measured in the lower region of the trunk and diabetes, morbidity due to cardiovascular diseases, cardiovascular mortality, or overall mortality. In contrast, recent studies suggest that WC is better correlated with some cardiometabolic risk factors when compared to measurements obtained at other sites, at least in Caucasian women^{9,11}. However, these results should be interpreted with caution since ethnic differences in the relationship between anthropometric parameters, visceral fat and cardiometabolic risk have been reported¹⁵⁻¹⁸.

In studies involving Brazilian populations, similar correlations have been observed between circumferences measured at different sites of the trunk, percent abdominal fat¹⁹, and insulin resistance evaluated by the HOMA-IR index²⁰. However, despite the growing application of these anthropometric parameters in national studies^{1,3,5,8,17}, further investigations evaluating the consequences of the

use of different sites of measurement in the Brazilian population are needed in view of the small number of studies on this topic^{19,20}. Therefore, the objectives of the present study were to compare WC and AC measurements and to determine their association with cardiometabolic risk factors in a sample of apparently healthy university employees.

METHODOLOGICAL PROCEDURES

A cross-sectional study involving a representative sample of employees from the Universidade Estadual de Santa Cruz, Ilhéus, coastal city of the State of Bahia, northeastern Brazil, was conducted between May and September 2008. After consulting the Human Resources Management of the institution, a population of 291 employees (46.7% men and 53.2% women) aged 18 years or older, who were actively working and available on the Campus, was selected.

Adopting a level of confidence of 1.96 (95% confidence interval), an estimated prevalence of central obesity of 20% according to the criteria proposed by Lean et al.²¹, and a tolerable sampling error of five percentage points, the necessary sample size calculated as proposed by Luiz and Magnanini²² was 171 subjects. After adding 20% for eventual losses, 205 employees were selected by drawing lots and invited to participate in the study. A random study design stratified by gender was used, with the proportional allocation of men and women in relation to the total population of employees.

Exclusion criteria were smoking, use of hypoglycemic, antihypertensive or hypolipidemic agents, pregnancy, systemic diseases, and failure to meet the pre-assessment recommendations. The study was approved by the Ethics Committee of Universidade Estadual de Santa Cruz (protocol 072/06) and was conducted in accordance with the Declaration of Helsinki.

After they had signed the informed consent form, the volunteers were submitted to measurement of blood pressure, anthropometric assessment and blood collection during a single visit after an overnight fast. In addition, the subjects answered a self-reported questionnaire regarding personal and sociodemographic data. Systolic (SBP) and diastolic (DBP) blood pressure was measured by auscultation using a calibrated aneroid sphygmomanometer (Glicomed®, Brazil) placed around the arm. After 10 min of rest while sitting in a silent room, two measurements were obtained at intervals of 2 min and the mean value was considered for analysis.

Body weight and height were measured to the nearest 0.1 kg and 0.5 cm, respectively, using a calibrated mechanical scale equipped with a stadiometer (Filizola®, Brazil), with the subjects barefoot and wearing light clothing. The body mass index (BMI) was calculated by dividing body weight by the square of the height (kg/m^2). The cut-off values for overweight and obesity were ≥ 25 and $\geq 30 \text{ kg}/\text{m}^2$, respectively²³.

Skin color was self-reported by the subjects according to the following categories: mulatto, white, black, yellow, and indigenous, with the last two categories being classified as minorities.

Abdominal circumference (AC) was measured at the umbilicus and WC at the minimal waist. Two measurements were made at each site by a single trained examiner using an inextensible metal tape (Sanny®, Brazil). The tape was placed directly onto the skin at the end of a normal expiration, perpendicular to the longitudinal axis of the body and horizontal to the floor. The subjects were standing upright with feet together, looking straight ahead, and the arms hanging loosely at the sides. Mean values were calculated for each site.

After the anthropometric measurements, 5-ml blood samples were collected from the antecubital vein for subsequent analysis of total cholesterol, HDL-cholesterol, triglycerides, and glycemia by colorimetric enzymatic methods (Doles®) using a VERSAMax microplate reader. The fraction of LDL-cholesterol was determined by the equation of Friedewald for triglycerides $< 400 \text{ mg}/\text{dl}$.

For statistical analysis, the Kolmogorov-Smirnov test was applied before parametric statistics to confirm the normal distribution of the data. Descriptive statistics for all variables studied is reported as the mean and standard deviation. The intraclass correlation coefficient was used to analyze the reproducibility of the circumference measures and the relative technical error of measurement was calculated according to Silva et al.²⁴. Paired and unpaired *t*-tests were adopted for the comparison between genders and sites of measurement, respectively. The correlation between circumference measures and risk factors was evaluated using Pearson's correlation coefficient. The data were analyzed for each gender using the SPSS 13.0 for Windows program (SPSS, Inc., Chicago, USA). Significant correlation coefficients were compared by Steiger's *Z*-test²⁵ using the spreadsheet available at <http://www.stat-help.com/spreadsheets.html>. A level of significance of less than 5% was adopted for all tests.

RESULTS

Of the 205 subjects invited to participate in the study, 179 followed the invitation (response rate = 87.3%). After application of the exclusion criteria, 126 subjects (55 men and 71 women) were included in the study.

There was a predominance of mulattoes ($n = 72$, 57.1%), followed by whites ($n = 29$, 23.0%), blacks ($n = 21$, 16.7%), and minorities ($n = 4$, 3.2%). Overweight and obesity, characterized by BMI ≥ 25 and $\geq 30 \text{ kg}/\text{m}^2$, respectively, were observed in 38.9% and 12.7% of the subjects. No significant differences ($p > 0.05$) in age, BMI, total cholesterol or LDL-cholesterol were observed between genders. However, men presented significantly greater ($p < 0.05$) height, body weight, blood pressure, glycemia and triglycerides, whereas HDL-cholesterol levels were significantly higher in women ($p < 0.05$). The characteristics of the volunteers are shown in Table 1.

High and significant ($p < 0.01$) intraclass correlation coefficients were observed for AC (0.990) and WC (0.996), which presented technical errors of measurement of 0.71 and 0.70%, respectively. Despite the high correlations between circumference measures obtained at different sites ($p < 0.01$), AC was significantly higher than WC ($p < 0.01$) in the two genders, with the mean difference between measures being greater among women ($p < 0.01$) (Table 2).

Table 1. Characteristics of the volunteers.

	Men (n = 55)	Women (n = 71)
Age (years)	38.5 ± 11.9	34.8 ± 10.3
Height (cm)	170.9 ± 8.0	161.5 ± 6.9*
Body weight (kg)	76.2 ± 13.9	64.3 ± 12.7*
BMI (kg/m^2)	25.9 ± 3.9	24.7 ± 4.7
SBP (mm/Hg)	126.1 ± 13.0	113.9 ± 12.0*
DBP (mm/Hg)	87.0 ± 9.6	79.0 ± 10.1*
Glycemia (mg/dl)	88.5 ± 10.6	83.3 ± 10.7*
TG (mg/dl)	139.6 ± 97.7	105.2 ± 52.9*
TC (mg/dl)	161.9 ± 40.2	162.8 ± 37.2
HDL-c (mg/dl)	38.0 ± 11.3	54.0 ± 20.6*
LDL-c (mg/dl)	98.1 ± 35.9	93.4 ± 36.6

BMI: body mass index; SBP: systolic blood pressure; DBP: diastolic blood pressure; TG: triglycerides; TC: total cholesterol; HDL-c: HDL-cholesterol; LDL-c: LDL-cholesterol. * $p < 0.05$ compared to men.

Table 2. Comparison and correlation between waist and abdominal circumference.

	Men (n = 55)	Women (n = 71)	Total (n = 126)
WC (cm)	86.3 ± 9.5	76.7 ± 10.6*	80.9 ± 11.2
AC (cm)	90.1 ± 11.3 [‡]	85.3 ± 12.2**	87.4 ± 12.0 [‡]
Cdif (cm)	3.8 ± 4.2	8.6 ± 4.1*	6.5 ± 4.7
Pearson's <i>r</i>	0.934 [§]	0.946 [§]	0.919 [§]

WC: waist circumference; AC: abdominal circumference; Cdif: AC – WC. **p* < 0.01 compared to men; [‡]*p* < 0.01 compared to WC; [§]*p* < 0.01.

The associations between circumference measures obtained at different sites and cardiometabolic risk factors are shown in Table 3. WC was significantly associated with two (SBP and DBP) and four (SBP, DBP, triglycerides, and HDL-cholesterol) factors in men and women, respectively. On the other hand, AC was significantly associated with one risk factor (SBP) in men and five factors (SBP, DBP, triglycerides, HDL-cholesterol, and LDL-cholesterol) in women. No significant differences (*p* > 0.05) were observed between correlation coefficients in cases in which the two circumference measures were significantly associated with only one risk factor.

DISCUSSION

The present results showed that WC was significantly correlated with, but was also significant lower than, AC in both genders, with this difference being greater among women (Table 2). These findings agree with those reported for other populations^{9,11,14,20}, indicating a substantial influence of the site of measurement on circumference measured in the lower region of the trunk.

In view of the variety of protocols adopted in studies involving Brazilian populations^{1,3,5}, comparisons should be made with caution since the prevalence estimates of central obesity¹⁰ and metabolic syndrome¹¹ are affected by the site of circumference measurement. Nevertheless, until recently little attention has been paid to the scientific basis for the choice of the exact site of measurement in the lower region of the trunk, which is superior to other sites because of its association with cardiometabolic risk factors¹³.

In middle-aged subjects with overweight/obesity and mild to moderate dyslipidemia, Willis et al.¹¹ found WC to be better correlated with eight risk factors than AC in postmenopausal women, whereas less clear evidence favoring the former was obtained for men. Recently, Mason & Katzmarzyk⁹ reported a similar magnitude of correlations between circumference measures obtained at four sites and cardiometabolic risk factors in a predominantly white sample (age: 20 to 66 years; BMI: 18.76 to 49.2 kg/m²). The only exception was the fact that WC was significantly better correlated with DBP and HDL-cholesterol in women when compared to measurements made at the umbilicus, iliac crest, or midpoint between the iliac crest and the lowest rib.

On the basis of the studies cited above, it seems plausible that WC is slightly superior to circumference measured at other locations, at least in Caucasian women. However, these data should not be extrapolated in view of the existence of ethn racial differences in the relationship between anthropometric parameters, visceral fat and cardiometabolic risk¹⁵⁻¹⁸. In this respect, the Brazilian population is characterized by a mixture of races^{18,26,27}, a fact demonstrated in the present study by the predominance of mulattoes, a genetic

Table 3. Pearson's correlation coefficients between waist and abdominal circumferences and cardiometabolic risk factors in men and women.

	SBP	DBP	Glycemia	TG	TC	HDL-c	LDL-c
Men (n = 55)							
WC	0.314*	0.295*	0.190	0.235	0.117	-0.072	-0.008
AC	0.278*	0.208	0.239	0.218	0.221	0.011	0.102
Comparison	<i>p</i> > 0.05	NC	NC	NC	NC	NC	NC
Women (n = 71)							
WC	0.427**	0.490**	0.050	0.362**	0.196	-0.276*	0.237
AC	0.368**	0.434**	0.084	0.420**	0.189	-0.276*	0.240*
Comparison	<i>p</i> > 0.05	<i>p</i> > 0.05	NC	<i>p</i> > 0.05	NC	<i>p</i> > 0.05	NC

WC; waist circumference; AC; abdominal circumference; SBP; systolic blood pressure; DBP; diastolic blood pressure; TG; triglycerides; TC; total cholesterol; HDL-c; HDL-cholesterol; LDL-c; LDL-cholesterol. **p* < 0.05; ***p* < 0.01; NC = not calculated.

group including subjects not classified as white, black or minority (yellow and indigenous)²⁶.

In healthy men connected to the Federal University of Viçosa, Vasques et al.²⁰ observed moderate but significant associations between the HOMA-IR index and circumference measured at the minimal waist and umbilicus, immediately above the iliac crests, and at the midpoint between the iliac crest and lowest rib. Although the authors suggested better performance of the last parameter in the prediction of insulin resistance, similar correlations were observed between the different measurements and this risk factor ($r = 0.434$ to 0.464). Unfortunately, no information about the ethnic distribution of the sample was provided in that study.

Weak to moderate correlation coefficients were obtained between circumference measures obtained at different sites of the trunk and the risk factors analyzed (Table 3), in agreement with previous studies^{10,11,28}. In agreement with the scarce literature on this topic^{9,11}, the correlations varied according to gender, site of measurement and specific risk factor, with consistently higher values being observed for women. However, WC and AB generally showed similar associations with most of the risk factors analyzed. Similar findings have been reported by Mason & Katzmarzyk⁹ and Vasques et al.²⁰.

In women, AC was significantly correlated with a larger number of risk factors than WC (5 vs 4). The opposite was observed for men, in whom WC and AC were significantly correlated with 1 and 2 factors, respectively. Although in a first analysis these results can be interpreted as evidence of the superiority of AC in women and of WC in men, more careful analysis of the data revealed a tendency towards a significant correlation between WC and LDL-cholesterol in women ($p = 0.052$), in addition to the lack of significant differences between correlation coefficients in the two genders. Taken together, these findings seem to indicate a consistent advantage of one of the sites of measurement.

The divergences compared to the study of Willis et al.¹¹ might be explained not only by the characteristics of the sample studied, but also by the differences in the factors analyzed by these authors, such as HDL-cholesterol particle size and insulin resistance which were more highly correlated with WC than AC in women.

The possible higher correlations of one site of circumference measurement with cardiometabolic risk factors might be explained by the better cor-

relation of this site with visceral adipose tissue. Within this context, although studies have shown that different sites of measurement provide similar estimates of total body and trunk fat^{13,14,18,19}, Willis et al.¹¹ observed a slightly higher correlation between WC and visceral adipose tissue area determined by computed tomography when compared to AC. However, further studies investigating subjects with different characteristics are needed to draw major conclusions.

According to Agarwall et al.¹³, considering the high correlation between existing protocols and the lack of a clear biological explanation, the preference for one protocol should take into account the maximization of convenience and the minimization of measurement errors. However, the intraobserver technical errors of measurement obtained in this study were low and similar for WC (0.71%) and AC (0.70%), and therefore do not support the choice of one measurement over the other.

Limitations of the present study include the miscegenation of the sample investigated and the analysis of only two sites of measurement of circumference. Although potentially confounding in the identification of specific ethnic relationships, it should be noted that the distribution of the present sample was similar to that reported in other studies involving Brazilian populations^{17,18,19,27}, a fact increasing the external validity of the present results. In addition, WC and AC were chosen for investigation since both measurements involve anatomical landmarks that are relatively simple to localize and are widely used^{9,11,12}.

CONCLUSION

The present results suggest that the site of measurement has a substantial influence on circumference measured in the lower region of the trunk in Brazilian subjects, particularly women. These findings indicate the need for standardization of a measurement protocol that would permit valid comparisons between regional and international studies. However, considering the association with traditional cardiometabolic risk factors, the present findings do not provide clear evidence for the superiority of a single measurement (WC or AC). Large-scale longitudinal studies are needed to compare the predictive capacity of different circumference measures for the development of cardiometabolic risk factors and cardiovascular diseases in different populations.

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