Anthropometric Indicators of Insulin Resistance

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Abstract

Some studies have analyzed the efficacy of anthropometric indicators in predicting insulin resistance (IR), for they are more economic and accessible. In this study, the objective was to discuss the measures and anthropometric indices that have been associated with IR. A bibliographic review was done, based on Scielo, Science Direct and Pubmed. Among these studies, waist and sagittal abdominal diameter presented better predictive capacity for IR, with more consistent results. The waist-to-thigh, waist-to-size, neck-to-thigh ratios, the conicity and the sagittal index have showed positive results; nevertheless, more studies are necessary to consolidate them as predictors to IR. The obtained results, with the use of body mass index and of the waist-to-hip ratio, were inconsistent. In the Brazilian population, the realization of studies evaluating the performance of these indicators in predicting IR is suggested, since the results of the studies conducted in other populations are not always applicable to ours, due to ethnical differences resulting from the great miscegenation in the country.

Introduction

Insulin resistance (IR) syndrome is one of the main risk factors for cardiovascular diseases, presenting high morbimortality and socioeconomic expenses. The IR, which is considered a link between the other physiological changes that compound the complex state of this syndrome, is associated with visceral obesity; arterial hypertension; intolerance to glucose and to type 2 diabetes; dyslipidaemia; hyperuricemia, and other metabolic changes[1-,3].

The evaluation of the IR has received considerable attention in the last few years. In Brazil, the determination of IR has not been in the routine medical exams yet, and is not available in most of the health services. The laboratorial methods for the determination of IR are expensive and with standardization deficiencies for its execution, limiting the comparison between different laboratories results' and its application in clinical practice[4].

Studies have correlated the isolated anthropometric measures and the anthropometric indexes with IR[5-9]. The anthropometric indicators arise as an alternative for IR's evaluation with lower cost and higher easiness of application in epidemiological studies and in health basic attention services. Because of the importance of this theme, the objective was to discuss about the main measures and the anthropometric indexes that have been associated with IR.

Methodology

A bibliographic review was performed on available periodics in scientific bases, such as Scielo, Science Direct and Pubmed. The keywords used for the search of articles were: insulin resistance; anthropometry; body mass index; waist circumference; sagittal abdominal diameter; waist-hip ratio; conicity index; waist-thigh ratio; neck circumference; and waist-stature ratio. Published articles were selected between 1990 and 2007, besides of the incorporation of classic previously published papers concerning the theme. Most of the studies included in this review were transversal. Some case-control and cohorts works were also discussed. Articles characterized by scientific rigidity, concerning the sample's size and statistical analysis appropriate to the objectives of the study.

Insulin resistance

Laboratorial determination

IR can be determined directly from the management of a predetermined quantity of exogenous insulin, or indirectly, based on the concentrations of endogenous insulin[10].

The euglycemic hyperinsulinemic clamp is an example of a direct technique that allows the determination of a metabolized insulin quantity, by the peripheric tissues during the stimulation with insulin. Although nowadays it is the golden standard technique for evaluating the IR *in vivo*, it is costly, slowly and of high complexity, being feasible its application in population studies, and especially in clinical practice[11].

The Homeostasis Model Assessment (HOMA) index represents one of the alternatives to the clamp technique for evaluating IR. It is a mathematic model that predicts IR's level from the basal glycaemia and insulinaemia, in homeostasis conditions, being represented by the equation[12]:

HOMA = [Fasting insulinaemia (mU/l) x Fasting glycaemia (mmol/l)] / 22.5

Key words

Insulin resistance; anthropometry; obesity; intra-abdominal fat; abdominal circumference.

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The HOMA has been widely used, specially in population studies, due to its easiness of application and to the strong and significant correlation with the direct techniques of evaluation of IR, observed in validations papers[13,14]. Nevertheless, for diagnosis or individual follow-up, its use still requires caution in questions related to the blood sample and to the defective standardization of assays to be used by the laboratories in the insulin dosage[4], pointing the need of more accessible and viable methods for clinical practice.

Anthropometric indicators

The development of computed tomography and of magnetic resonance image represented an important advance in the research of a body composition in human beings, because they allow accurate and precise measurement of the visceral and subcutaneous fat, located in the abdominal region. Ultrasonography and dual energy x-ray absorptiometry (DEXA) can also be used to evaluate abdominal fat, although the latter does not distinction between subcutaneous and visceral fat[15,16]. However, these techniques are costly and many times unavailable.

The anthropometric measures are indicatives of the nutritional state, present low cost, inocuity, simplicity in its execution and have acted as obesity indicators[17]. The correlations between the anthropometric indicators and IR have been widely studied, detaching them as non-invasive indicators for the evaluation of risk of IR, both in the epidemiologic search as in clinical practice.

The anthropometric indexes can be classified according to the evaluated obesity type[17]. Amongst the central obesity indicators there are: waist perimeter (WP), the sagittal abdominal diameter (SAD), conicity index (COI) and the waist-stature ratio. The body fat distribution has been evaluated by the waist-hip ratio, the sagittal index (SI), the waist-thigh ratio and the neck-thigh ratio. For the generalized obesity, the body mass index (BMI) has been the most used. Table 1 summarizes the main discussed studies in this review, which evaluated anthropometric indicators as predictors of IR.

Although the obesity indicators are related to IR, it should be noteworthy that IR is not a metabolic alteration exclusive of obesity and diabetes *mellitus* type 2 porters, as it happens in patients with of lipoatrophic diabetes, in which there is a genetic defect of insulin's action in skinny subjects. In the same way, some patients with normal BMI can present IR because of the visceral fat accumulation, composing a phenotype known as Metabolically Obese Normal Weight (MONW)[18].

Waist perimeter

The practicality in the application of WP, its association with cardiovascular risk factors and the strong correlation with the visceral fat area measured by computed tomography, from the order 0.73 to 0.81[19,20], are characteristics that have made it the most used indicator of abdominal adiposity. Besides that, the evaluation of the WP is in the proposals of the European Group for the Study of Insulin Resistance[21], the International Diabetes Federation[22] and of the National Cholesterol Education Program (NCEP-ATP III)[23], for the diagnosis of the IR syndrome.

In 1995, Han et al[24] have showed that the WP values above 80 and 88 cm for women, and above 94 and 102 cm for men, indicated increased and very increased risk, respectively, of metabolic complications. Later, the NCEP-ATP III[23] adopted the 88 and 102 cm values for the diagnosis of central obesity in men and women, respectively, these which have been used especially in Brazil. Populations differ between each other, according to the risk level presented for a WP datum, being impossible to determine cut points globally applicable. The International Diabetes Federation recommends the use of different cut points, according to ethnicity (Table 2)[22].

Although WP is largely diffusive, there are different descriptions for assessing and, consequently, consensus absence between researchers and published protocols, which can create conflicts at the time the measure is taken. Between the most used, there is the medium point between the iliac crest and the last rib, recommended by the World Health Organization (WHO)[25]; the smallest waist between the thorax and the hip, recommended by the Anthropometric Standardization Reference Manual[26]; the level immediately above the iliac crests, as recommended by the National Institute of Health[27]; and the umbilical level[8] (Figure 1).

Ross et al[28] have checked that the protocol used for measurement of the WP does not have essential influence in its association with cardiovascular diseases and type 2 diabetes. In Wang et al study[29], although no correlations between WP and morbidity risks have been carried out, the authors suggest that the comparisons among different papers are only valid when the same anatomic place is used for checking. These researchers have made comparisons between WP measures, taken in four places (smallest waist; immediately below the last rib; medium point between the iliac crest and the last rib and right above the iliac crest) in 111 subjects. In both sexes, differences were found, showing that the four places are not identical.

Several studies have evaluated the relation between WP and IR. In a study carried out with 8,400 subjects, WP associated positively and independently with type 2 diabetes[30]. In Weidner et al work[31], WP was the first anthropometric variable in the multivariated regression analysis, contributing with approximately 37% for a variation in insulin's sensibility. In a case-control study carried out with 300 Indians, WP was identified as the precisest predictor of risk for type 2 diabetes and its biochemical indicators[32].

In a paper carried out with Caucasians, WP was identified as a strong predictor of IR, especially in men. The best cut points of WP were evaluated for predicting IR, being 97.5 cm and 106.5 cm the values found for women and men, respectively. Yet, when the values of 88 cm for women and 102 cm, for men are compared, recommended by the NCEP-ATP III[23], the new cut points did not seem to be superior in identifying subjects with IR[33].

In Pouliot et al study[19], the increment in WP measures was consistent to the increase of glycaemia and insulinaemia of fasting and post-prandial, especially in women, suggesting that these measures are cardiovascular risk indicators. The authors suggest that the WP values above 100 cm are related to the greatest chance of development of metabolic complications.

Table 1 - **Studies that evaluated the performance of anthropometric indicators in indentifying IR**

Ref.	Study's design	Sample	Anthropometric indicators studied	Statistical analysis	Main results
7	Transversal	n = 59 M; 35 to 65 years old; BMI: 27.7 - 39.0 kg/m²	SAD, BMI, WP, waist-hip ratio	Correlation and multiple linear regression	SAD: higher correlation with IS (r = -0.61; p < 0.01), variable that better explained variation in IS (R² = 0.38, p < 0.001) and only independent predictor of IR.
8	Transversal	n = 6,007 (2,934 M and 3,073 W); 17 to 95 years old; BMI: 24.9 ± 3.5 kg/m²	BMI, WP, waist-thigh ratio, waist-hip ratio	ROC curve and logistic regression	Waist-thigh ratio: higher predictive accuracy for diabetes (area below the curve of 0.749, p < 0.0001) and increased Odds Ratio, for diabetes risk (1.811; p < 0.0001).
17	Transversal	n = 2,895 (1,412 M and 1,483 W); 46.0 ± 13.0 years old; BMI: 24.0 ± 3.4 kg/m²	BMI, WP, waist-stature ratio, waist-hip ratio	ROC curve	Waist-stature ratio: higher predictive accuracy for cardiovascular risk factors (p < 0.001).
19	Cohort	n = 151 (81 M and 70 W); 23 to 50 years old; BMI: 18 – 47 kg/m²	SAD, WP and waist-hip ratio	Correlation and ANOVA	SAD and WP: stronger correlations with FI (p < 0.01) and a more consistent increase of FI in the distribution per quintile.
31	Transversal	n = 84 (55 M and 39 W); 18 – 80 years old	COI, WP, HP, waist-hip ratio.	Multivariate regression	WP: first variable in the regression analysis, contributing for 37% of the IS variation.
32	Case-control	n = 150 healthy controls and 150 type 2 diabetic cases; 53.5 ± 10 years old; BMI: 22.58 ± 3.9 kg/m²	COI, BMI, WP, waist-hip ratio	ROC curve	WP: higher predictive accuracy for diabetes risk (area below the curve of 0.77 M and, 0.74 W, p < 0.05).
33	Transversal	n = 164 (78 M and 86 W), healthy subjects; 22 – 50 years old; BMI: 29.7 ± 0.7 kg/m²	BMI and WP	Multiple linear regression stepwise ROC curve	WP: the only independent predictor of IR (r² = 0.496; p< 0.0005) and higher predictive accuracy for IR (area below the curve of 0.93 M and 0.89 W, p < 0.05).
38	Transversal	n = 1,420 young adults; 20 to 38 years old	SAD, BMI, WP, HP, waist-stature ration, waist-hip ratio	Pearson's correlation Canonical correlation	SAD and waist-stature ratio: strongest correlations with FI (p < 0.001) SAD: strongest correlation with FI (p < 0.05).
44	Transversal	n = 157 W; 36 – 69 years old; BMI: 18.7 – 41.2 kg/m²	SAD, BMI, WP, waist-hip ratio	Correlation Multiple linear regression	SAD: strongest correlation with IR (r = 0.48; p < 0.0001) and only independent predictor of IR.
51	Cohort	n = 541 (217 M and 324 W); BMI: median of 24.7 kg/m²	BMI, WP, Neck's perimeter, waist-hip ratio	Comparison between quintiles	Neck's perimeter and other anthropometric indicators increased at the same time as FI.
52	Transversal	n = 561 healthy subjects (231 M and 330 W); 46.0 ± 16 years old; BMI: 26.5 ± 5.0 kg/m²	Neck's perimeter	Correlation	The neck's perimeter correlated with the IR syndrome components' (p < 0.05).
59	Transversal	n = 280 healthy women; 18 to 24 years old	COI, waist-hip ratio	Correlation	COI and WHR: presented weak and similar correlations with IR (r = 0.13 and r = 0.12, p < 0.05).
62		Transversal	n = 330 (139 M and 191 W) healthy subjects, age: 50 ± 1 year old and BMI: 18.5 – 46.6 kg/m²	BMI, WP	Correlation and ANOVA BMI and WP: correlations with IS of 0.57 and 0.57; p < 0.001. Stratification by BMI: subjects with higher WP had less IS. Stratification by WP: subjects with higher BMI had less IS. Both the indexes had similar performance.
64	Transversal	n = 267 type 2 diabetics; 30 – 79 years old and BMI: 17 – 24.9 kg/m²	BMI and biochemical indicators	Correlation and logistic regression	BMI: higher correlation with IR (r = 0.25) and only factor associated with IR in the regression analysis (Odds Ratio = 1.51; p < 0.001)

WP - waist perimeter; HP - hip's perimeter; SAD - sagittal abdominal diameter; M - men; COI - conicity index; FI - fasting insulinaemia; BMI - body mass index; W - women; IR - insulin resistance; IS - insulin sensibility; WHR - waist to hip ratio.

Sagittal abdominal diameter

The SAD represents an abdominal height, comprising the distance between the back and the abdomen[34]. It can be checked with the person standing[35] or in the supine position (Figure 2), this last position is the most used[7,35,36].

In the supine position, the visceral adipose tissue tends to raise the abdominal wall in the sagittal direction, and the abdominal adipose subcutaneous anterior or lateral tissue compresses the abdomen or tends to descend to both sides due to the gravity strength. Thus, it is expected that the assessed SAD in the supine position reflects specially the volume of the visceral adipose tissue[37].

The anatomical place used for the assessing differs between the studies, being used the smallest waist between the thorax and hip[38]; the highest abdominal height[39]; the umbilical scar[40]; the medium point between the last rib and the iliac crest[36];

and the medium point between the iliac crests[41]. The latter coincides with the localization of the lombar vertebral L4 and L5, the most used place by the images techniques for quantification of the visceral adipose tissue area and, maybe, the most indicated for assessing of SAD[42].

Table 2 - Cut points for the classification of central obesity from the waist perimeter

Ethnicity	Waist perimeter (cm)	
	Men	Women
Central and South America (Amerindians)	≥ 90	≥ 80
China	≥ 90	≥ 80
Europe	≥ 94	≥ 80
Japan	≥ 85	≥ 90
Southeast Asia	≥ 90	≥ 80

Font: Alberti et al[22]

The measurement of SAD can be done by anthropometry with the help of one abdominal *caliper*, or by image techniques, like the computed tomography or magnetic resonance image, since lots of studies have showed strong correlation between both techniques[36,43].

SAD has been recommended as an indicator of deposition of visceral abdominal fat and of cardiovascular risk evaluation[44,45]. Recently, cut points were proposed for SAD evaluation in Brazilians, based on a quantity of increased visceral abdominal fat, which corresponds to a superior value to 100 cm^2. For the female and male sex, the cut points were 19.3 and 20.5 cm, respectively[20].

SAD has showed strong association with glucose intolerance and with IR. Gustat et al[38] have identified SAD as an independent predictor of glycaemia and insulinaemia, pointing this anthropometric measure as an excellent marker of IR.

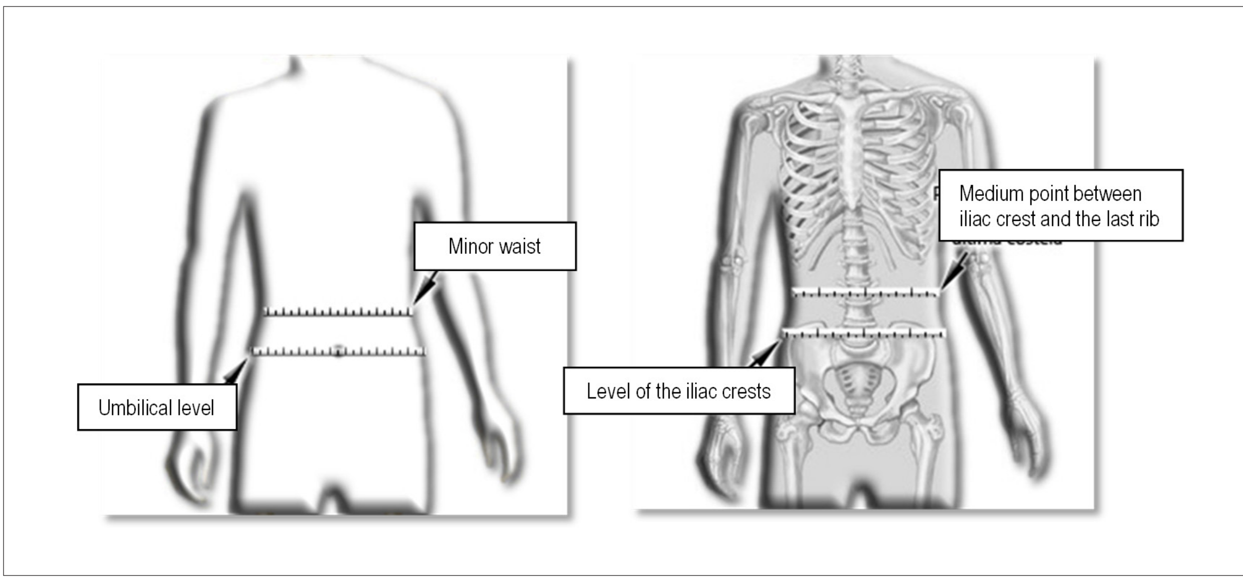

Figure 1 - Illustration of the anatomical places used for assessing waist's perimeter.

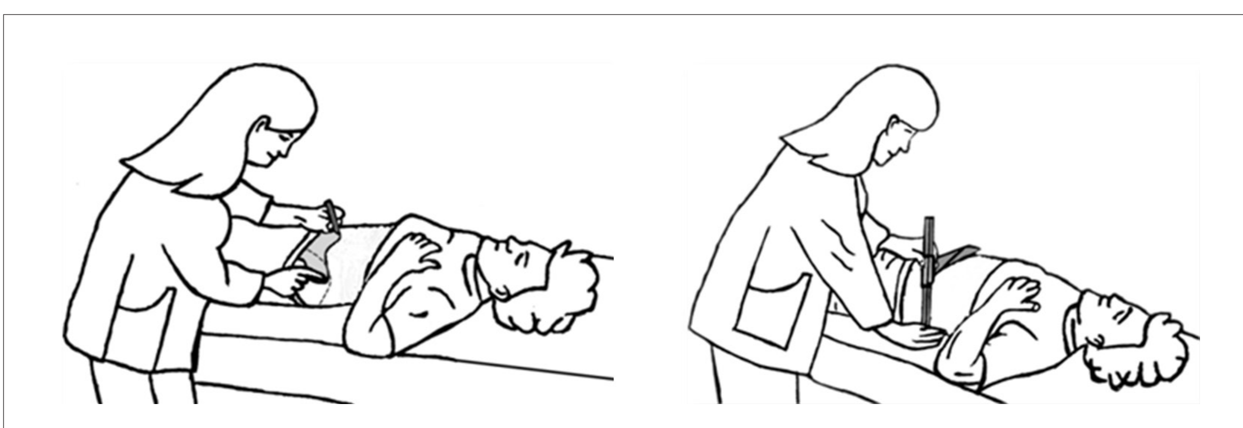

Figure 2 - Assessing of the SAD in the supine position.

In Risérus et al study[7], SAD presented stronger correlation with IR, glycaemia, insulinaemia, C-peptide and hyperproinsulinemia than the BMI, WP and waist-hip ratio. In the analysis of a univariated multiple regression, including all the anthropometric variables, SAD was the only independent predictor of IR. The study of Petersson et al[44], which was done with Swedish women, the SAD was also the best clinical marker of IR among the others, including WP, the waist-hip ratio and the BMI. In Pouliot et al study[19], besides WP, the SAD increment was also consistent to the increase on the fasting and post-prandial glycaemia and insulinaemia. In this paper, SAD values above 25 cm were associated with the highest development probability of metabolic disturbances with atherogenic potential.

Waist-hip ratio

The waist-hip ratio is the index of regional distribution of body fat most used in the epidemiological research. It is based on the ratio between the WP values and the hip's perimeter (HP). The anatomical place most used for the assessing of HP is in the height of the greatest trochanter, recommended by the WHO[25]. The waist and hip's perimeter reflect different aspects of the body composition, and possess independent and opposite effects in determining the risk of cardiovascular diseases and its risk factors. Narrow waists and large hips are associated with protection against cardiovascular diseases. This ratio has been explained by the following theory: narrow hips reflect a reduced quantity of muscular mass, which contributes for the minor insulin activity in the skeptical musculature and for the minor concentration and activity of lipoproteic lipase in the muscles, with concomitant reduction in the capture and use of fatty acid by the muscular cells. In contrast, large hips present higher concentration of lipoproteic lipase due to the biggest quantity of muscular tissue. Besides that, there is lower turnover of fatty acids in the gluteofemoral adipose tissue in relation to the visceral adipose tissue, which aids insulin sensibility. However, the independent effects of each one of the perimeters can be confused in the waist-hip ratio, so the interpretation of its values is much more complex[46].

Waist-hip ratio is partially independent of total adiposity. Skinny and obese individuals can present the same waist-hip ratio value, even though there is a substantial interindividual variation in the total fat mass and in the visceral and subcutaneous abdominal adipose tissue[19]. Moreover, waist-hip ratio can be unaltered even when changes in the body adiposity happens, due to similar alterations in both perimeters that not alter the final relation. Thus, it is important to be cautious when using waist-hip ratio as an indicator of visceral fat accumulation, being this an inappropriate relation to assess changes in visceral fat quantity during the loss or gain of weight[47].

In Pouliot et al study[19], although the waist-hip ratio has not been the best predictor of disturbances in the glucose and insulin metabolism, authors have suggested that the waist-hip ratio values above 0.8 for women, and 1.0 for men, would be associated with these metabolic alterations.

In Riserus et al[7], Mamtani et al[32] and Petterson et al[44] studies, waist-hip ratio has presented as a less useful instrument to predict IR, compared to the other anthropometric measures studies.

Sagittal index

Although less known and used between researchers and health professionals, the SI was proposed as an alternative to waist-hip ratio for estimation of the body fat distribution and for the prediction of morbidities. The SI is represented by the reason between SAD (cm) and the thigh medium perimeter (cm). In order to use it, SAD and the thigh medium perimeter, assessed in the medium point between the inguinal fold and the proximal border of patella (Figure 3), they would be measured with better representivity of the tissues in interest, compared to the waist and hip's perimeter, respectively[47].

The measure of the thigh's medium perimeter comprises the skeptical musculature, the femur and the subcutaneous and intramuscular adipose tissue. These three tissues are analogue to the ones that surround the intra-abdominal content, composed of the skeptical musculature, the vertebras and the subcutaneous adipose tissue. As the visceral adipose tissue is the abdominal compartment of interest, the thigh's medium perimeter represents a measure of comparison with the abdominal measures[47]. As an advantage, in contrary to the hip's perimeter, the thigh's medium perimeter is not affected by the variations in the pelvic architecture. Besides, the thigh's medium perimeter and the SAD are measured with increased precision[34]. The thigh's medium point is the most used to represent the central portion of the muscle, which reflects the muscular mass and the practice of physical exercises. Individuals with increased content of muscular mass and subcutaneous adipose tissue in the thigh can present a bigger answer to the signalization of insulin and low cardiovascular risk[47].

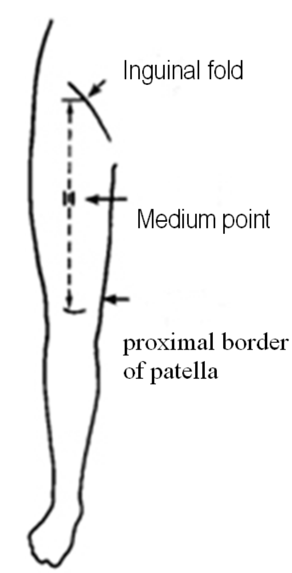

Figure 3 - *Illustration of the anatomical place used for assessing the thigh's medium perimeter.*

In a study carried out in Brazil, the SI presented lesser correlation with the visceral adipose tissue than SAD; however, there was no correlation of the SI with the area of subcutaneous abdominal fat[20]. In the study of Kahn et al[48], among the traditional anthropometric measures, like BMI and the waist-hip ratio, the SI was a better predictor of sudden coronary death in men. Smith et al[49] evaluated the strength of the association of six anthropometric parameters with known factors of cardiovascular risk in men of different ethnicities. SI was the one which presented the highest Odds Ratio for the cardiovascular disease. Although these papers have presented good results for the SI, studies evaluating its utility in predicting IR and other factors of cardiovascular risk are still scarce.

Waist-thigh ratio

Waist-thigh ratio presents a fundamental similar to the one applied in the SI, regarding the use advantages' of the thigh's perimeter in prejudice to hip's perimeter, calculated from the ratio between WP values' (cm) and the thigh's medium perimeter (cm).

In Chuang et al study[8] with Orientals (n = 6,007), between the 32 evaluated measures by laser scanning in three dimensions, the WP, representing the trunk, and the thigh's medium perimeter, representing the inferior part of the body, were the best indicators of type 2 diabetes. By the comparison between the waist-thigh ratio and the known anthropometric indicators, among them there is the BMI, the waist-hip ratio and thigh's perimeter, the authors have identified stronger correlations for the waist-thigh ratio. Kahn et al[48] have showed in their study that, the waist-thigh ratio have had great performance for evaluating cardiovascular risk disease, parallel to SI.

Neck-thigh ratio

Neck-thigh ratio comprises the reason between neck's perimeter (cm), assessed in the medium point of the neck's height (Figure 4), and the thigh's medium perimeter (cm), those which have been used as distribution indexes of subcutaneous adipose tissue of superior and inferior body parts, respectively. Following the tricompartimental body composition (visceral and subcutaneous adipose tissue), after adjustment for scarce mass and visceral adipose tissue, Sjöström et al identified positive correlation between neck's perimeter and cardiovascular risk factors related to IR, while the thigh's perimeter showed inverse correlation[50].

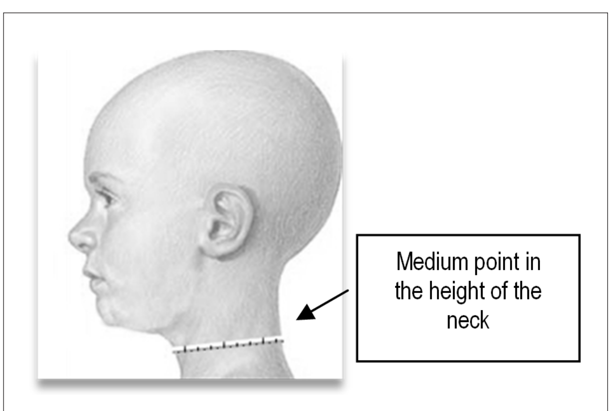

Figure 4 - Ilustração do local anatômico utilizado para a aferição do perímetro do pescoço.

Laakso et al[51], in a study carried out with 541 adults distributed according to quintiles of the neck's perimeter, identified major frequencies of hyperglycemia and hyperinsulinemia in the superior quintiles of measure, suggesting the use of neck's perimeter, in population screenings as a marker of risk individuals for IR. Ben-Noun and Laor[52] also found significant correlation between the neck's perimeter, with several cardiovascular risk factors related to IR.

Although papers evaluating neck-thigh ratio are rare, it is noteworthy that the neck's perimeter represents a quick and easy measure to happen, yonder not presenting variations in its extent throughout the day.

Waist-stature ratio

Waist-stature ratio is the reason between WP (cm) and the stature (cm). It is assumed that, for a determined stature, there is an acceptable fat degree stored in the body's superior part. Even so the precise effect of stature on the WP is quantitatively unknown, some authors assert that stature has an influence on the magnitude of WP through growing and adult life[53,54].

Studies show that, although waist-stature ratio has good correlation with visceral fat, it should be the anthropometric indicator used for the prediction of metabolic risks associated with obesity[17,54]. The most used argument is that WP[54] and the BMI[55] need several cut points, depending on the ethnicity and gender[22,25], which would supposedly difficult its use. According to these authors, WP value's maintenance below the value corresponding to stature's measure, would represent a simple and effective message for all the population, in a way that it can helps to prevent IR syndrome[54,55]. A study conducted with Iranian men showed that the waist-stature ratio presented better performance in predicting type 2 diabetes, compared to BMI[9].

Amongst waist-stature ratio, there would be the relation with cardiovascular risk factors, including fasting insulinaemia[17]; the increased sensibility in detecting precociously risk factors, when compared to BMI; and the simplicity of execution united to easiness of one cut point for individual's classification, in which the 0.5-value, determined based on the great balance between sensibility and specificity, could be universally used[55,56]. Ho et al[17] study found 0.48 value as the best cut point for the prediction of hyperinsulinemia in Chinese men.

In spite of waist-stature ratio uses stature and allows its application in several ethnicities, it can be questioned if the distinguished standard of body fat distribution, among men and women, would difficult the use of only one cut point for both sexes. However, men are taller and present higher measures for WP in relation to women. Thus, waist-stature ratio means are similar to both sexes due to the adjustment for the stature[54].

Conicity index

COI represents an abdominal obesity indicator and was proposed by Valdez[57]. This index considers that, individuals with less accumulation of fat in the central part would have a body form similar to a cylinder, while those with bigger accumulation would assimilate to a double cone, with this as a common basis.

COI equation's regards WP measures, body weight, stature and 0.109 constant, which represents the conversion of volume and mass units' for lengths units[58]:

$$\text{Conicity index} = \frac{\text{WP (m)}}{0.109 \times \sqrt{\frac{\text{Body weight (kg)}}{\text{Stature (m)}}}}$$

COI is a simple interpretation, once the denominator is the cylinder produced by the evaluated weight and stature. Hence, a COI equals to 1.20 means that the WP is 1.20 higher than the cylinder perimeter created from the by the evaluated weight and stature, reflecting the adiposity excess in the abdominal region. COI does not have a measure unit and its theoretical range is of 1.00 (perfect cylinder) to 1.73 (double cone)[58].

In its advantages, there is the fact of including in its stature, a WP adjustment for weight and stature, allowing direct comparisons of abdominal adiposity among the subjects our populations. Farther on, COI has a weak correlation with stature that is desirable for any indicator of obesity[57,58].

In a multicenter study, with 2,240 adults, insulinaemia has presented correlation standards consistent with COI[58]. Pitanga and Lessa[6] conducted a work in Brazil, with 2,297 people, and identified COI as a glycaemia discriminator and of cardiovascular risk. These authors made a table to make easy the use of COI, in which, from weight and stature values, it has already calculated the index denominator. Thus, conicity of any waist value, for a given weight and stature, can be promptly analyzed, enabling to foretell the risks of diseases associated with abdominal adiposity, like IR.

In contrast, in Mantzoros et al study[59], carried out in Greece, with 280 healthy women of 18 to 24 years old, COI presented a very weak correlation ($r = 0.13$, $p = 0.03$) with fasting insulinaemia. Mamtani and Kuljarni[32], comparing the performance of various anthropometric parameters related to central obesity, have checked that COI was the one which presented less predictive accuracy for the central obesity measures'. In the same study, COI did not show correlation with fasting and post-prandial glycaemia. So, it is observed the need of more investigations about this index, to determine its viability in the risk prediction of IR.

Body mass index

The BMI is weight in kilograms divided by height in meters squared[60]. It represents the most known and used indicator of nutritional status to evaluate adults and old-aged, due to its easiness of application and low cost. Due to its incapacity of evaluating the distribution of body fat, it characterizes as an indicator of generalized adiposity. Changes in the BMI do not reflect the anatomical place in which the subject can have lost or loosen weight[61]. Generally, BMI shows weaker correlations with visceral fat than the WP and SAD[20,43].

The papers that evaluated the capacity of BMI in predicting IR are presenting conflicting results. In the study of Farin et al[62], there were no differences in the magnitude of correlations between BMI with IR in Caucasians. From the regression analysis, both indicators of generalized and central adiposity showed the same capacity of identifying subjects with IR. In the paper of Ascaso et al[63], conducted with Spanish people, both WP or the BMI correlated with IR. In the logistic regression analysis, only the BMI remained in the model as an Odds Ratio of 2.6, while WP lost statistical significance. Chang et al[64] identified the BMI as the most important determinant of IR in Orientals. However, the correlations among the BMI and IR were weak, and this was the only anthropometric indicator used in the study. Ybarra et al[33] affirmed that the best cut points of BMI to predict IR, are values from 29.5 kg/m^2, for women, and 30.5 kg/m^2, for men. Such cut points assimilate to 30 kg/m^2, proposed by the WHO[25], for obesity's classification. Nevertheless, as this paper was conducted with Spanish people, it can not be generalized to the other ethnicities. Stern et al[65] evaluated 2,321 subjects of several ethnicities and identified, as cut points for predicting IR, BMI values' > 28.7 kg/m^2.

Even though the mentioned papers have indicated positive results for the BMI in the prediction of IR, several studies which evaluated central adiposity measures[7,17,44,54,66] or of body fat distribution[8,17], showed their superiority related to the BMI, probably due to the association between IR and the accumulation of visceral adipose tissue that is better represented by these measures. Moreover, due to the BMI's incapacity of distinguishing thin or fat body mass, its use for the prediction of IR can overestimate the risk in individuals with increased quantity of muscular mass, like athletes, and overestimate the risk in old-aged whose muscular mass, generally, is reduced and there is an increased accumulation of visceral adipose tissue[17].

Conclusion

The scarcity of studies comparing several anthropometric indicators in only one paper difficults the conclusion of which one is the best indicator for predicting IR. Yet, WP and SAD seem to present better predictive capacity for IR, once the results were more consistent among the papers. Waist-thigh ratio, the COI, the SI, neck-thigh ratio and waist-height ratio have demonstrated positive results; however, more studies are necessary to solidify them as IR indicators. The results of the BMI and waist-hip ratio were more inconsistent. Although it is extremely useful, from a clinical point of view, to identify adiposity anthropometric indicators that present the best capacity of identifying subjects with IR, it is important to consider that, from them, the risk will always be evaluated, for they are alternative methods and do not explain IR as a whole. Important variables which have an influence in the modulation of insulin's action, as the life style and the genetic factors, must be considered.

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