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Original article

Waist circumference in children and adolescents correlate with metabolic syndrome and fat deposits in young adults

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SUMMARY

Background & aims: To determine the relevance of waist circumference (WC) measurement and monitoring in children and adolescents as an early indicator of overweight, metabolic syndrome (MS) and cardiovascular problems in young adults in comparison with visceral and subcutaneous adiposity.
Methods: A cohort study with 159 subjects (51.6% female) started in 1999 with an average age of 13.2 years. In 1999, 2006 and 2008 weight, height, and WC were evaluated. In 2006 blood samples for laboratory diagnosis of MS were added. In 2008 abdominal computed tomography (ACT) to quantify the fat deposits were also added.
Results: The WC measured in children and adolescents was strongly correlated with body mass index (BMI) measured simultaneously. A strong correlation was established between WC in 1999 with measures of WC and BMI as young adults. WC strongly correlated with fat deposits in ACT. The WC in 1999 expressed more subcutaneous fat (SAT), while the WC when young adults expressed strong correlation with both visceral fat (VAT) and SAT. The correlation of WC with fat deposits was stronger in females. WC and not BMI in 1999 was significantly higher in the group that evolved to MS.
Conclusions: The WC in children and adolescents was useful in screening patients for MS. WC expressed the accumulation of abdominal fat; especially subcutaneous fat.

1. Background & aims

In recent decades the prevalence of obesity is increasing in many countries around the world. This fact is of concern because excess body fat, especially abdominal fat, is directly related to changes in lipid profile. It is also associated with increased blood pressure and hyperinsulinemia, which are considered risk factors for developing chronic diseases such as diabetes mellitus type 2 and cardiovascular diseases. However, the question now is how many of these changes are already present in obese children and adolescents. European studies on cardiovascular risk had already shown in the 80's that abdominal obesity would be a better predictor of cardiovascular disease than body mass index (BMI).[1]

Data from the Bogalusa Heart Study allowed cutoff points of BMI and waist circumference (WC) in children and adolescents for cardiovascular disease risk.[2] Also using data from four British cohort studies (over 9000 patients), BMI and WC were good parameters to access risk of obesity and its consequences.[3]

The BMI has been routinely used in clinics and as an evaluation tool in public health for decades to identify individuals and populations at risk of future cardiovascular disease and diabetes. However, in recent years, the BMI has been criticized as a measure of risk because it reflects both fat mass and lean body mass, and because it is not possible to discriminate the distribution of fat.[4] There is a growing body of evidence suggesting that abdominal fat is more important as a risk factor for cardiovascular and metabolic disease than is general adiposity.[5] The mechanisms by which abdominal fat contributes to the risk of these diseases are not fully understood. The visceral adipose tissue is a very active metabolic element of abdominal fat, and probably plays a fundamental role in this process.[6]

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The aim of our study was to determine the importance of monitoring the measure of WC in a cohort of children and adolescents as a screening tool for metabolic syndrome (MS) in young adults. We compared WC in 1999 with the diagnostic of MS as young adults (2006) and deposits of fat in the abdominal computed tomography (ACT) scan and blood pressure in 2008.

2. Materials and methods

We conducted a cohort study, longitudinal, observational, descriptive and analytical, with cross-cutting interventions. The cohort involved children and adolescents (7–18 years old) residing in Veranópolis, South of Brazil in 1999, both from urban and rural areas, with at least one parent alive. Veranópolis is a city with a population predominantly of white Caucasians, originally from Italy, Europe, internationally known for its high longevity. The sample was obtained from a representative and random choice of the age group investigated. Exclusion criteria was[1]: with a history of any chronic diseases or coagulopathy[2]; with acute pathology, such as infectious diseases[3]; in oral anticoagulant therapy and oral contraceptives[4]; pregnant or females with delayed menstruation.

The study was carried out on cross-cutting assessments: (1999) personally identifiable information was collected; anthropometric data (weight, height, and WC) was collected in all three assessments; (2006) blood was collected for measurement of triglycerides, serum total cholesterol, LDL and HDL and blood glucose; (2008) ACT was also performed. All assessments were made by the same team of professionals.

Standardized protocols were used to anthropometric parameters[7]: weight, height, WC. WC was obtained from the narrowest point between the lower edge of the cage framework and the iliac crest using a flexible tape measure, but not elastic. We calculated the Z score of height, weight, WC and BMI using reference values of mean and standard deviation for each of them by age, thus standardizing the sample.[8–11]

Cutoff points determined by Katzmarzyk et al.[2] were used for cardiovascular risk and the criteria for De Ferranti et al.[12] for diagnosis of MS.

Abdominal CT exams were performed on the same day of the anthropometric measurement. The examinations were acquired with HiSpeed CT® scan equipment (GE, Milawukee, USA). Patients were positioned supine with feet facing the inside of the machine, and then focused the cuts on the umbilicus. We obtained only one cut in each patient, for reducing the radiation (about 2.3 mGy per examination). The images were obtained with 120 kVp, 100 mAs, field of view (FOV) of 36–40 cm, thickness 10 mm, tilt table, cut from 1 s, matrix 515 × 512, with filter and window to share moles. The images were acquired in DICOM 3.0® protocol and stored for later analysis. Data analysis was performed using manipulation by the computer program "Image J 1.45S"® (free download at internet)". The analyses were done by two radiologists blinded to clinical and anthropometric data of patients. Initially, the images were manipulated so that only densities between (−190) to (−30) Hounsfield units were analyzed (defined densities for fat by set-ups of literature.[13] It was initially designed the outer contour (abdominal perimeter), and it was calculated by the computer in mm^2 the total fat of the abdomen (TF). It was then designed the outline of the inner portion of the abdomen, following the inner edge of the interface between the muscle wall and the underlying fat. The psoas muscles were also excluded. The value obtained was termed internal or visceral fat (VAT). The difference between the values of total fat and internal fat was termed external or subcutaneous fat (SAT).

2.1. Statistical analysis

Data was entered into a spreadsheet in Microsoft Office Excel 2007®, and subsequently exported to the analysis in SPSS-18.0®. To compare quantitative variables with symmetrical distribution, we used the Student *t* test for independent samples and those whose distribution was skewed by the Mann–Whitney test. Categorical variables were associated by Chi-square test with Yates correction. Quantitative variables were correlated by Pearson correlation coefficient. It was considered a significant level of 5%.

2.2. Ethical aspects

The research project was approved by the Scientific Committee of the Medical School, and by the Research Ethics Committee of PUCRS, Brazil, for their implementation, in accordance with Resolution No. 196/96 of the National Board of Health. All participants who agreed to participate in this study were required to sign the consent form at each stage in 1999, 2006 and 2008, if they were under the age of 18, consent was signed by the parents.

3. Results

159 children and adolescents were enrolled in this study. In 1999, during the first survey, the average age was 13.2 ± 2.2 years and 51.6% were females. This and other characteristics of the population are in Table 1.

WC in 1999 showed a very strong correlation with BMI in the same year ($r = 0.917$, $p < 0.001$), as well as when it was compared with BMI in 2006 and 2008 ($r = 0.685$, $p < 0.001$ and $r = 0.545$, $p < 0.001$ respectively). WC in 1999 showed a strong correlation with WC in 2006 and 2008 ($r = 0.631$, $p < 0.001$ and $r = 0.619$ $p < 0.001$ respectively). No differences were seen regarding gender.

Table 1
Anthropometric and laboratory characteristics of the study population in the three times of observation.

	1999	2006	2008
	$n = 159$	$n = 159$	$n = 159$
Age, years	13.2 ± 2.6	20.7 ± 2.6	22.7 ± 2.6
Sex, n(%)	–	–	–
Male	77 (48.4)	–	–
Female	82 (51.6)	–	–
Weight, Kg	53.3 ± 15.3	67.6 ± 14.6	71.1 ± 15.6
Zweight	0.5 (−0.1 a 1.3)	0.15 (−0.3 a 0.8)	0.36 (−0.2 a 0.9)
Height, m	1.6 ± 0.1	1.7 ± 0.1	1.7 ± 0.1
Zheight	0.22 (−0.5 a 0.8)	−0.12 (−0.7 a 0.4)	−0.05 (−0.5 a 0.6)
BMI, Kg/m^2	21.4 ± 3.9	23.5 ± 3.8	24.3 ± 3.9
ZBMI	0.43 (0.1 a 1.3)	0.19 (−0.3 a 0.7)	0.4 (−0.2 a 0.9)
WC, cm	72.7 ± 11.1	77.1 ± 10.1	84.1 ± 10.6
ZWC	0.1 (−0.2 a 0.7)	−0.55 (−1 a −0.1)	−0.37 (−0.9 a 0.3)
VAT, cm^2	–	–	52 (37 a 80)
SAT, cm^2	–	–	229 (146 a 319)
TF, cm^2	–	–	280 (190 a 397)
SBP, mmHg	109.6 ± 11	119.1 ± 15	130.5 ± 18
DBP, mmHg	68.1 ± 7	72.1 ± 13.5	78.7 ± 13.3
HDL, mg/dL	–	53.1 ± 10.8	–
Trigl, mg/dL	–	81 (61 a 109)	–
Gluc, mg/dL	–	87.9 ± 16.5	–

Data presented in mean ± sd or median (P25 a P75); and for categorical variables n(%). Zweight = Z score for weight; Zheight = Z score for height; BMI = body mass index; ZBMI = Z score for BMI; WC = waist circumference; ZWC = Z score for waist circumference; VAT = visceral fat at abdominal CT scan; SAT = subcutaneous fat at abdominal CT scan; TF = total fat at abdominal CT scan; SBP = systolic blood pressure; DBP = diastolic blood pressure; HDL = serum HDL cholesterol; Trigl = serum triglycerides; Gluc = serum glucose.

3.1. Fat deposits in the abdominal CT scan

In 2008, 133 of 159 individuals underwent abdominal computed tomography (CT) to quantify the accumulation of fat in the abdomen. This quantification was defined in: total abdominal fat, which was distributed in subcutaneous fat (SAT) and visceral fat (VAT). The comparison of Z score for WC in 1999 and 2006, with the accumulation of fat in the abdominal CT in 2008 showed stronger correlation with SAT (Pearson correlation with WC Z score in 2006 $r = 0.622$, $p < 0.001$) (Fig. 1). The Z score for WC in 2006 in females showed a stronger correlation both for VAT and SAT in relation to male (female WC vs VAT $r = 0.522$, $p < 0.001$, and WC vs SAT $r = 0.725$, $p < 0.001$; and males WC vs VAT $r = 0.249$, $p = 0, 46$, and WC vs SAT $r = 0.532$, $p < 0.001$). The comparison of Z score for WC and abdominal CT fat deposits in 2008 showed strong correlation for VAT and SAT, stronger for SAT (Fig. 2). All analysis showed stronger correlations between WC and VAT and SAT in women.

3.2. Metabolic syndrome

Adopting the criteria proposed by De Ferranti et al.,[12] 8.8% (14/159) of individuals in this cohort filled the criteria for MS in 2006. Waist circumference but not BMI in 1999 correlated with diagnosis of Metabolic Syndrome in 2006 (Table 2).

4. Discussion

4.1. Main results

a) The WC measurement as a child or adolescent correlates strongly with BMI measured simultaneously, and established a strong correlation with measurements of WC as young adults, as well as the evolution of BMI; b) WC correlates strongly with deposits of fat in abdominal CT, and WC as a child and adolescent best expresses the subcutaneous fat (SAT), whereas WC when young adults, both expressed strong correlation with visceral fat (VAT) and with SAT. The correlation of WC with the fat deposits was stronger in females; c) diagnosis of MS as a young adult correlates better with higher WC than BMI during childhood and adolescence.

4.2. Importance of WC

WC is an excellent parameter to assess obesity.[14,15] Its measurement is easier and cheaper, requiring only a tape measure. To determine the BMI requires a weighing scale and a stadiometer. Based on our results we believe that WC can be used as a measure of population screening for obesity, as well as an element in the diagnosis of metabolic syndrome.

Most individuals with increased WC remained so in the three assessments. This occurred in both sexes. Early recognition of signs of obesity, especially abdominal obesity is very important, targeting the control of its serious consequences.

Fat deposits in the abdominal CT scan: the correlation of Z score for WC in all the tests was stronger with SAT. In 2008 this correlation occurred with both SAT and VAT. Several authors have reported that VAT (visceral fat) correlates more strongly with metabolic risk factors and metabolic syndrome than SAT (subcutaneous fat).[16–18] These studies are limited, however, because in general the same patients have increased both SAT and VAT, which makes it difficult to distinguish the actual contribution of each one compared to the presence of signs of MS. Pou et al.[19] found increased SAT and VAT in patients with high BMI. They also showed that VAT increases with age, while SAT significantly decreased among old individuals.[19] In our study, the WC clearly expressed the accumulation of abdominal fat, once again reinforcing the importance of a simple anthropometric measurement for the early suspicion of MS, and its usefulness for prevention of severe complications in adulthood. We found in this cohort that waist circumference did not express a direct relationship with VAT, but as the study of Pou et al.,[19] clearly expressed an increase in abdominal fat, both subcutaneous and visceral, particularly in the analysis of 2008. The progressively stronger correlation between WC and VAT in each of the three assessments can express the interference of age on visceral fat as Pou et al. reported.[19]

The correlation between WC and abdominal fat distribution varies among different ethnic groups. Among blacks there is a greater accumulation of SAT in relation to BMI than whites and Asians.[20] The largest amount of VAT is related to low levels of adiponectin, which is associated with increased risk of cardiovascular disease.[21] We can therefore speculate that the strongest correlation between WC and SAT in this cohort, can express a characteristic of this population and may indicate a positive factor that can contribute to their longevity.

Waist circumference nine years earlier already showed a strong correlation with findings in the abdominal CT, while in all measurements the WC better expressed the abdominal fat deposits among girls, especially in 2006 and 2008, when everyone already completed puberty. The difference between the sexes was evident,

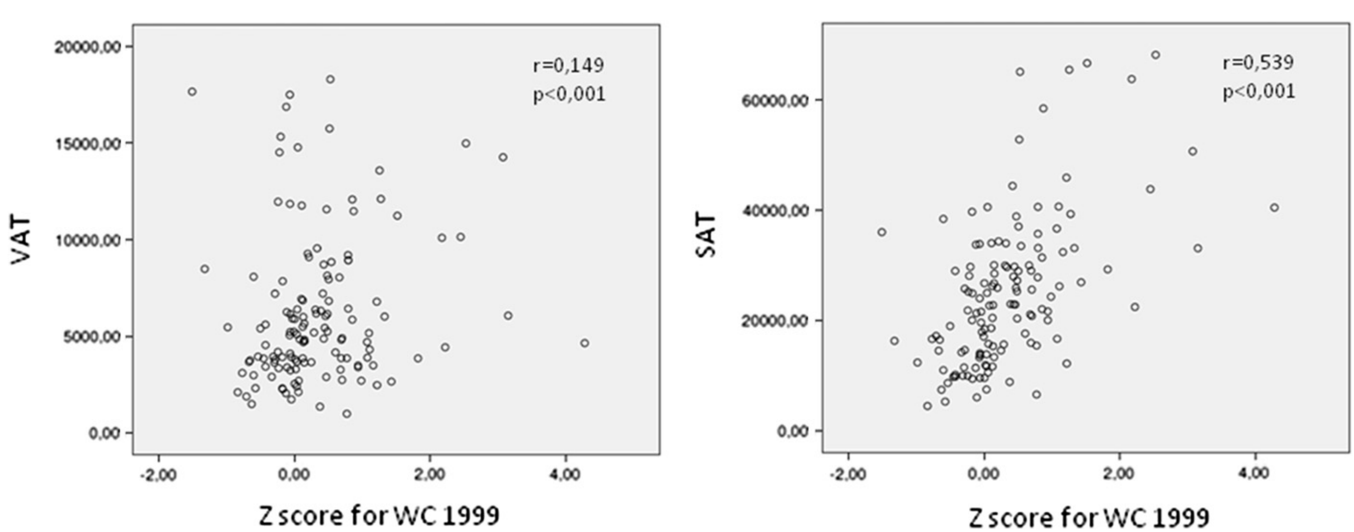

Fig. 1. Comparison of waist circumference (WC) in 1999 with visceral fat (VAT) and subcutaneous fat (SAT) in abdominal CT in 2008. [Pearson Correlation Coefficient (r)].

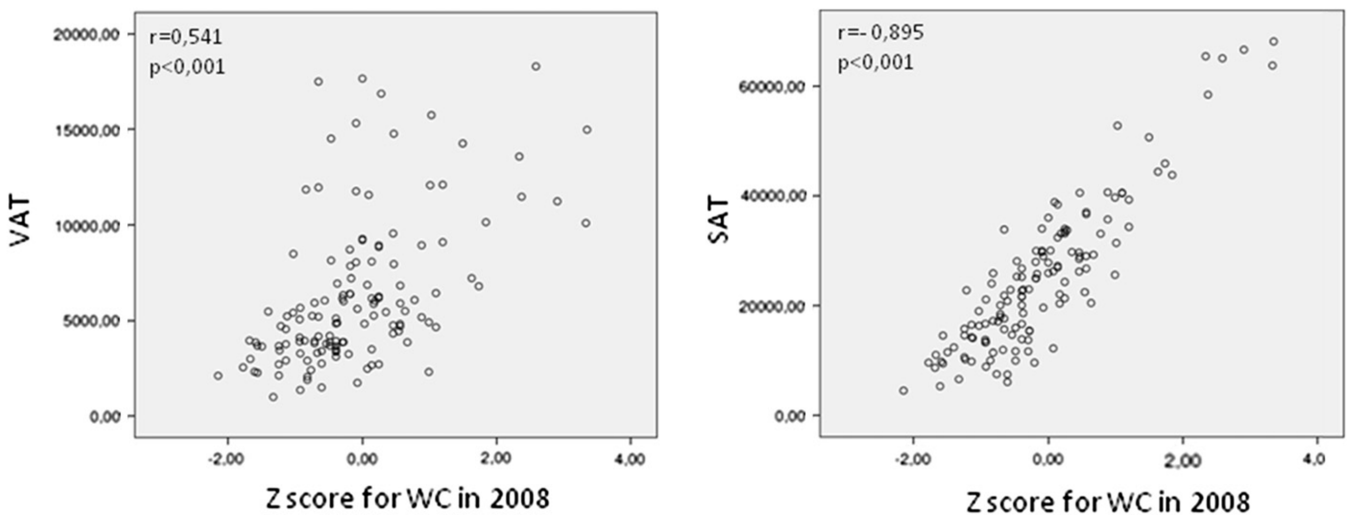

Fig. 2. Comparison of waist circumference (WC) in 2008 with visceral fat (VAT) and subcutaneous fat (SAT) in abdominal CT in 2008. [Pearson Correlation Coefficient (*r*)].

suggesting that there may be hormonal influences for this fatty deposition.

In men, obesity is called android, with accumulation of VAT, while women's obesity is called gynecoid, with predominance of SAT, either in abdomen as well as in thighs and buttocks.[22–24] In our series, the hip circumference was not measured. Waist circumference was not significantly different between the sexes, but abdominal fat deposits correlate more strongly with women's WC. This may explain why the correlation of WC was stronger with the SAT.

It is recognized that VAT, more than SAT, exerts a greater influence on the hepatic release of free fatty acids which, in turn, has a greater effect in raising blood pressure than the brain.[25] The brain may increase blood pressure (BP) through vagal afferent signals, increasing adrenal sympathetic activity.[25,26]

Hayashi et al.[27] followed a cohort of 300 subjects for 10–11 years with normal BP at the beginning. Of these, 92 developed hypertension. VAT and SAT was higher in hypertensive compared to those who remained with normal BP. We know that adipocytes of fat tissue have recognized endocrine effect, are able to synthesize and release several peptide and non peptide compounds, particularly the VAT.[28,29] Some of these, such as adiponectin and plasminogen activator inhibitor, have a proven relationship with the BP.[20,21,29,30] Adiponectin has a protective effect and its levels are inversely proportional to the amount of VAT[21] and WC.[31] Adiponectin in vitro has shown improvements in insulin function, as protection against aterosclerosis.[25] Therefore, the endocrine function adipocytes may have a key role in the risk of developing hypertension, especially, but not exclusively, associated with VAT.

In a sample of children aged 10–14 years in Cyprus,[32] WC was a better predictor of cardiovascular disease risk than BMI. Those with WC above the 75th percentile had significantly higher odds of having high BP, elevated total cholesterol, low density lipoprotein cholesterol and high levels of triglycerides.[32] In Italy, a sample of prepubertal children (3–11 years old), those with a WC above 90th percentile were more likely (19%) to have multiple risk factors ($\geq$2), compared with children with values below the 90th percentile (9.4%).[33]

Metabolic Syndrome: De Ferranti et al.[12] defined criteria for diagnosing MS in children and adolescents, similar to ATP-III criteria for adults. This definition seems well accepted now, and was recently quoted in a major publication that evaluated the various criteria in a population of 2624 teenagers, and was considered the criteria with the highest sensitivity, without losing specificity.[34] Using these criteria in our cohort we identified 8.8% of individuals with MS in 2006. The prevalence of MS in the population studied was considered low. Studies of the Brazilian population have shown important changes in eating habits and physical activity.[35–40] We speculate about the negative influence on the historical longevity of this community because of the rates of MS, especially when associated with the cardiovascular risk parameters already discussed.

The MS group had significantly higher WC in 1999, indicating that WC has emerged nine years earlier than estimated in those children and adolescents that would evolve with MS. The BMI was also different, but did not reach statistical significance.

Waist circumference is an important element in screening patients for MS associated with other elements that lead to this diagnosis: triglycerides and LDL and HDL cholesterol, glucose and blood pressure.

Many authors consider BMI as a better parameter to assess and monitor patients with MS[41,42] while others prefer WC.[3,4,31,32,43–45] Our study shows that the two parameters are good and that they correlate strongly with each other, but the WC has better expressed the evolution to MS.

The population that participated in this analysis had distinctive ethnic characteristics, thus generalizing the results may be limited to white-caucasian populations of European origin, specifically of Italian origin.

Table 2
Comparison between waist circumference and body mass index in 1999 with diagnosis of metabolic syndrome in 2006.

		2006		
		With Metabolic Syndrome	Without Metabolic Syndrome	*p*
		$n = 14(8.8)$	$n = 145(91.2)$	
1999	WC	80.9 ± 13.2	71.9 ± 10.3	0.03
	BMI	23.9 ± 5.1	21.2 ± 3.7	0.07

Results presented in mean ± SD and categorical variables *n*(%). WC = waist circumference; BMI = body mass index. Statistic: Student *t* test for independent samples.

5. Conclusions

The findings of this analysis of the cohort of adolescents in Veranópolis indicate that waist circumference in children and adolescents is extremely useful in screening patients for metabolic syndrome and cardiovascular risk. WC is an anthropometric parameter of simple measurement, requiring less equipment costs, and this study was better than BMI, which had already been reported by other authors.[3,4,31,32,43–45]

As the WC in this population was associated with more subcutaneous fat than visceral, it would be appropriate to evaluate the behavior of pro-inflammatory cytokines and adiponectin to better understand the pathophysiology of these findings.

Conflict of interest

The authors hereby declare that the article is original, is not under consideration for publication anywhere else and has not been previously published. Moreover, the authors declare no potential or actual personal, political or financial interest in the material, information or techniques described in the paper.

Statement of authorship

All authors state that all authors have made substantial contributions and final approval of the conceptions, drafting, and final version of the manuscript.

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Manoel Pitrez was the coordinator of the trial. Luiz Vargas, João Santana, Eduardo Pitrez and Augusto Medeiros where responsible for the data collection. Emilio Morigushi was the coordinator of the Veranópolis project, where several studies have been done to understand the longevity of this population. Neide Bruscato was responsible to keep the subjects of our cohort always in contact. José Spolidoro was responsible for the data interpretation and writing of the manuscript, which was his PhD thesis, under the orientation of Jefferson Piva.

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