Waist and waist-to-height ratio: useful to identify the metabolic risk of female adolescents?

Circunferência da cintura e relação cintura/estatura: úteis para identificar risco metabólico em adolescentes do sexo feminino?

Circunferencia de la cintura y relación cintura/estatura: ¿son útiles para identificar riesgo metabólico en adolescentes del sexo femenino?

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ABSTRACT

Objective: To evaluate if the waist circumference and the waist-to-height ratio (WHTR) are predictors of cardiovascular risk factors in female adolescents.

Methods: 113 adolescents aged 14 to 19 years old were assessed according to anthropometric data (weight, height, waist circumference), biochemical and clinical parameters (total cholesterol, LDL-C, HDL-C, triglyceride, fasting glucose, insulin, homeostasis model to assess insulin resistance – HOMA-IR), leptin, homocysteine and blood pressure. The cut points used for identification of abdominal fat were waist and WHTR values ≥90th percentile.

Results: Teenagers with abdominal obesity presented greater values of triglycerides (except for WHTR), insulin, HOMA-IR, leptin and systolic and diastolic blood pressure, while the HDL-C was reduced in the group with waist circumference ≥90th percentile, however without statistical significance (p=0.052).

Conclusions: The present study showed that waist and WHTR are useful measures to identify female adolescents with a high cardiovascular risk, however the waist circumference presented a better performance.

Key-words: adolescent; abdominal fat; waist circumference; cardiovascular diseases.

RESUMO

Objetivo: Avaliar se a medida da circunferência da cintura e a relação cintura/estatura (RCE) são preditoras de fatores de risco cardiovasculares em adolescentes do sexo feminino.

Métodos: Avaliaram-se 113 adolescentes de 14 a 19 anos quanto à antropometria (peso, estatura e circunferência da cintura), parâmetros bioquímicos e clínicos (colesterol total, LDL-C, HDL-C, triglicerídeos, glicemia de jejum, insulina, *homeostasis model assessment to assess insulin resistance* – HOMA-IR*,* leptina, homocisteína e pressão arterial). Considerou-se como ponto de corte de obesidade abdominal valores de cintura e RCE≥percentil 90.

Resultados: As adolescentes com obesidade abdominal apresentaram valores significantemente maiores de triglicerídeos (exceto para a RCE), insulina, HOMA-IR, leptina, pressão arterial sistólica e diastólica; o HDL-C foi mais baixo no grupo com cintura ≥percentil 90, porém sem significância estatística (p=0,052).

Conclusões: O presente estudo demonstrou que a cintura e a RCE são medidas úteis para identificar adolescentes do sexo feminino com maior risco cardiovascular; contudo, a circunferência da cintura, isoladamente, apresentou melhor desempenho.

Palavras-chave: adolescente; gordura abdominal; circunferência da cintura; doenças cardiovasculares.

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RESUMEN

Objetivo: Evaluar si la medida de la circunferencia de la cintura y la relación cintura/estatura (RCE) son predictivas de factores de riesgo cardiovasculares en adolescentes del sexo femenino.

Métodos: Se evaluó a 113 adolescentes de 14 a 19 años respecto a la antropometría (peso, estatura y circunferencia de la cintura), parámetros bioquímicos y clínicos (colesterol total, LDL-C, HDL-C, triglicéridos, glucemia de ayuno, insulina, *homeostasis model assessment - HOMA*, leptina, homocisteína y presión arterial). Se consideró como punto de corte de obesidad abdominal valores de cintura y RCE≥percentil 90.

Resultados: Las adolescentes con obesidad abdominal presentaron valores significantemente más altos de triglicéridos (excepto para RCE), insulina, HOMA, leptina, presión arterial sistólica y diastólica; el HDL-C fue más bajo en el grupo con cintura ≥percentil 90, pero sin significancia estadística (p=0,052).

Conclusiones: El presente estudio demostró que la cintura y RCE son medidas útiles para identificar a adolescentes del sexo femenino con mayor riesgo cardiovascular; sin embargo, la circunferencia de la cintura, aisladamente, presentó mejor desempeño.

Palabras clave: adolescente; grasa abdominal; circunferencia de la cintura; enfermedades cardiovasculares.

Introduction

Obesity and its associated cardiovascular risk factors tend to perpetuate themselves from childhood into adulthood[1]. This includes visceral fat, the amount of which increases in both absolute and relative terms over time[2]. The use of effective measures for screening of asymptomatic risk groups that may suffer the irreversible adverse health effects of obesity at later ages would enable early intervention and development of prevention strategies, thus reducing the morbidity, mortality, and high socioeconomic burden of these diseases[3].

Waist-to-height ratio (WHtR) and waist circumference are considered useful measurements for identification of high metabolic and cardiovascular risk in overweight children and adolescents[4]. The rationale for their use is the assumption that, for any given height, there is a maximum acceptable abount of truncal fat[5].

Standardized international cutoff points for waist circumference in children and adolescents have yet to be established. Nevertheless, several countries, including New Zealand[6], the United Kingdom[7], Canada[8], the United States[9], and Spain[10], have published population-specific reference standards for waist measurement. In light of the rather arbitrary definition of these values in some countries and of population-specific ethnic and lifestyle differences (including dietary habits and physical activity) that interfere with body fat distribution, it is imperative that the usefulness of these parameters be assessed before their wider use can be recommended[11].

WHtR has an added advantage over isolated waist circumference measurement, because its adjustment for height allows establishment of a single, population-wide cutoff point that remains applicable regardless of gender, age, and ethnicity[12]. Within this context, the present study was conducted in order to ascertain whether the waist circumference and WHtR cutoffs proposed thus far in the literature are indeed capable of predicting cardiovascular risk in a sample of female adolescents.

Method

The present study was carried out in the municipality of Viçosa, state of Minas Gerais, Brazil, which, according to 2000 census data, is home to 13,752 adolescents between the ages of 10 and 19 years[13]. The sample screened for eligibility included 418 adolescents (thus corresponding to 9.3% of the total population in the target gender and age range). The final sample, after application of all criteria for inclusion and exclusion, consisted of 113 female adolescents between the ages of 14 and 19 years, all recruited from public municipal schools, and thus corresponded to 2.5% of the total female population in the target age range. Sample size was calculated on the basis of prior domestic[14,15] and international[16,17] studies; the present study included a greater number of participants, in an attempt to ensure more reliable results.

The criteria for inclusion were interest in taking part in the study, no participation in any weight loss or weight management program, non-smoking status, no use of any dietary supplements or medications that might interfere with glucose and lipid metabolism, no chronic diseases, no pacemakers or prosthetic or medical devices, and no prior pregnancy. Furthermore, all adolescents included in the sample were required to have experienced their first menstrual period at least one year prior to the date of enrollment, which would increase their odds of being past the most intense period of puberty-related physical changes[18].

Body weight was measured with a 10kg capacity, 0.05kg resolution digital scale (*Marte Balanças e Equipamentos de Precisão*, São Paulo, Brazil). Height was measured with a 200cm stadiometer calibrated to 1cm and 1mm increments (Alturexata, Belo Horizonte, Brazil). All measurements followed the techniques proposed by Jellife[19] Body mass index (BMI) was obtained by dividing each subject's body weight (in kg) by the square of their height (in m), and classified according to World Health Organization cutoff points[20]. Body fat percentage was measured by the tetrapolar bioelectrical impedance method (Biodynamics Model BIA 310 Body Composition Analyzer, Biodynamics Corporation, Seattle, USA), following a specific protocol recommended for assessment of body composition[21]. Waist circumference was measured under participants' clothes, at the end of a normal exhalation, with a TBW® brand flexible but inelastic tape measure (TBW, São Paulo, Brazil)[12]. Measurements were taken in duplicate and the mean considered for analysis. WHtR was computed as the ratio of waist circumference to height (both in cm)[12]. As no national reference standard for waist circumference exists thus far, we chose to determine the 90th percentile of the study itself, as it has been the most widely used parameter in studies assessing waist measurement in adolescents[4,11]; coincidentally, the 90th percentile for WHtR in our sample equaled 0.50, which has been proposed as a cutoff rate for diagnosis of excess abdominal fat. The advantage of WHtR over isolated waist circumference measurement is that the former provides a single cutoff (0.50) which is applicable across all age ranges (>5 years) and in both genders, because it is adjusted for height. The message "keep your waist circumference to less than half your height" has been widely assessed and considered for public health purposes[12].

Samples were collected for metabolic testing at the clinical laboratory of the Universidade Federal de Viçosa (UFV) Health Division, shortly after anthropometric assessment. All participants had been fasting for 12 hours. Peripheral venous blood samples were collected (14ml; 10ml for serum and 4ml for plasma) and immediately centrifuged for 10 minutes at 3500 rpm in an Excelsa® II Model 206 BL bench centrifuge (Fanem).

Total cholesterol, HDL cholesterol, and triglycerides were quantitated by enzymatic methods using a Cobas Mira Plus® automated benchtop chemistry analyzer (Roche). LDL cholesterol was calculated using the Friedwald equation[22]. Blood glucose was measured by the glucose oxidase method, also with the Cobas Mira Plus® analyzer. Insulin levels were measured by electrochemiluminescence assay in the Modular E® automated analyzer (Roche). Insulin resistance was assessed by means of the homeostatic model assessment (HOMA-IR), which is approximated by the equation: [(fasting insulin concentration [µU/mL] × fasting blood glucose [mmol/L])/22.5][23]. Leptin concentrations were quantitated by radioimmunoassay, using the double-antibody/polyethylene glycol (PEG) technique, with readings performed on a Wizard® automated gamma counter (Perkin Elmer). Homocysteine levels were quantitated by high-performance liquid chromatography (HPLC) assay (Immundiagnostik, Bensheim, Germany).

Blood pressure was measured with an Omron® Model HEM-741 CINT automatic sphygmomanometer. Three readings were obtained (left arm, supine, with participants at rest for at least 5 minutes), each 1 minute apart.

The present study was approved by the UFV Human Subject Research Ethics Committee. Participants were included in the study sample on a fully voluntary basis, after they and their parents and/or legal guardians had provided written informed consent.

Statistical analyses were performed in the Sigma-Statistic and SPSS® 12.0 software environments. The significance

Table 1 – General characteristics of the study sample

Variable	Mean (SD)	Median (range)
Age (years)	15.8±1.3	15.7 (14.0-18.8)
BMI (kg/m2)	22.8±4.1	22.0 (17.8-41.4)
BF (%)	28.7±5.1	29.7 (20.1-42.4)
Waist (cm)	71.0±7.8	69.6 (60.4-105.2)
WHtR	0.44±0.05	0.43 (0.36-0.63)
Total cholesterol (mg/dL)	157±29	155 (97-287)
HDL cholesterol (mg/dL)	50±13	49 (28-94)
LDL cholesterol (mg/dL)	94±25	92 (47-195)
Triglycerides (mg/dL)	72±29	66 (24-219)
Glucose (mg/dL)	81±8	80 (45-104)
Insulin (mcU/mL)	11.9±7.4	10.6 (2.1-47.8)
HOMA	2.4±1.7	2.1 (0.4-12.3)
Leptin (ng/mL)	14.4±15.4	10.8 (2.2-120.2)
Homocysteine (mcmol/L)	7.9±3.4	7.5 (0.5-21)
SBP (mmHg)	104±9	103 (84-131)
DBP (mmHg)	70±8	70 (54-95)

BF: body fat; BMI: body mass index; DBP: diastolic blood pressure; HDL: high density lipoprotein; HOMA: homeostasis model assessment; LDL: low density lipoprotein; SBP: systolic blood pressure; WHtR: waist-to-height-ratio.

level was set at $p<0.05$. The Student *t* test and Mann-Whitney U were used for comparison of means of normally and non-normally distributed variables respectively.

Results

The general characteristics of the study sample, regarding age, anthropometric parameters, biochemical measurements, and blood pressure, are shown in Table 1. The study sample comprised 78 (69%) adolescents with BMIs in the normal range and 35 (31%) at risk of overweight or obesity.

Mean and median values for the various risk factors assessed in the sample, stratified by presence or absence of abdominal obesity and by waist circumference and WHtR, are shown in Tables 2 and 3. Significantly elevated triglyceride levels (except for WHtR), insulin levels, HOMA-IR scores, leptin concentrations, and systolic and diastolic blood pressure measurements were found among adolescents with abdominal obesity. A trend toward significantly lower HDL cholesterol ($p=0.052$) was found in adolescents with a waist circumference at or above the 90th percentile. Abdominal obesity was present in 9.7% of adolescents in the sample, regardless of the marker used to assess adiposity.

Discussion

The present study sought to ascertain whether waist circumference and WHtR are good predictors of cardiovascular risk in a sample of female adolescents, using cutoff points proposed in the existing literature. Significantly higher levels of triglycerides

Table 2 – Comparison of cardiovascular risk factors in subjects with waist circumference above or below the 90th percentile

Variable	Waist circumference above or below 90th percentile (≥80,9cm)		p-value
	<90th percentile n=102	≥90th percentile n=11	
Total cholesterol (mg/dL)	156.0 (29.2)	169.4 (25.2)	NS
HDL cholesterol (mg/dL)	50.4 (12,5)	43.0 (9.9)	NS
LDL cholesterol (mg/dL)	95.0 (46.6-195.0)	105.1 (75.4-149.6)	NS
Triglycerides (mg/dL)	64 (24-145)	83 (38-219)*	<0.05
Glucose (mg/dL)	80 (45-96)	84 (71-104)	NS
Insulin (mcU/mL)	10.2 (2.1-23.8)	22.2 (11.8-47.8)‡	<0.001
HOMA	1.96 (0.41-5.34)	4.4 (2.6-12.3)‡	<0.001
Leptin (ng/mL)	9.8 (2.2-120.2)	14.1 (9.1-50.4)*	<0.05
Homocysteine (mcmol/L)	7.3 (0.5-21.0)	8.25 (3.3-18.9)	NS
SBP (mmHg)	101 (84-122)	112 (98-131)†	<0.01
DBP (mmHg)	68.8 (6.5)	79.4 (8.9)‡	<0.001

DBP: diastolic blood pressure; HDL: high density lipoprotein; HOMA: homeostasis model assessment; LDL: low density lipoprotein; SBP: systolic blood pressure; NS: nonsignificant. Values expressed as mean (SD) or median (range).

Table 3 – Comparison of cardiovascular risk factors in subjects with waist-to-height ratio above or below the 90th percentile.

Variable	WHtR above or below 90th percentile (≥0.50)		p-value
	<90th percentile n=102	≥90th percentile n=11	
Total cholesterol (mg/dL)	167.2 (28.2)	156.4 (29.0)	NS
HDL cholesterol (mg/dL)	50.1 (12.7)	44.7 (9.6)	NS
LDL cholesterol (mg/dL)	91.4 (46.0-195.0)	103.0 (75.4-149.6)	NS
Triglycerides (mg/dL)	65 (24-219)	87 (30-114)	NS
Glucose (mg/dL)	80.5 (45.0-104.0)	80 (71-92)	NS
Insulin (mcU/mL)	10.4 (2.1-47.8)	18.8 (6.8-39.8)	<0.001
HOMA	1.98 (0.41-12.26)	3.46 (1.29-8.55)	<0.001
Leptin (ng/mL)	9.8 (2.2-120.2)	17.2 (10.8-50.4)	<0.01
Homocysteine (mcmol/L)	7.5 (0.5-21.0)	5.8 (3.3-18.9)	NS
SBP (mmHg)	101 (84-122)	107 (101-131)	<0.001
DBP (mmHg)	69.0 (6.7)	78.6 (9.2)	<0.01

DBP: diastolic blood pressure; HDL: high density lipoprotein; HOMA: homeostasis model assessment; LDL: low density lipoprotein; SBP: systolic blood pressure; WHtR: waist-to-height ratio; NS: nonsignificant. Values expressed as mean (SD) or median (range).

(in the waist circumference group only) insulin, and leptin, HOMA-IR scores, and systolic and diastolic blood pressures were found in adolescents with waist circumference and WHtR measurements above the proposed cutoffs. Furthermore, HDL cholesterol was lower in the high waist circumference group, although the difference did not reach statistical significance. These results are in line with those of prior studies[16,24].

Regarding risk factors, we found no between-group differences in total cholesterol levels, which may be explained by the presence of lower HDL and higher LDL levels in the abdominal obesity group, thus precluding any significant change in total cholesterol.

We found no between-group differences in homocysteine levels. The Third National Health and Nutrition Examination Survey (NHANES III) also detected no association between homocysteine levels—on other risk factors (HDL cholesterol and systolic blood pressure)—and waist measurement in adolescents, which suggests that this parameter may not be related to other components of the metabolic syndrome, although it may be an independent risk factor for cardiovascular disease[25].

The precise mechanism underlying the association between abdominal and metabolic and ccardiovascular risk has yet to be elucidated, but evidence indicates that excess free fatty acids could contribute to a state of insulin resistance in the presence of visceral obesity; hepatic insulin resistance, in turn, is associated with decreased degradation of apolipoprotein B and increased hepatic synthesis of glucose and triglyceride-rich lipoproteins[26]. Furthermore, adipose tissue is believed to play a role in the production of proinflammatory factors (TNF-α, IL-6) and hormones (leptin, resistin, visfatin) that have been associated with the metabolic syndrome in children and adolescents[27]. Some authors have recently proposed the “lipid overflow–ectopic fat” model, which posits that visceral obesity is a marker of the inability of subcutaneous adipose tissue to store excess energy, leading to a buildup of muscle fat, epicardial fat, and liver fat and, ultimately, to an altered metabolic profile[26].

Waist circumference and WHtR have been considered important measurements for pinpointing location of adiposity, as they are simple, valid parameters for diagnosis of abdominal obesity[6] and, in young populations, are better predictors of cardiovascular risk than BMI[4].

The frequency of abdominal or central obesity in the study population was 9.7% according to both methods. A study of adolescents between the ages of 11 to 16 found a prevalence rate of abdominal obesity (defined as WHtR >0.50) of 11.7%[5]. Conversely, the NHANES study reported a higher prevalence of central obesity in females, whether determined by isolated waist circumference measurement >90th percentile or by WHtR >0.50 (17.8% *vs* 36.4% respectively)[28]. This difference may be associated with the fact that the aforementioned study used a different site for waist circumference measurement (immediately above the iliac crest), thus changing the prevalence of abdominal obesity. The lack of standardized methods mandates caution during comparison of results between studies, in order to avoid under- or overestimating prevalence rates.

There is no consensus on cutoff points for classification of abdominal obesity in adolescents. Defining adequate cutoffs for specific populations is particularly important when one considers that certain populations, such as Asians, tend to be shorter and exhibit higher cardiovascular morbidity rates with lower waist circumference values[11]. Use of the WHtR instead, with broad dissemination of the message “keep your waist circumference to less than half your height,” across all ages and both genders, has been proposed[5,12]. Although the WHtR has been recommended as a replacement for isolated waist circumference measurement as an indicator of abdominal adiposity, in the present study, increased waist circumference was a better predictor of more risk factors; furthermore, three adolescents with a waist circumference at or above the 90th percentile did not have a WHtR ≥0.50 (due to height above the 95th percentile), whereas two whose WHtR exceeded 0.50 did not have a high waist circumference (one had height at the 5th percentile). Wang[29] provides an interesting example: a 90cm waist might be considered perfectly normal for a tall male, but would be associated with a predisposition to morbidity in a shorter individual. Therefore, before one of these two measurements is chosen as the superior indicator of health risk, further longitudinal studies should be conducted to establish the true extent of the influence of height on weight measurements.

These findings suggest the importance of assessing abdominal obesity as well as BMI to predict risk of comorbidity in adolescents, as is done in adults. Nevertheless, it should be noted that the 90th percentile for waist circumference obtained in the present study cannot be extrapolated to other groups, and may not apply to all individuals assessed, as waist circumference cutoffs for adolescents should be age-specific in order to take into account the growth process and the changes in body composition and body fat distribution that take place during this stage of life. We cannot recommend that health services calculate specific waist circumference cutoffs for their target populations, which would be unfeasible and inadequate. Therefore, it is paramount that a representative, nationwide study be conducted to establish gender- and age-specific waist circumference cutoffs for adolescents, preferably based on cardiovascular risk, and/or establishment of a single international database comprised of data pooled from several countries.

In conclusion, the present study showed that waist circumference and WHtR are both useful measurements for detection of cardiovascular and metabolic risk in adolescents. However, isolated waist circumference measurement was superior for this purpose. In light of the impact of abdominal obesity on cardiovascular risk factors, efforts should be made to establish nationally or internationally accepted waist circumference cutoffs for adolescent populations. Furthermore, young populations as a whole should be targeted by health education measures designed to promote changes in dietary habits and foster involvement in physical activities.

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References

1. Bao W, Srinivasan SR, Wattigney WA, Berenson GS. Persistence of multiple cardiovascular risk clustering related to syndrome X from childhood to young adulthood. The Bogalusa Heart Study. Arch Intern Med 1994;154: 1842-7.
2. Goran MI, Ball GD, Cruz ML. Obesity and risk of type 2 diabetes and cardiovascular disease in children and adolescents. J Clin Endocrinol Metab 2003;88:1417-27.
3. Boden-Albala B, Sacco RL, Lee HS, Grahame-Clarke C, Rundek T, Elkind MV *et al*. Metabolic syndrome and ischemic stroke risk: Northern Manhattan Study. Stroke 2008;39:30-5.
4. Maffeis C, Banzato C, Talamin G; Obesity Study Group of the Italian Society of Pediatric Endocrinology and Diabetology. Waist-to-height ratio, a useful index to identify high metabolic risk in overweight children. J Pediatr 2008;152: 207-13.
5. McCarthy HD, Ashwell M. A study of central fatness using waist-to-height ratios in UK children and adolescents over two decades supports the simple message--'keep your waist circumference to less than half your height'. Int J Obes (Lond) 2006;30:988-92.
6. Taylor RW, Jones IE, Williams SM, Goulding A. Evaluation of waist circumference, waist-to-hip ratio, and the conicity index as screening tools for high trunk fat mass, as measured by dual-energy X-ray absorptiometry, in children aged 3-19 y. Am J Clin Nutr 2000;72:490-5.
7. McCarthy HD, Jarrett KV, Crawley HF. The development of waist circumference percentiles in British children aged 5.0-16.9 y. Eur J Clin Nutr 2001;55:902-7.
8. Katzmarzyk PT, Srinivasan SR, Chen W, Malina RM, Bouchard C, Berenson GS. Body mass index, waist circumference, and clustering of cardiovascular disease risk factors in a biracial sample of children and adolescents. Pediatrics 2004;114:e198-205.
9. Fernández JR, Redden DT, Pietrobelli A, Allison DB. Waist circumference percentiles in nationally representative samples of African-American, European-American, and Mexican-American children and adolescents. J Pediatr 2004;145:439-44.
10. Moreno LA, Mesana MI, González-Gross M, Gil CM, Ortega FB, Fleta J *et al*. Body fat distribution reference standards in Spanish adolescents: the AVENA Study. Int J Obes (Lond) 2007;31:1798-805.
11. International Diabetes Federation − IDF [homepage on the Internet]. The IDF consensus definition of the Metabolic Syndrome in children and adolescents 2007 [cited 2009 Sep 06]. Available from: http://www.idf.org/home
12. Ashwell M, Hsieh SD. Six reasons why the waist-to-height ratio is a rapid and effective global indicator for health risks of obesity and how its use could simplify the international public health message on obesity. Int J Food Sci Nutr 2005;56:303-7.
13. Instituto Brasileiro de Geografia e Estatística [homepage on the Internet]. Censo 2000 [cited 2010 Apr 02]. Available from: http://www.ibge.gov.br/censo/
14. Oliveira CL, Veiga GV, Sichieri R. Anthropometric markers for cardiovascular disease risk factors among overweight adolescents. Nutr Res 2001;21:1335-45.
15. Fontanive RS, Costa RS, Soares EA. Comparison between the nutritional status of eutrophic and overweight adolescents living in Brazil. Nutr Res 2002;22:667-78.
16. Hirschler V, Aranda C, Calcagno Mde L, Maccalini G, Jadzinsky M. Can waist circumference identify children with the metabolic syndrome? Arch Pediatr Adolesc Med 2005;159:740-4.
17. De Lorenzo A, Martinoli R, Vaia F, Di Renzo L. Normal weight obese (NWO) women: an evaluation of a candidate new syndrome. Nutr Metab Cardiovasc Dis 2006;16:513-23.
18. Bronhara B, Vieira VC. Proporcionalidade corporal na avaliação antropométrica de adolescentes pós-menarca. Rev Nutr 2007;20:27-37.
19. Jelliffe DB. The assessment of the nutritional status of the community (with special reference to field surveys in developing regions of the world). Monogr Ser World Health Organ 1966;53:3-271.
20. World Health Organization [homepage on the Internet]. The WHO child growth standards [cited 2010 Apr 10]. Available from: http://www.who.int/childgrowth/en
21. Barbosa KB. Consumo alimentar e marcadores de risco para a síndrome metabólica em adolescentes do sexo feminino: comparação entre instrumentos de inquérito dietético [tese de mestrado]. Viçosa (MG): UFV; 2006.
22. Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clin Chem 1972;18:499-502.
23. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. Diabetologia 1985;28:412-9.
24. Savva SC, Tornaritis M, Savva ME, Kourides Y, Panagi A, Silikiotou N *et al*. Waist circumference and waist-to-height ratio are better predictors of cardiovascular disease risk factors in children than body mass index. Int J Obes Relat Metab Disord 2000;24:1453-8.
25. Gillum RF. Distribution of total serum homocysteine and its association with parental history and cardiovascular risk factors at ages 12-16 years: the Third National Health And Nutrition Examination Survey. Ann Epidemiol 2004;14: 229-33.
26. Després JP, Lemieux I. Abdominal obesity and metabolic syndrome. Nature 2006;444:881-7.
27. Wärnberg J, Marcos A. Low-grade inflammation and the metabolic syndrome in children and adolescents. Curr Opin Lipidol 2008;19:11-5.
28. Li C, Ford ES, Mokdad AH, Cook S. Recent trends in waist circumference and waist-height ratio among US children and adolescents. Pediatrics 2006;118:e1390-8.
29. Wang J. Standardization of waist circumference reference data. Am J Clin Nutr 2006;83:3-4.