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Neck circumference as predictor of excess body fat and cardiovascular risk factors in adolescents

Perímetro do pescoço como preditor de excesso de gordura corporal e fatores de risco cardiovascular em adolescentes

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A B S T R A C T

Objective

To verify whether neck circumference can predict cardiovascular risk factors and excess body fat in adolescents.

Methods

This cross-sectional study included male and female adolescents aged 10 to 14 years from *Viçosa, Minas Gerais*. The following data were collected: anthropometric measurements, blood pressure, percentage of body fat according to dual energy X-ray absorptiometry, and levels of fasting glucose, fasting insulin, triglycerides, total cholesterol, high-density lipoprotein, and low-density lipoprotein. The anthropometric measurements were used for calculating indices and assessing nutritional status. The receiver operating characteristic curve tested whether neck circumference could predict cardiovascular risk. We also investigated how neck circumference related to the study parameters. The significance level was set at 5% (*p*<0.05).

Results

A total of 260 adolescents were assessed of which 50.4% (n=131) were females, 20.4% (n=53) had excess body weight according to the body mass index-for-age index, and 42.7% (n=111) had excess body fat. Blood pressure (3.9%, n=10) and all biochemical parameters were affected, varying from 1.9% (n=5) for glucose to

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65% (n=169) for total cholesterol. Neck circumference correlated with body fat, waist circumference, hip circumference, weight, height, body mass index, waist-to-height ratio, homeostasis model of assessment - insulin resistance, fasting insulin, blood pressure, and high-density lipoprotein (<0.05). It predicted excess body fat and changes in fasting insulin and blood pressure in both sexes, blood glucose and high-density lipoprotein in females, and triglycerides in males (area under the curve >0.5; p<0.05, varying from 0.610 for high-density lipoprotein to 0.817 for blood pressure).

Conclusion

Neck circumference was capable of predicting excess fat and cardiovascular risk factors in adolescents.

Indexing terms: Adiposity. Adolescent. Cardiovascular diseases. Neck.Triage.

R E S U M O

Objetivo

Verificar a capacidade do perímetro do pescoço, predizer fatores de risco cardiovascular e excesso de gordura corporal na triagem de adolescentes.

Métodos

Estudo transversal com adolescentes de 10 a 14 anos, de ambos os sexos, residentes em Viçosa, Minas Gerais. Foram realizadas avaliações de medidas antropométricas, pressão arterial, gordura corporal pelo Absortometria Radiológica de Dupla Energia, glicemia e insulinemia de jejum, triglicerídios, colesterol total e frações lipoproteína de alta densidade e lipoproteína de baixa densidade. As medidas antropométricas foram utilizadas para cálculo de índices e avaliação do estado nutricional. O perímetro do pescoço foi testado como preditor de risco cardiovascular através da Curva ROC e verificada sua relação com os parâmetros avaliados. Adotou-se significância de p<0,05.

Resultados

Foram avaliados 260 adolescentes: 50,4% (n=131) do sexo feminino, 20,4% (n=53) com excesso de peso pelo índice de massa corporal/Idade e 42,7% (n=111) com excesso de gordura corporal. Houve alterações em todos os parâmetros bioquímicos - com variação de 1,9% (n=5) para glicemia a 65% (n=169) para colesterol total - e na pressão arterial (3,9%, n=10). O perímetro do pescoço correlacionou-se com gordura corporal, perímetro da cintura, perímetro do quadril, peso, estatura, índice de massa corporal, relação cintura/estatura, homeostasis model of assessment-insulin resistance, *insulinemia, pressão arterial e lipoproteína de alta densidade (p<0,05), sendo capaz de predizer o excesso de gordura corporal e alterações na insulina de jejum e na pressão arterial para ambos os sexos; glicemia e lipoproteína de alta densidade para o sexo feminino e triglicerídeos para o masculino (*Area Under the Curve *>0,5; p<0,05, com variação entre 0,610 para lipoproteína de alta densidade e 0,817 para pressão arterial).*

Conclusão

O perímetro do pescoço foi capaz de predizer o excesso de gordura corporal e fatores de risco cardiovascular na população adolescente.

Termos de indexação: *Adiposidade. Adolescente. Doenças cardiovasculares. Pescoço. Triagem.*

I N T R O D U C T I O N

Adolescence is a period of physical, behavioral, and emotional changes that marks the transition between childhood and adulthood. During this phase, which chronologically lasts from ages 10 to 19 years, individuals are consolidating food habits, and so are more vulnerable both to nutritional deficiencies because of the high amounts of energy and nutrients needed to meet the intense growth that occurs during this period, and to obesity because of the excessive intake of energy-dense foods. Besides food, other factors such as smoking, alcohol abuse, and inactivity contribute to adolescents' vulnerability to the risk factors for metabolic disorders and cardiovascular diseases[1,2].

According to the *Programa de Orçamento Familiares* (POF, Family Budget Survey) conducted by the *Instituto Brasileiro de Geografia e Estatística* (IBGE, Brazilian Institute of Geography and Statistics), between 2008 and 2009 roughly 20% of the adolescents living in metropolitan areas in Brazil were overweight[3]. Excess body weight, when due to the accumulation of body fat, is closely related to the incidence of obesity and many other diseases, so early detection is important[4].

Neck circumference has been investigated as a screening instrument for overweight individuals because it is easy to measure, inexpensive, noninvasive, and unlike waist circumference, it does not vary throughout the day. Moreover, neck circumference correlates with many fat-related anthropometric measurements and cardiovascular risk factors[5-8].

Given that anthropometric assessment is easy and practical and that early detection of excess body fat in adolescents is important, the objective of this study was to verify the extent to which neck circumference can predict cardiovascular risk factors and excess body fat in adolescent screenings.

METHODS

This epidemiological, cross-sectional study included male and female adolescents aged 10 to 14 years and 11 months selected by simple random sampling in all public and private schools in the rural and urban areas of the municipality of *Viçosa, Minas Gerais*, Brazil. The inclusion criteria were: not taking medication that affects the metabolism of lipids and carbohydrates or blood pressure, and not having been diagnosed with infections and/or acute inflammations and chronic Non-Communicable Diseases (NCD).

The sample size was determined by considering all the 10-to-14-year-old adolescents living in the municipality in 2010, which totaled 5,752[9], and a rate of excess body fat of 17.5% found by another study of the local adolescent population with similar ages[10]. The acceptable variability was 5.0% with a 95% confidence level, totaling 214 adolescents. Considering a sample loss of 20.0%, at least 257 volunteers would be needed for the sample, 129 of each gender. The tool StatCalc of the software Epi Info version 6.04 was used for the cross-sectional studies in the calculation.

Students were selected among those who signed the Informed Consent Form, respecting the proportion of students of each age in each school. When a participant refused to participate in any of the study stages or dropped out, another student was selected to replace him/her. Thirteen individuals were excluded from the study because of the following reasons: taking anticonvulsants (1); inappropriate fasting (2); blood could not be collected for technical reasons (1); history of myelomeningocele (1); nose cancer (1); taking growth hormone (1); hormonal changes (3); taking dietary supplements and/or vitamins (3).

The project was approved by the Human Research Ethics Committee of the *Universidade Federal de Viçosa* (UFV) under Protocol number 0140/2010. The adolescents and their guardians signed an Informed Consent Form created as recommended by Resolution 196/96 of the National Health Council.

Anthropometric and body composition assessment

Body weight was determined by an electronic digital scale with a maximum capacity of 150 kg and accuracy of 50 g. Height was determined by a portable stadiometer with a maximum length of 2.13 m and accuracy of 0.1 cm. All measurements were taken twice, and the average was used for the study. When the two height measurements differed by more than 0.5 cm, a new measurement was taken. Body Mass Index (BMI)-for-age and height-for-age were

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calculated to characterize the population, using the World Health Organization's (WHO) cut-off points (Z-scores) as reference[11].

Waist circumference was measured by a two-meter flexible, inelastic tape measure with an accuracy of 0.01 cm, making sure not to squeeze the soft tissues, at the midpoint between the last rib and the iliac crest[12]. The waist-to-height ratio was given by dividing the waist circumference in cm by the height in centimetre.

The hip circumference was measured at the gluteal region at the widest circumference between the waist and the knees[13]. The waist-to-hip ratio was then calculated by dividing the waist circumference in cm by the hip circumference in centimetre.

Neck circumference was measured at its midpoint, except when the individual had a pronounced Adam's apple, in which case the neck circumference was measured right below it. The adolescents were advised to stare at the horizon and stand up straight[14].

All anthropometric measurements were taken by the same individual who had been duly trained for the task.

The percentage of Body Fat (%BF) was determined by the device Dual Energy X-ray Absorptiometry (DEXA) (Lunar Prodigy Advance DXA System - analysis version: 13.31, GE Healthcare) at the Diagnostic Imaging sector of the Health Division of the UFV and analyzed according to adolescent-specific classification proposed by Lohman[15], who suggests 15% to 25% of body fat for females and 10% to 20% for males.

Biochemical assessment

Participants' blood (12 mL) was collected by trained professionals after a 12-hour fast by venipuncture using disposable syringes. The laboratory of clinical analyses of the Health Division of the UFV performed the biochemical analyses. The following were determined: total cholesterol, triglycerides, High Density Lipoprotein-cholesterol (HDL-c), Low Density Lipoprotein-cholesterol (LDL-c), fasting glucose, and fasting insulin.

The blood was centrifuged by the centrifuge Excelsa Model 206 BL for 10 minutes at 3,500 rpm right after collection but allowing enough time for the blood to coagulate. Total cholesterol, HDL-c, and triglycerides were automatically determined by the device Cobas Mira Plus (Roche®) using an enzymatic method. LDL-c was given by the Friedewald equation. Nobody's triglyceride level exceeded 400 mg/dL. Fasting glucose was automatically determined by the device Cobas Mira Plus (Roche®) using the glucose oxidase method. Fasting insulin was determined by electrochemiluminescence.

Serum lipids were assessed as recommended by the I Guidelines for Preventing Childhood and Adolescent Atherosclerosis[2]. Fasting glucose levels were classified as recommended by the *Sociedade Brasileira de Diabetes*[16] (Brazilian Diabetes Society) and fasting insulin as recommended by the *Sociedade Brasileira de Cardiologia*[2] (Brazilian Cardiology Society). High and borderline values were considered abnormal as follows: total cholesterol ≥150 mg/dL, LDL-c ≥100 mg/dL, HDL-c <45 mg/dL, triglycerides ≥100 mg/dL, fasting glucose ≥100 mg/dL, and fasting insulin ≥15 μU/mL.

Insulin resistance was given by the Homeostasis Model Assessment - Insulin Resistance Index (HOMA-IR) according to the fasting insulin and glucose levels as follows: HOMA-IR=fasting insulin (μU/mL)xfasting glucose (mmol/L)/22.5 and interpreted as recommended by the *Sociedade Brasileira de Cardiologia*[2].

Blood pressure

Blood pressure was measured by a digital blood pressure monitor recommended by the *Sociedade Brasileira de Cardiologia* and as recommended by the manufacturer and interpreted according to the VI Brazilian Guidelines on Hypertension. Both the systolic and diastolic blood pressures were assessed for changes[17].

Blood pressure was classified according to height percentiles for both genders as follows: normal when blood pressure <90th percentile (<120/80 mmHg); borderline when 90th percentile <blood pressure <95th percentile; high when blood pressure >95th percentile. A blood pressure equal to or above 120/80 mm/Hg, even when <95th percentile, was considered borderline. Borderline and high blood pressures were considered abnormal.

Statistical analyses

The data were entered twice in the spreadsheet Excel 2010 and analyzed by the programs Epi Info 6.04, Sigma Stat for Windows 3.5 and MedCalc 12.

The Kolmogorov-Smirnov test identified the variables with normal distribution, determining which other tests should be used: Student's *t* test or Mann-Whitney test, and Pearson or Spearman correlations.

Receiver Operating Characteristic (ROC) curves were constructed to verify the ability of neck circumference to predict biochemical, body composition, and blood pressure changes in the study adolescents and to determine the respective cut-off points for females and males. The Areas Under the Curves (AUC) were calculated along with their respective 95% Confidence Intervals (95%CI). The null hypothesis was accepted when AUC ≤0.50. The ROC curve quantitatively describes the performance of a diagnostic test whose result can be treated as a continuous ordinal or categorical variable depending on how it compares with the gold standard[18].

The following were calculated: positive and negative predictive values, sensitivity, and specificity of neck circumference for predicting biochemical, body composition, and blood pressure changes associated with cardiovascular risk.

The significance level was set at 5% ($p<0.05$).

RESULTS

Subject characteristics

A total of 260 adolescents participated in the study. Their median age, weight, and BMI were, respectively: 12.4 (10.1-14.9) years; 43.3

Table 1. Descriptive characteristics of the sample of 260 students aged 10 to 14 years from public and private schools from *Viçosa* (MG), Brazil, 2011.

Characteristics	Female		Male		Total	
	%	n	%	n	%	n
Gender	50.4	131	49.6	129	100.0	260
BMI-for-age						
Underweight	0.8	1	6.2	8	3.4	9
Normal weight	81.7	107	70.5	91	76.2	198
Overweight	10.7	14	15.5	20	13.1	34
Obese	6.8	9	7.8	10	7.3	19
H-for-age						
Stunted	2.3	3	1.5	2	1.9	5
Normal height	97.7	28	98.5	127	98.1	255
%BF						
Low	9.2	12	19.4	25	14.2	37
Normal	36.6	48	49.6	64	43.1	112
Excessive	54.2	71	31.0	40	42.7	111

Note: H: Height; %BF: percentage of Body Fat; BMI: Body Mass Index.

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(25.1-92.8) kg; and 18.3 (12.5-33.8) kg/m^2. Their mean height were 153.6±10.1 cm. These parameters did not differ significantly between the genders (p>0.05).

The median neck circumferences for the general population, males, and females were, respectively: 30.2 (25.5-39.5) cm, 30.5 (25.7-39.5) cm, and 29.9 (25.5-34.5) cm. Males had greater neck circumferences (p<0.05).

Table 1 shows other characteristics of the study sample.

Clinical and biochemical assessments

Table 2 shows the following results: biochemical tests, insulin resistance, and blood pressure. Females had higher triglyceride levels, HOMA-IR, and diastolic blood pressure, while males had higher fasting insulin levels (p<0.05). The other study parameters did not vary significantly between the genders (p>0.05).

Relationship between neck circumference and cardiovascular risk variables

Neck circumference presented correlations that varied from 0.51 to 0.88 with fat-related parameters and fat distribution, such as waist and hip circumferences, percentage of body fat, weight, and BMI. It also correlated with waist-to-height ratio, HOMA-IR, fasting insulin, and blood pressure, with amplitudes varying from 0.29 to 0.62. The waist-to-hip ratio and HDL-c were also positively correlated with neck circumference.

Regarding the lipid profile, neck circumference correlated positively with triglycerides in females and negatively with HDL-c in both genders. For these parameters and stratum, neck circumference may be used (Table 3).

Predictive ability of neck circumference

Table 4 shows the AUC, sensitivity, specificity, positive predictive value, and negative predictive value of neck circumference for the study parameters with significant results. It also shows the neck circumferences associated with abnormal parameters (cut-off points).

The area under the curve varied from 0.616 for HDL-c to 0.807 for blood pressure. Sensitivity varied from 61.9% for HDL-c to 80.0% for blood pressure and fasting glucose. Specificity

Table 2. Measurements and rates of biochemical and blood pressure changes in students aged 10 to 14 years from public and private schools in *Viçosa* (MG), Brazil, 2011.

Parameters	Female	Changes		Male	Changes		Total	Changes	
		%	n		%	n		%	n
Total cholesterol (mg/dL)	158.3±31.3	71.8	94	165.4±26.7	58.1	75	161.9±29.2	65.0	169
HDL-c (mg/dL)	52 (24-100)	23.7	31	51 (32-117)	31.0	40	52 (24-117)	27.3	71
LDL-c (mg/dL)	93.2 (42.2-165.4)	41.9	55	93 (2.9-149.2)	34.1	44	93 (2.9-165.4)	38.1	99
Triglycerides (mg/dL)	66 (28-206)**	18.3	24	62 (7-194)**	8.5	11	64 (7-194)	13.5	35
Fasting glucose (mg/dL)	86 (67-114)	2.3	3	86 (70-195)	1.6	2	86 (67-195)	1.9	5
Fasting insulin (mcU/mL)	8.4 (1.1-45.7)*	17.6	23	9.9 (1.8-36.4)*	7.8	10	6.3 (1.1-45.7)	12.7	33
HOMA-IR	2.1 (0.4-7.2)*	17.6	23	1.4 (0.2-10.6)*	7.8	10	1.8 (0.2-10.6)	12.7	33
SBP (mmHg)	96.5 (72.5-124.5)	2.3	3†	96 (73.5-143)	5.4	7†	96.5 (72.5-143)	3.9	10†
DBP (mmHg)	60.9±6.3*			58.7±7.8*			59.8±7.1		

Note: **p<0.05; *p<0.001; Student's t test or Mann-Whitney test; †prevalence of blood pressure changes considering both systolic and diastolic blood pressures. Data with normal distribution were expressed as means ± standard deviations. Data with abnormal distribution were expressed as medians and their respective amplitudes. The following were considered abnormal: total cholesterol ≥150 mg/dL, LDL-c ≥100mg/dL, HDL-c <45 mg/dL, triglycerides ≥100 mg/dL, fasting glucose ≥100 mg/dL, and fasting insulin ≥15 mU/mL; blood pressure was considered abnormal when above the 90th height percentile.

HDL-c: High Density Lipoprotein-cholesterol; LDL: Low Density Lipoprotein-cholesterol; HOMA-IR: Homeostasis Model Assessment - Insulin Resistance; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure.

Table 3. Correlation between neck circumference and anthropometric and cardiovascular risk parameters of students aged 10 to 14 years from public and private schools in *Viçosa* (MG), Brazil, 2011.

Parameters	Female (r)	Male (r)	Total (r)
Body fat	0.67*	0.61*	0.51*
Waist circumference	0.67*	0.83*	0.74*
Hip circumference	0.78**	0.87*	0.75*
Weight	0.83**	0.92*	0.88*
Body mass index	0.73**	0.81*	0.75*
W-to-He ratio	0.43*	0.46*	0.41*
W-to-H ratio	-0.05	0.23**	0.14**
HOMA-IR	0.33*	0.50*	0.35*
Fasting insulin	0.36*	0.49*	0.36*
SBP	0.65**	0.63*	0.62*
DBP	0.43*	0.33*	0.29*
Total cholesterol	-0.19**	-0.29*	-0.27*
LDL-c	-0.08	-0.26**	-0.18**
HDL-c	-0.26**	-0.26**	-0.27*
Triglycerides	-0.01	0.20**	0.06

Note: Pearson or Spearman correlation. *$p<0.001$; **$p<0.05$.
W-to-He ratio: Waist-to-Height ratio; W-to-H ratio: Waist-to-Hip ratio; HOMA-IR: Homeostasis Model Assessment - Insulin Resistance; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; HDL-c: High Density Lipoprotein-cholesterol; LDL-c: Low Density Lipoprotein-cholesterol.

varied from 57.3% for fasting insulin to 78.4% for blood pressure.

In summary, the cut-off points of 28.8 cm for girls and 30.4 cm for boys indicate the possibility of parameter changes associated with cardiovascular risk.

DISCUSSION

The study adolescents were in consonance with the national reality[3]: 20.3% (n=53) had excess body weight, being overweight or obese according to their BMI-for-age. Nevertheless, a higher percentage was classified as having excess body fat (42.7%, n=111), showing that many normal-weight adolescents are already at risk for obesity-related metabolic disorders.

Changes in glucose metabolism, blood pressure, and lipid profile were also found by other studies on adolescents of the same age group[19-20].

Table 4. Ability of neck circumference to predict the cardiovascular risk of students aged 10 to 14 years from public and private schools in *Viçosa* (MG), Brazil, 2011, according to the receiver operating characteristic curve.

Parameters	AUC	95%CI	Sensit%	Specif%	PPV%	NPP%	COP
Body fat							
Total	0.676*	0.615-0.733	64.0	65.1	57.7	70.8	>30.3
Female	0.711*	0.625-0.786	67.6	66.7	70.6	63.5	>29.55
Male	0.728*	0.643-0.803	75.0	60.7	46.2	84.4	>30.4
Fasting glucose							
Total	0.682*	0.621-0.738	80.0	67.5	4.6	99.4	>31.1
Female	0.827*	0.751-0.887	100.0	75.8	8.8	100.0	>31.0
Fasting insulin							
Total	0.703*	0.643-0.757	72.7	57.3	19.8	93.5	>30.4
Female	0.659**	0.571-0.739	95.7	36.1	24.2	97.5	>28.8
Male	0.902*	0.837-0.947	100.0	74.0	24.4	100.0	>31.7
HDL-c							
Total	0.616**	0.554-0.676	61.9	59.3	36.4	80.6	>30.4
Female	0.645**	0.557-0.727	64.5	64.0	35.7	85.3	>30.4
Triglycerides							
Male	0.700**	0.613-0.777	54.6	86.4	27.3	95.3	>33.5
Blood pressure							
Total	0.807*	0.754-0.854	80.0	78.4	12.9	99.0	>31.7
Female	0.908*	0.844-0.951	100.0	69.5	7.1	100.0	>30.8
Male	0,747***	0.663-0.819	85.7	71.3	14.6	98.9	>31.7

Note: *$p<0.001$; **$p<0.05$.
AUC: Area Under the Curve; SD: Standard Deviation; 95%CI: Confidence Interval of 95%; Sensit: Sensitivity; Specif: Specificity; PPV: Positive Predictive Value; NPP: Negative Predictive Value; COP: Cut-Off Point; HDL: High Density Lipoprotein-cholesterol.

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Chaves *et al*.[19] corroborate the present findings in their study of a similar population: 21.0% were overweight or obese and 54.2%, 26.7%, 25.8%, and 20.0% presented changes in their total cholesterol, LDL-c, HDL-c, and triglyceride levels, respectively. They also found prevalences of hyperinsulinemia and hyperglycemia of 8.3% and 1.7%, respectively. In both studies, the worst results were for total cholesterol and the best, for fasting glucose.

The results reinforce the need of identifying this population early to develop an effective intervention. Such identification requires practical and rapid screening methods with good accuracy and sensitivity. Waist circumference has been used for this purpose and relates to cardiovascular risk factors both in Brazilian and other adolescents[21-24].

However, waist circumference varies throughout the day and its measurement may abash adolescents because of the body changes they experience during puberty. In this sense, neck circumference is an option and its use is being investigated in different ethnicities and age groups[8, 25-27].

In the present study, neck circumference was capable of predicting excess body fat for both genders (AUC >0.7) and correlated with the measurements and indices used for identifying fat deposits, such as hip circumference, waist-to-height ratio, and waist circumference. Neck circumference also correlated with weight and was associated with BMI, proving to be a useful instrument.

Hatipoglu *et al.*[6] assessed healthy and obese Turkish children and adolescents aged 6 to 18 years and also found neck circumference to correlate with BMI and waist circumference, considering it a good supplementary instrument for detecting overweight and obesity. Nafiu *et al.*[7] found that these variables, in addition to body weight, also correlated with neck circumference in a population of the same age bracket in the United States of America, stating that neck circumference can be a good predictor of excess weight.

Although neck circumference did not correlate with blood glucose level, it predicted blood glucose changes in females quite well. Meanwhile, hyperinsulinemia, even by itself, has been pointed out as a good indicator of insulin resistance in adolescents[24], and neck circumference has shown good sensitivity for predicting hyperinsulinemia in female and male adolescents. Given that neck circumference has also correlated with HOMA-IR, there is evidence that it may be useful for screening adolescents with high blood glucose.

Studies that investigated the relationship between neck circumference and parameters associated with impaired glucose metabolism in adolescents were not found, but Vallianou *et al.*[25], Laakso *et al.*[28], Ben-Noun & Laor[29] and Yang *et al.*[30] found neck circumference to be associated with insulin resistance indicators in adults.

Neck circumference also indicated blood pressure changes well, correlating with both systolic and diastolic blood pressure. High AUC (0.807) and sensitivity (80%) show that neck circumference could identify a large number of adolescents at risk.

Ben-Noun & Laor[5,29] found neck circumference to correlate with blood pressure in adult Israelis and an association between the changes that occurred in both parameters over time. Studies with adolescents were not found.

Even by itself, high blood pressure is a linear and continuous risk factor for cardiovascular diseases. In population-based studies, blood pressure is related with the risk of death and disease[17]. Faria *et al.*[20] found a 5.0% prevalence of high blood pressure in adolescents, and Pinto *et al.*[31] found that 5.6% and 9.9% of the adolescents aged 10 to 14 years from *Bahia*, Brazil, were hypertensive and prehypertensive, respectively.

Lauer & Clarck[32] found that blood pressure and excess adiposity during adolescence correlated with blood pressure during adulthood in a study that followed 2,445 individuals. This fact restates the importance of neck circumference:

not only it is associated with blood pressure and capable of predicting blood pressure changes, but it is also related to body fat.

While neck circumference was not associated with total cholesterol and LDL-c, it correlated with HDL-c and predicted low HDL-c in females. On the other hand, neck circumference correlated with triglycerides and predicted triglyceride changes only in males.

Gonçalves *et al.*[33] studied a population with similar ages and found significant prevalences of low HDL-c in boys (26.9%) and girls (30.6%) and high triglycerides in boys (18.6%) and girls (25.6%). Gontijo *et al.*[34] corroborated these findings in another study with adolescents aged 10 to 19 years. The high number of dyslipidemic adolescents reinforces the importance of identifying them for early intervention.

Ben-Noun & Laor[5] found neck circumference to be related to serum lipid levels in adults. Vallianou *et al.*[25] found neck circumference to correlate with HDL-c and triglyceride levels in adults, corroborating the present study.

The *Sociedade Brasileira de Cardiologia*[2] recommends that the identification and treatment of dyslipidemic children and adolescents should be done early to prevent atherosclerosis, among others. Simple and easy-to-use methods, such as measuring neck circumference, may help to identify these individuals.

The study adolescents already present changes in cardiovascular risk parameters, suggesting the importance of identifying and monitoring this population from the beginning of this life phase.

Protocols should be created for primary care and other units of the health care networks that use simple, accurately reproducible measurements, such as neck circumference, a convenient and accessible alternative. However, the diagnosis must be confirmed by more specific methods, ones that can better measure the study parameters.

The suggestion of specific cut-off points for the neck circumference of adolescents can be considered a strength of the present study, since cut-off points enable the use of this measurement. However, a study limitation is the absence of data for the last years of adolescence, preventing the determination of references for this entire life phase.

Finally, the prediction of changes was generally more sensitive than specific. Since the sensitivity of screening instruments is more important than specificity for the nutritional diagnosis, we reiterate that neck circumference is a good alternative for this end.

CONCLUSION

Neck circumference was capable of predicting excess body fat and cardiovascular risk factors in adolescents aged 10 to 14 years. It is easy and quick to measure, noninvasive, and inexpensive, and can be used as a screening tool in population-based studies.

Many changes have been found in the study parameters, demonstrating the importance of health care programs for adolescents that promote their health and prevent future diseases.

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CONTRIBUTORS

All authors participated in all phases of the article's research.

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