ANALYSIS OF THE IMPACT OF SOCIODEMOGRAPHIC AND HEALTH VARIABLES ON THE ASSOCIATION WITH OVERWEIGHT, CENTRAL OBESITY, AND CARDIOVASCULAR RISK FACTORS AMONG ADOLESCENTS

Daniella Mota Mourão Schreiber[1], Tassiana Mota Mourão Alvarenga[2], Rilder Soares Zuquim[3], André Luiz Gomes Carneiro[4], Geraldo Magela Durães[5], Waldney Roberto de Matos e Ávila[6], João Paulo Alves de Paula[7], Kaio Fellipe Sousa Jacome[8], Rodrigo Gonçalves da Silva[9], Claudiana Donato Bauman[10], Rene Ferreira da Silva Junior[11]

[1]Doctor of Biomedical Sciences, Afya Medical Education, Brazil. [2]Master of Science in Health Sciences, Northern Minas University Center, Brazil. [3]Bachelor's degree in Biomedicine, Faculty of Health and Humanities Ibituruna, Brazil. [4]Doctor of Sports Science, State University of Montes Claros, Brazil. [5]Doctor of Sports Science, State University of Montes Claros, Brazil. [6]Master's degree in Physical Education, State University of Montes Claros, Brazil. [7]Bachelor's Degree in Physical Education, Sete Lagoas University Center, Brazil. [8]Medical Degree, Pitágoras Integrated Colleges, Brazil. [9]Bachelor's degree in Physical Education, State University of Montes Claros, Brazil. [10]Doctor of Health Sciences, State University of Montes Claros, Brazil. [11]Doctor of Health Sciences, Federal Institute of Southeast Minas Gerais, Brazil.

Abstract: The aim of this study was to evaluate the association between overweight and central obesity with cardiovascular risk factors in adolescents. A cross-sectional study was conducted with 634 adolescents aged 10 to 16 years, of both genders, from public schools, stratified by clusters. Anthropometric, hemodynamic, metabolic variables and physical activity level were analyzed using the IPAQ (International Physical Activity Questionnaire). Descriptive analyses were presented using means, standard error, percentages, and confidence intervals. Poisson regression with weighting and logistic regression for complex samples were performed, adjusted for gender and age group. The prevalence of overweight was high among adolescents (31.4%), as were some cardiovascular risk factors: elevated triglycerides (45%) and sedentary lifestyle (46.9%). The mean body mass index was higher in 16-year-old adolescents (21.8). It was shown that the prevalence ratio of overweight was 1.11 (1.06-1.17) times higher in those with low HDL cholesterol. Central obesity was present in 10.5%, and its presence in adolescents was predictive of altered insulin resistance (odds ratio = 4.03; p = 0.05) and uric acid (odds ratio = 3.54; p = 0.02). It was possible to demonstrate that the prevalence of cardiovascular risk factors was high in adolescents. Overweight and central obesity are associated with several cardiovascular risk markers, making it necessary to avoid weight gain and encourage weight loss in this population, raising awareness among government and society that a healthy lifestyle at this stage can reduce cardiovascular risk factors in adulthood.

Keywords: Overweight, Central obesity, Cardiovascular risk, Adolescents.

INTRODUCTION

The high mortality rates from cardiovascular diseases (CVD) worldwide, as well as the high cost of treatment for individuals, their families, and the government, justify concerns about preventing CVD risk factors. In 2019, 17.9 million people died from CVD, representing 32% of deaths recorded worldwide, with 85% of these deaths due to coronary artery disease and strokes (World Health Organization, 2021).

Data from the Cardiovascular Statistics - Brazil 2021 and estimates from the GBD (Global Burden of Disease) show that 43% of deaths in Brazil in 2019 were attributed to CVD, which corresponds to 12% of total deaths and 43% of deaths from CVD, a prevalence that has been increasing due to population growth and aging (Oliveira et al, 2022).

The increase in CVD is associated with the presence of several risk factors, such as age, sex, inadequate diet, excess weight, systemic arterial hypertension (SAH), and sedentary lifestyle (National Heart, Lung, and Blood Institute, 2012; SBEM, 2022). Changes in behavioral risk factors through reducing salt in the diet, consuming fruits and vegetables, smoking cessation, avoiding harmful alcohol intake, and regular physical activity are effective in preventing CVD (World Health Organization, 2021). And these changes should begin as early as possible in people's lives.

Obesity is an epidemic today, being one of the most serious health problems in the world, and this number increases every year and in all age groups. The increase in excess weight worldwide is alarming, and with it, the risks of diseases such as diabetes mellitus (DM), dyslipidemia, and hypertension (HTN) grow, which are important risk factors for cardiovascular disease (CVD) (National Heart, Lung, and Blood Institute, 2012; SBEM, 2022; Lindberg et al., 2020). Childhood and adolescent obesity is associated with a greater chance of maintaining obesity and disability in adulthood, as well as premature death. Obese adolescents are 89% more likely to become obese adults (Kartiosuo et al., 2019). Studies have shown that adolescent obesity increases the incidence of risk factors for CVD and is associated with a higher risk of cardiovascular morbidity and mortality in adulthood (Sommer; Twig, 2018). A prospective study demonstrated that individuals with childhood obesity have a three times greater risk of death in adulthood compared to those who live without it (Lindberg et al., 2020). The presence of obesity in adolescence has also been associated, probably with a causal relationship, with a high probability of various CV morbidities, including ischemic heart and cerebrovascular diseases, as well as non-ischemic heart diseases related to the condition (Sommer; Twig, 2018). Therefore, it is crucial to identify factors that may impact the risk of early morbidity and mortality in individuals with adolescent obesity in order to enable preventive actions and promote long-term health.

According to the Pan American Health Organization (PAHO), more than 1 billion people worldwide are obese, including 650 million adults and 340 million adolescents (PAHO, 2022). In Brazil in 2022, of adolescents aged 10 to 19 years monitored in Primary Health Care (PHC) of the SUS (Brazilian Unified Health System), 20.8% and 14.8% presented overweight and obesity, respectively, according to BMI (Body Mass Index) for age (Ministry of Health, 2022). BMI is a good predictor of increased risk for CVD in adulthood, and early interventions that prevent obesity from adolescence are essential to reduce morbidity and mortality in adulthood (Boyer; Nelson; Holub et al., 2015). Data from the Brazilian Institute of Geography and Statistics (IBGE) in 2019 showed that obesity already affected about 6.7% of adolescents, being higher in females (8%), and that one in five adolescents aged between 15 and 17 years was overweight, with 22.9% of women and 16% of boys.

Obesity, and especially central obesity, increases the risk of several metabolic diseases and cardiovascular diseases (CVDs). Regardless of BMI, overweight individuals have excess body fat and a high degree of cardiometabolic dysregulation, which can promote risk factors for chronic diseases and decreased quality of life (National Heart, Lung, and Blood Institute, 2012; SBEM, 2022; Lindberg et al., 2020). Central obesity is associated with insulin resistance (IR) and consequently alterations in glucose metabolism, an atherogenic lipid profile (high triglycerides and low HDL cholesterol), and increased blood pressure (BP), with the set of alterations being called metabolic syndrome (MS) (Zimmet et al., 2021).

The ERICA (Cardiovascular Risk Study in Adolescents) in Brazil showed a prevalence of central obesity in 12.6% of adolescents, being higher in those with increased triglycerides (TG) and blood pressure (Kuschnir et al., 2016). Metabolic syndrome (MS) was present in 2.6% of adolescents aged 12 to 17 years, according to IDF (International Diabetes Federation) criteria, showing a strong association between MS and the nutritional status of these adolescents, indicating that preventing obesity at this age can reduce CV risk in adulthood (Kuschnir et al., 2016).

In Montes Claros, northern Minas Gerais (MG), the prevalence of overweight in adolescents was high (26.4%), occurring mainly in females (Cruz et al., 2014). Metabolic syndrome (MS) occurred in 7.9% of adolescents aged 10 to 16 years and was directly related to overweight in adolescents from Montes Claros (MG) (Cruz et al., 2014), as well as in ERICA (Kuschnir et al., 2016). Adolescents with insulin resistance (IR) present a high cardiometabolic risk due to a higher prevalence of obesity, visceral adiposity, hyperglycemia, and MS compared to those who do not exhibit IR (Zimmet et al., 2007; Kuschnir et al., 2016).

In recent years, researchers have been seeking simple ways to assess CV risk, encouraging the early identification of those who need interventions, such as physical activity (PA), to improve quality of life and reduce the risk of CVD in adulthood (Boyer; Nelson; Holub, 2015). Studies demonstrate several benefits of PA in adolescents, such as increased muscle mass; reduced BMI and improved body composition; blood glucose regulation and control of type 2 diabetes; as well as improved physical fitness and self-esteem (Pitrez-Filho et al., 2012). PAHO and the World Health Organization (WHO) suggest approximately 60 minutes of aerobic PA per day for children and adolescents (PAHO, 2021). PAHO estimates that up to 5 million deaths per year could be avoided if the world's population were more active (PAHO, 2021).

The objective of this study was to estimate the prevalence of overweight and central obesity in a representative sample of adolescents from public schools in Montes Claros (MG), as well as to evaluate their associations with CV risk factors, in order to subsequently propose interventions in this age group.

METHODS

This is a descriptive and cross-sectional study with adolescents aged 10 to 16 years, enrolled in state schools in the urban area of Montes Claros (MG). The study was approved by the Research Ethics Committee of the State University of Montes Claros (Unimontes), under number 1.503.680. All adolescents signed an Assent Form and their guardians signed an Informed Consent Form, which explained the objectives of the study.

The sample selection was by probabilistic clusters, and the sample size was established to estimate the population parameters with a prevalence of 0.50, ensuring a larger sample size. A 95% confidence interval (CI) and a 5% precision level were established. Correction was made for finite population and design effects, adopting a deff equal to 1.5. A 10% increase was established to compensate for possible non-responses and losses.

The sample was stratified into four regions (north, south, east, and west), comprising 63 state public schools, with a total student population of 77,833. Clusters were selected at two levels: schools and school level (primary and secondary education). The sample weight was calculated by multiplying the inverse of the inclusion probabilities at each stage of sample selection and was calibrated considering estimates of the adolescent population enrolled in schools located in the geographic strata considered for gender and age group.

For this study, 634 adolescents who met the inclusion criteria were analyzed, excluding those with any physical disability that prevented the assessment of weight, height, and waist circumference (WC). Also excluded were pregnant adolescents (n=1); adolescents with inflammatory and infectious diseases (n=1); those using medications that influence their metabolic and hemodynamic profile; those unable to have blood drawn (n=5); and adolescents without a signed Informed Consent Form from their guardians.

Data collection was performed by a multidisciplinary team in August 2016. The team was properly calibrated, with kappa coefficients for questionnaire application of 0.99 (inter-examiner) and 0.98 (intra-examiner), and for anthropometric and hemodynamic assessments of 1.0 and 0.9, respectively.

A questionnaire was used to identify the student: age, gender, educational level, medications used, tobacco and alcohol consumption, religion, and ethnicity. Age was categorized into the following groups: 10-11 years, 12-13 years, 14-15 years, and 16 years.

Weight was measured using an electronic scale (Líder, São Paulo, model P 150M), with a capacity of 150 kg and a precision of 50 g. Height was measured with a portable stadiometer (Alturexata, Minas Gerais) with a limit of 2 m and a precision of 0.1 cm. Weight and height were measured barefoot and in light clothing (Araki et al., 2013). BMI was calculated by dividing weight (kg) by the square of height (m), and classified according to WHO tables for gender and age. The cut-off points were: Z-score $\geq$ -2 and $\leq$ 1 (normal); Z-score > 1 and $\leq$ 2 (overweight); Z-score > 2 (obesity)

(Onis et al., 2007). BMI was categorized as normal and excess weight (overweight and obesity). Waist circumference (WC) was assessed by averaging two measurements with an inextensible measuring tape (Sanny, São Paulo), with a precision of 0.1 cm. The midpoint between the lower margin of the last rib and the upper border of the iliac crest was used, measured with the individual in a horizontal plane, arms along the body and feet together (Araki et al., 2013). The cutoff point adopted was ≥ 90th percentile (p90) for gender and age (Zimmet et al., 2007).

Blood pressure (BP) was measured using an Omron 705-IT automatic oscillometric sphygmomanometer, validated for adolescents (Stergiou; Yiannes; Rarra, 2006). It was measured with the subject seated and feet on the floor, after five minutes of rest, with the right arm supported and at heart level. The average of the two measurements was recorded, with a 3-minute interval (Stergiou; Yiannes; Rarra, 2006). Hypertension was defined as systolic and/or diastolic BP ≥ 95th percentile (for age, gender, and height), and prehypertension as systolic and/or diastolic BP ≥ 90th percentile and < 95th percentile or BP ≥ 120/80 mmHg (Malachias et al., 2016).

Physical activity (PA) was self-reported using the IPAQ (International Physical Activity Questionnaire), short version with nine questions, validated for Brazilian adolescents (Guedes; Lopes; Guedes, 2005). For PA, categorization was performed at the following levels: inactive (sedentary, irregularly active A and B) and active (active and very active).

Blood samples for biochemical tests were collected at the school itself, after a 12-hour fast, by a specialized team, respecting biosafety standards. Biochemical parameters were analyzed in a single laboratory with current quality standards required for its qualification. All methods used were from Bioquímica LabTeste and performed on automated equipment from Lab MaxPleno. Blood glucose (GLI) was analyzed using the God-Trinder enzymatic method, and the cutoff value established for hyperglycemia was ≥ 100 mg/dL (Zimmet et al., 2007). Insulin resistance (IR) was determined using the HOMA-IR formula = (GLI x 0.0555 x insulin)/22.5, with a value ≥ 3.16 adopted (Keskin et al., 2005).

For total cholesterol (TC), triglycerides (TG), and uric acid, the Trinder enzymatic method was used, and for HDL cholesterol (HDLc), a colorimetric enzymatic method was used. LDL cholesterol (LDLc) was calculated using the Friedewald equation, excluding adolescents with TG > 400 mg/dL due to the imprecision in its calculation (Faludi et al., 2017). Non-HDL cholesterol was calculated using the formula TC - HDLc. Dyslipidemia was defined by the presence of at least one of the following parameters: TC ≥ 170 mg/dL, HDLc ≤ 45 mg/dL, LDLc ≥ 110 mg/dL, Non-HDLc, or TG ≥ 90 mg/dL (Faludi et al., 2017). Adolescents with uric acid ≥ 5 mg/dL for females and ≥ 6 mg/dL for males were classified as having hyperuricemia (Ferraz; Delgado, 1988).

In the statistical analysis, the SPSS (Statistical Package for Social Science) version 20 (IBM, Chicago, IL, USA) program was used, adopting a significance level of 5% for all tests. All variables presented a normal distribution verified by the Kolmogorov-Smirnov test. ANOVA with weighting followed by the Bonferroni post-hoc test was used to determine the differences in quantitative variables for gender and age group, described by means ± standard error (SE). The association between metabolic, hemodynamic, anthropometric changes and physical activity (PA) was determined with chi-square tests for complex samples, stratified by gender and age group, which were described with their percentages and 95% confidence intervals.

Logistic regressions (forward stepwise method) were performed, considering changes in excess weight and waist circumference (WC) as dependent variables, with risk factors being systolic and diastolic blood pressure, glucose, insulin, insulin resistance, total cholesterol and fractions, triglycerides, uric acid, and fat distribution. For excess weight, the prevalence ratio (PR) with its confidence intervals (CI) was calculated using Poisson regression with sample weighting and robust variance. For WC, the PR for a complex sample was estimated using odds ratios (OR). All models were adjusted for gender and age group.

RESULTS

The sample consisted of 634 adolescents, 60.8% of whom were female, with a mean age of

13.8 years (± 1.7), and 41.5% were between 14 and 15 years old. The sample characteristics are shown in Table 1, and it was found that 26.2% of the adolescents studied and lived in the eastern region of the city of Montes Claros (Minas Gerais, Brazil). The majority (57.8%) identified as mixed-race, 63% stated that they did not have childhood obesity, and 59.3% reported engaging in physical activity. Obesity was identified in 12.1% of the adolescents and metabolic syndrome (MS) in 3.4%. It was observed that 53% of the adolescents presented active and very active levels of physical activity, while sedentary behavior was observed in 11.4% according to the IPAQ (Guedes; Lopes; Guedes, 2005).

Table 1. Characterization of the studied population.

	Variables	Sample % (n = 634)
Region	North	22.3 (120)
	South	25.92 (179)
	East	26.2 (136)
	West	25.6 (199)
Ethnicity	Mixed race	57.8 (365)
	White	18.6 (118)
	Black	17.4 (110)
	Other	6.2 (41)
Religion	Catholics	56.9 (365)
	Evangelicals	40.7 (252)
	Other	2.4 (17)
Childhood obesity	No	63.0 (394)
	Yes	37.0 (240)
Practice of physical activity	No	40.7 (255)
	Yes	59.3 (379)
Nutritional status	Normal weight	68.4 (430)
	Overweight	19.5 (126)
	Obesity	12.1 (78)
	Excess weight	31.4 (204)
Metabolic syndrome	No	96.6 (613)
	Yes	3.4 (21)

Level of physical activity	Sedentary	11.4 (72)
	Irregularly active B	35.5 (226)
	Irregularly active A	0 (0)
	Active	40.1 (256)
	Very active	12.9 (80)

Table 2 shows the ANOVA of risk factors by age group with their means and standard deviations. Statistical differences were observed for BMI, WC, as well as for other factors including: systolic and diastolic blood pressure, glucose, non-HDL cholesterol, triglycerides, and uric acid. Significant differences in the means of WC and uric acid were found between adolescents aged 10-11 years and all other age groups. There was no difference for insulin resistance.

Table 2. Description of anthropometric, hemodynamic, and metabolic variables of adolescents by age group from public schools in Montes Claros, Minas Gerais, Brazil.

Variables	Average age range (AER)				
	10-11 years	12-13 years	14-15 years	16 years	p-value
BMI	20.0 (0.4)[a]	20.7 (0.3)[a]	21.2 (0.2)[a]	21.8 (0.4)[b]	0.02
WC	68.0 (1.0)[a]	71.6 (0.8)[b]	71.6 (0.6)[b]	72.5 (0.9)[b]	0.01
SBP	108.0 (1.4)[a]	108.8 (1.0)[a]	116.3 (0.8)[b]	117.8 (1.3)[b]	< 0.001
DBP	65.1 (0.6)[ad]	64.9 (2.2)[ad]	68.3 (1.0)[ae]	70.1 (0.8)[be]	< 0.001
Blood glucose	81.9 (0.8)[a]	82.3 (0.6)[a]	80.8 (0.5)[a]	78.7 (0.7)[b]	< 0.001
RI	1.6 (0.1)	2.0 (0.2)	1.5 (0.3)	1.6 (0.1)	0.25
TC	158.1 (3.0)	155.7 (2.1)	150.4 (1.7)	153.4 (2.7)	0.09
HDLc	47.0 (1.2)	47.3 (0.8)	47.9 (0.7)	47.5 (1.0)	0.89
LDLc	91.7 (2.6)	89.6 (1.9)	84.8 (1.5)	88.2 (2.3)	0.08
TG	100.5 (4.5)[ab]	101.1 (3.2)[a]	90.6 (2.6)[b]	90.4 (4.0)[ab]	0.03
Auric, uric acid	4.0 (0.1)[a]	4.6 (0.1)[b]	4.6 (0.1)[b]	4.6 (0.1)[b]	< 0.001

Analysis of variance with sample weighting. Different letters correspond to significant differences; identical letters indicate no differences. SE, standard error; BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; RI, insulin resistance; TC, total cholesterol; HDLc, HDL cholesterol; LDLc, LDL cholesterol; TG, triglycerides; Auric, uric acid.

Table 3 shows the prevalence and associations of variable changes with gender. Overweight adolescents (31.4%) did not differ significantly between genders, nor for any other variable. Central obesity was 10.5%, with a higher prevalence in males. Elevated triglycerides were observed in females, who were also more sedentary, although without significant difference.

Table 3. Anthropometric, hemodynamic, metabolic changes and physical activity level in adolescents by gender from public schools in Montes Claros (MG) – Brazil.

Variables	Total % (CI 95%)	Gender % (CI 95%)		
		Feminine	Masculine	p-value
Excess weight[1]	31.4 (19.9-45.7)	31.7 (24.7-39.7)	30.9 (13.4-56.4)	0.88
WC high (≥ p90)	10.5 (4.5-22.7)	9.9 (4.7-19.7)	11.6 (2.8-37.1)	0.72
Metabolic syndrome[2]	3.4 (2.3-4.9)	3.4 (2.1-5.4)	3.3 (1.3-8.1)	0.93
SBP (≥ p95)	15.1 (13.8-16.5)	16.1 (12.0-21.3)	13.6 (8.9-20.1)	0.48
DBP (≥ p95)	6.8 (4.5-10.2)	6.8 (3.7-12.1)	6.9 (5.1-9.4)	0.92
Blood glucose	1.5 (0.7-3.3)	1.9 (0.5-7.2)	0.8 (0.1-6.7)	0.46
RI	7.1 (5.2-9.5)	7.1 (4.6-10.9)	7.0 (3.7-13.0)	0.98
TC	26.5 (17.1-38.7)	27.3 (18.6-38.0)	25.4 (14.6-40.5)	0.26
HDLc	44.0 (32.8-55.8)	41.2 (29.9-53.5)	48.3 (31.1-65.8)	0.33
LDLc	18.3 (10.2-30.7)	18.2 (9.3-32.4)	18.6 (10.8-30.1)	0.88
TG	45.0 (36.5-53.8)	47.9 (36.8-59.3)	40.5 (36.7-44.5)	0.06
Auric, uric acid[3]	17.4 (12.3-24.1)	16.3 (12.3-21.3)	19.1 (7.7-39.9)	0.65
Sedentary	11.4 (7.8-16.4)	13.9 (9.7-19.5)	7.5 (3.4-15.9)	0.09
Irregularly active B	35.5 (24.7-48.0)	38.7 (25.9-53.4)	30.5 (18.4-46.1)	
Active	40.1 (32.2-48.7)	38.1 (27.6-49.9)	43.3 (38.9-47.8)	
Very active	12.9 (8.6-19.0)	9.3 (4.4-18.6)	18.6 (10.1-31.8)	

Chi-square test. CI, confidence interval; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; RI, insulin resistance; TC, total cholesterol; HDLc, HDL cholesterol; LDLc, LDL cholesterol; TG, triglycerides; Auric, uric acid. [1] Overweight = overweight and obesity (Z-score > 1 for gender and age); [2] Metabolic syndrome = WC ≥ p90 plus two alterations: TG ≥ 150 mg/dL; HDL-c < 40 mg/dL; fasting glucose ≥ 100 mg/dL; SBP/DBP ≥ 130/85 mmHg and diagnosis of ≥ 16 years similar to adults; [3] ≥ 5 mg/dL for females and ≥ 6 mg/dL for males.

Table 4 presents crude and adjusted PR values with respective CIs for overweight according to the independent variables. The adjusted PR for WC was 1.44 (95% CI 1.37-1.51; p= 0.001), indicating that an increase of each BMI unit raises the probability of central obesity by 44%. It was also shown that overweight adolescents have a 1.11 times higher prevalence of low HDLc, as do those with hyperuricemia, adjusted for gender and age group.

Table 4. Final Poisson regression model of overweight in adolescents from public schools in Montes Claros, Minas Gerais, Brazil.

Variables		CP ratio (CI 95%)	CP ratio (CI 95%)	p-value
WC (≥ p90)	Yes	0.68 (0.66 - 0.70)	1.44 (1.37 - 1.51)	0.00
	No	1	1	
SBP (≥ p95)	Yes	0.86 (0.85 - 0.88)	1.16 (1.09 - 1.24)	0.00
	No	1	1	
Blood glucose (≥ 100 mg/dL)	Yes	1.29 (1.21 - 1.37)	0.79 (0.74 - 0.85)	0.00
	No	1	1	
HDL-c (< 45mg/dL)	Yes	0.91 (0.89 - 0.94)	1.11 (1.06 - 1.16)	0.00
	No	1	1	
Auric; uric acid[1]	Yes	0.89 (0.88 - 0.91)	1.11 (1.05-1.18)	0.00
	No	1	1	

Model adjusted for gender and age range. The goodness of fit of the final model was assessed using the Deviance test. PR, prevalence ratio; CI, confidence interval; WC, waist circumference; SBP, systolic blood pressure; HDLc, HDL cholesterol; Auric; uric acid. [1] ≥ 5 mg/dL for females and ≥ 6 mg/dL for males.

Table 5 describes the crude and adjusted OR for increased WC in adolescents. In the logistic regression analysis, WC was a predictor of changes in IR, and it was also shown that WC impacted the chance of changes in diastolic BP, TG, and uric acid.

Table 5. Final model of multiple regression of waist circumference in adolescents.

Variables		OR bruto (IC 95%)	OR ajustado (IC 95%)	p-value
DBP (≥ p95)	Yes	0.10 (0.00 - 9.90)	1.75 (1.35 - 2.26)	0.00
	No	1	1	
RI (≥ 3.16)	Yes	0.91 (0.13 - 6.64)	4.03 (1.70 - 9.57)	0.05
	No	1	1	

TG (≥ 90 mg/dL)	Yes	1.23 (0.60 - 2.56)	2.53 (1.43 - 4.47)	0.01
	No	1	1	
Auric, uric acid[1]	Yes	1.92 (0.42 - 8.71)	3.54 (1.50 - 8.36)	0.02
	No	1	1	
Model adjusted for gender and age range. The goodness of fit of the final model was assessed using the Nagelkerke test (Pseudo R-squared = 0.291). OR, odds ratio; CI, confidence interval; PAD, diastolic blood pressure; RI, insulin resistance; TG, triglycerides; Auric, uric acid. [1] ≥ 5 mg/dL for females and ≥ 6 mg/dL for males.				

DISCUSSION

Obesity is a chronic and multifactorial disease, developed due to an imbalance of positive energy influenced by various genetic, environmental, and behavioral factors, and is an important cardiovascular risk factor (Lee; Yoon, 2018). CVDs are major causes of mortality worldwide, and adolescence is a good time to establish a healthy lifestyle (Pitrez et al., 2012; Boyer; Nelson; Holub, 2015). Several modifiable CVD risk factors, such as obesity, smoking, and alcoholism, can begin at this stage, making prevention necessary.

The high percentage of overweight in the study (31.4%) is noteworthy, highlighting the impact of current eating habits and sedentary lifestyles on adolescent health. Studies suggest that boys who become obese at age 15 are more likely to experience dissatisfaction in their social and emotional relationships, with future psychological consequences (Assunção et al., 2013). Early intervention is necessary to prevent the repercussions of obesity on the mental health of this population. In another study, Sousa showed a positive correlation between obesity-related quality of life and adherence to weight control, as well as a positive association between parental and caregiver influence on adherence and increased physical comfort, social life, and family relationships, emphasizing the importance of behavioral changes and adherence to weight control as pillars for improving the quality of life among overweight adolescents (Sousa et al., 2017).

Obesity was present in 12% of participants and 19.5% were overweight, with no difference by gender. Overweight was higher than that reported in the ERICA study in the Southeast region of Brazil (26%), with a higher prevalence of obesity in men (Bloch et al., 2016). In 2014, a study conducted in Montes Claros with 382 schoolchildren aged 10-16 years showed a prevalence of overweight of 26.4%, being higher in the female gender (17.5%), evidencing an increase in weight gain in this population as occurs worldwide (Cruz et al., 2014). Our findings demonstrate that overweight presents a significant difference for the age group ($p = 0.01$), being higher in adolescents aged 10-11 years (47.6%), showing a decrease with age, which may be related to puberty at this stage. The results are consistent with those found by ERICA, which also showed a higher prevalence of overweight among younger people (12-14 years old) (Bloch et al., 2016).

It is important to recognize that CV risk in adulthood can be significantly reduced if adolescent obesity is treated adequately and effectively. The prevalence of overweight was 1.44 times higher in adolescents with increased WC. The association of high WC (95% CI 1.37-1.51; $p < 0.001$) observed with nutritional status indicates that obesity prevention can have a significant impact on reducing the prevalence of various diseases such as DM, dyslipidemia, MS, and CVD in adulthood (Camargo; Añez, 2020).

Insulin resistance (IR) was observed in 7.1% of adolescents, with no association found with excess weight. A study observed that this association may be related to a mechanism of increased anabolic effect of insulin and growth hormone during rapid somatic growth during puberty (Morais et al., 2016). This is likely due to changes in insulin sensitivity resulting from alterations in fat distribution during this phase. A study showed that IR indicators presented a strongly positive correlation with BMI, particularly HOMA-IR (0.33; $p < 0.001$) and insulin (0.16; $p < 0.001$), but showed a weak positive correlation with glucose (0.12; $p = 0.01$) and triglycerides (0.12; $p = 0.02$), and a negative correlation with HDL cholesterol (-0.17; $p = 0.01$) in females (Nogueira et al., 2017).

Corroborating this study, which showed a high BMI associated with other risk factors such as high systolic blood pressure, hyperglycemia, low HDL cholesterol, and hyperuricemia, this suggests that excess weight is an important predictor of cardiovascular risk in this population.

Hypercholesterolemia was present in 26.5% of participants, lower than that reported in 774 adolescents aged 10 to 14 years (32%), which also showed no significant difference for gender (Arruda-Neta et al., 2017). The prevalence of high TG ($\geq$90 mg/dL) was evidenced in 45%, higher than in Neta's study (23%), probably due to the different reference values used (Arruda-Neta et al., 2017). Dyslipidemia is an important CV risk factor in this population and is associated with subclinical atherosclerosis and CVD in adulthood.

Non-HDL cholesterol showed mean values of 105.8 mg/dL (EE = 1.2), with a significant difference between age groups ($p = 0.045$), being lowest in adolescents aged 14 to 15 years (102.5 mg/dL; EE = 1.7). Non-HDL cholesterol includes all cholesterol containing atherogenic particles (LDLc, VLDLc, IDLc, and lipoprotein A) and excludes HDLc, which is considered anti-atherogenic. Measuring non-HDL cholesterol has several advantages because it is simple, low-cost, and not influenced by TG levels, and can be used for individuals with TG > 400 mg/dL. In their study of children and adolescents in Aracaju (northern Brazil), Araki et al. (2013) found average non-HDL cholesterol levels of 114.77 mg/dL, which was higher than in the present study, coinciding due to the absence of differences between genders, and also showed a difference for age (Onis et al., 2007). Obese individuals presented significantly higher levels of non-HDL cholesterol than those with normal BMI ($p = 0.02$). In this multiple analysis study model, it was shown that overweight adolescents had 1.11 times higher non-HDL cholesterol than those with normal BMI, as well as for HDLc.

Our findings are also similar to those found in a study with 1950 children and adolescents conducted in southern Brazil, which observed an increase in systolic blood pressure as BMI and waist circumference increased (Bloch et al., 2016). The ERICA study in Brazil showed a higher prevalence of hypertension in obese adolescents compared to those who were overweight or eutrophic, with approximately 20% of hypertension attributable to obesity (Bloch et al., 2016). It has also been demonstrated that high BMI and blood pressure levels in childhood and adolescence increase the cardiovascular risk in adults after following 1061 participants for approximately 28 years (Lai et al., 2014), agreeing with the fact that weight reduction at this stage can have a significant impact on adult life with a reduction in blood pressure and consequent improvement in cardiovascular risk in the future.

Central obesity increases the risk of metabolic diseases and metabolic syndrome, being an important predictor of cardiovascular risk in adolescents (Kuschnir et al., 2016). In this study, the mean waist circumference (WC) was 71.5 cm (SE 0.4), and it was observed that in the youngest group (10-11 years) the mean WC was lower (68.0 cm; SE 1.0) compared to all other age groups. The mean WC was similar to that of ERICA (72.2 cm) in adolescents from six capital cities in Brazil (Kuschnir et al., 2016).

High WC shows a good association with BMI and a strong relationship with DXA (Dual-energy X-ray) (Coutinho et al., 2015). Our results show a high prevalence of central obesity (10.5%), with no significant difference for gender and age, the same as observed in Brazilian adolescents (12.6%) according to ERICA (Kuschnir et al., 2016). A study with 1231 adolescents aged 14 to 17 years showed a prevalence of central obesity of 17.5%, being higher in males ($p=0.009$), and a significant association with a sedentary lifestyle was also evidenced, independent of other factors (Lai et al., 2014). In 2014, a study in Montes Claros showed a prevalence of high WC of 7.6%, being 12.5% in overweight adolescents and 69% in obese adolescents (OR= 15.55; $p< 0.001$), already evidencing an increase in central obesity among overweight schoolchildren in Montes Claros (Cruz et al., 2014).

This study demonstrated that adolescents with insulin resistance (IR) are four times more likely to present with altered waist circumference (WC) (OR= 4.03; $p= 0.05$), corroborating studies that showed IR in obese adolescents and its association with clinical and metabolic alterations, such as high BMI and WC, as well as elevated TG and low HDLc, resulting in increased CV risk in adulthood (Tebar et al., 2017; Lentferink et al., 2017). The metabolic behavior of visceral adipose tissue differs from subcutaneous adipose tissue, which is more subject to lipolysis, expresses a greater number of glucocorticoid receptors and is more sensitive to catecholamines, resulting in greater deterioration of insulin sensitivity, increased blood pressure and the atherosclerotic process (Lentferink et al., 2017; Romualdo; Nóbrega; Escrivão, 2014), thus central obesity, measured by WC, is more associated with

CVD.

Other variables, such as diastolic blood pressure, triglycerides (TG), and uric acid, also impacted the likelihood of waist circumference (WC) alterations. High TG levels are present in 45% of adolescents, and it was shown that the prevalence of central obesity was 2.53 (1.43-4.47) times higher in adolescents with high TG. The key to these alterations may lie in insulin resistance (IR), an essential alteration for the development of several diseases such as type 2 diabetes mellitus (DM2), metabolic syndrome (MS), polycystic ovary syndrome (PCOS), among others. Studies show an association between alterations in the lipid profile (high TG and low HDLc) in adolescents with IR, as well as an association between IR and WC (OR= 3.74; $p < 0.001$) and BMI (OR= 3.96; $p < 0.001$) (Lentferink et al., 2017).

Our findings demonstrate that hyperuricemia is associated with altered BMI (PR= 1.11; $p < 0.001$) and WC (OR= 3.54; $p < 0.001$), likely related to insulin resistance, consistent with studies that have shown an association between hyperuricemia and overweight (PR= 1.10; $p < 0.001$) (Reis et al., 2017) and its association with components of metabolic syndrome in overweight schoolchildren, increasing cardiovascular risk (Tebar et al., 2017; Lentferink et al., 2017). Hyperuricemia appears to contribute to impaired nitric oxide production and endothelial dysfunction, increased arterial stiffness, inappropriate activation of the renin-angiotensin system, and stimulation of oxidative stress, being an important cardiometabolic marker (Rodulfo et al., 2014).

Our study's main limitation is its cross-sectional nature, which does not allow us to establish cause-and-effect relationships, only relationships between variables, which can be influenced by several factors, such as diet and physical activity. Another limitation is the use of BMI for nutritional classification, as it does not differentiate between fat mass and lean mass. Further studies are needed to evaluate other factors that may influence cardiovascular markers, such as dietary intake and inflammatory markers, as well as the benefit of interventions, such as physical activity, on cardiovascular risk.

CONCLUSION

In summary, our findings indicated a high prevalence of overweight and central obesity in adolescents, as well as other CV risk factors (increased total cholesterol, triglycerides, and reduced HDL cholesterol). Early diagnosis of these CV risk factors and their associations at this stage of life is crucial to prevent weight gain and encourage weight loss in adolescents. It is essential to raise awareness among policymakers and the public that a healthy lifestyle implemented at this age can reduce CV risk factors in adulthood through nutritional re-education and regular physical activity, increasing life expectancy and improving the quality of life of the population.

REFERENCES

ARAKI, M. V. R. et al. Não-HDL colesterol em escolares e adolescentes. Scientia Plena, v. 9, n. 2, p. 1-8, 2013.

ARRUDA-NETA, A. C. P. et al. Índice de conicidade como preditor de alterações no perfil lipídico em adolescentes de uma cidade do Nordeste do Brasil. Cadernos de Saúde Pública, v. 33, n. 3, p.e00029316, 2017.

ASSUNÇÃO, M. C. F. et al. Tornar-se obeso na adolescência pode trazer consequências à saúde mental? Cadernos de Saúde Pública, v. 29, n. 9, p. 1859-1866, 2013.

BLOCH, K. V. et al. ERICA: prevalence's of hypertension and obesity in Brazilian adolescents. Revista de Saúde Pública, v. 50, supl. 1, p. 9-21, 2016.

BOYER, B. P.; NELSON, J. A.; HOLUB, S. C. Childhood body mass index trajectories predicting cardiovascular risk in adolescence. Journal of Adolescent Health, v. 56, n. 6, p. 599-605, 2015.

BRASIL. Ministério da Saúde. Sistema de Vigilância Alimentar e Nutricional: relatórios de acesso público. Brasília, DF: Ministério da Saúde, 2022.

BRASIL. Ministério da Saúde. PROTEJA: Estratégia Nacional para Prevenção e Atenção à Obesidade Infantil: orientações técnicas. Brasília: Ministério da Saúde, 2022.

CAMARGO, E. M.; AÑEZ, C. R. R. Diretrizes da OMS para atividade física e comportamento sedentário: num piscar de olhos. Genebra: Organização Mundial da Saúde, 2020.

COUTINHO, P. R. et al. Association between adiposity indicators, metabolic parameters and inflammatory markers in a sample of female adolescents. Archives of Endocrinology and Metabolism, v. 59, n. 4, p. 325-334, 2015.

CRUZ, I. R. D. et al. Nutritional status associated with metabolic syndrome in middle-school children in the city of Montes Claros-MG, Brazil. Journal of Human Kinetics, v. 43, p. 97-104, 2014.

FALUDI, A. A. et al. Atualização da Diretriz Brasileira de Dislipidemias e Prevenção da Aterosclerose – 2017. Arquivos Brasileiros de Cardiologia, v. 109, n. 2, supl. 1, p. 1-90, 2017.

FERRAZ, M. H. C.; DELGADO, R. B. Valores de referência para exames laboratoriais. In: LEÃO, E. et al. (org.). Pediatria ambulatorial. 3. ed. Belo Horizonte: Coopmed, 1988. p. 837-848.

GUEDES, D. P.; LOPES, C. C.; GUEDES, J. E. R. P. Reprodutibilidade e validade do Questionário Internacional de Atividade Física em adolescentes. Revista Brasileira de Medicina do Esporte, v. 11, n. 2, p. 151-158, 2005.

HEYWARD, V. H.; STOLARCZYK, L. M. Avaliação da composição corporal aplicada. 1. ed. São Paulo: Manole, 2000.

KARTIOSUO, N. et al. Predicting overweight and obesity in young adulthood from childhood body-mass index: comparison of cutoffs derived from longitudinal and cross-sectional data. The Lancet Child & Adolescent Health, v. 3, n. 11, p. 795-802, 2019.

KESKIN, M. et al. Homeostasis model assessment is more reliable than the fasting glucose/insulin ratio and quantitative insulin sensitivity check index for assessing insulin resistance among obese children and adolescents. Pediatrics, v. 115, n. 4, p. 500-503, 2005.

KUSCHNIR, M. C. C. et al. ERICA: prevalence of metabolic syndrome in Brazilian adolescents.

Revista de Saúde Pública, v. 50, supl. 1, p. 11s, 2016.

LAI, C. C. et al. Impact of long-term burden of excessive adiposity and elevated blood pressure from childhood on adulthood left ventricular remodeling patterns: the Bogalusa Heart Study. Journal of the American College of Cardiology, v. 64, n. 15, p. 1580-1587, 2014.

LEE, E. Y.; YOON, K. H. Epidemic obesity in children and adolescents: risk factors and prevention. Frontiers of Medicine, v. 12, p. 658-666, 2018.

LENTFERINK, Y. E.; ELST, M. A. J.; KNIBBE, C. A. J.; VAN DER VORST, M. M. J. Predictors of insulin resistance in children versus adolescents with obesity. Journal of Obesity, v. 20, n.111, p.68-79, 2017.

LINDBERG, L. et al. Association of childhood obesity with risk of early all-cause and cause-specific mortality: a Swedish prospective cohort study. PLoS Medicine, v. 17, n. 3, e1003078, 2020.

MAFFETONE, P. B.; RIVERA-DOMINGUEZ, I.; LAURSEN, P. B. Overfat adults and children in developed countries: the public health importance of identifying excess body fat. Frontiers in Public Health, v. 5, p. 190, 2017.

MALACHIAS, M. V. B. et al. 7ª Diretriz Brasileira de Hipertensão Arterial. Arquivos Brasileiros de Cardiologia, v. 107, n. 3, supl. 3, p. 1-83, 2016.

MORAIS, P. R. S. et al. Correlação da resistência à insulina e medidas antropométricas com pressão arterial de adolescentes. Arquivos Brasileiros de Cardiologia, v. 106, n. 4, p. 319-326, 2016.

NATIONAL HEART, LUNG, AND BLOOD INSTITUTE. Expert panel on integrated guidelines for cardiovascular health and risk reduction in children and adolescents. Bethesda: National Institutes of Health, 2012. (NIH Publication n. 12-7486).

NOGUEIRA-DE-ALMEIDA, C. A.; MELLO, E. D. Correlation of body mass index Z-scores with glucose and lipid profiles among overweight and obese children and adolescents. Jornal de Pediatria, v.222, n.10, p.100-110, 2017.

OLIVEIRA, G. M. M. et al. Estatística Cardiovascular – Brasil 2021. Arquivos Brasileiros de

Cardiologia, v. 118, n. 1, p. 115-373, 2022.

ONIS, M.; ONYANGO, A. W.; BORGHI, E.; SIYAM, A.; NISHIDA, C.; SIEKMANN, J. Development of a WHO growth reference for school-aged children and adolescents. Bulletin of the World Health Organization, v. 85, n. 9, p. 660-667, 2007.

ORGANIZAÇÃO MUNDIAL DA SAÚDE. Doenças cardiovasculares. Genebra, 2021. Disponível em: https://www.who.int/en/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds). Acesso em: 28 jul. 2022.

ORGANIZAÇÃO PAN-AMERICANA DA SAÚDE. Dia Mundial da Obesidade 2022: acelerar ação para acabar com a obesidade. Washington, DC, 2022. Disponível em: https://www.paho.org/pt/noticias/4-3-2022-dia-mundial-da-obesidade-2022-acelerar-acao-para-acabar-com-obesidade. Acesso em: 31 jul. 2022.

ORGANIZAÇÃO PAN-AMERICANA DA SAÚDE. Ministério da Saúde do Brasil lança Guia de Atividade Física para a População Brasileira, com apoio da OPAS. Washington, DC, 2021. Disponível em: https://www.paho.org/pt/noticias/30-6-2021-ministerio-da-saude-do-brasil-lanca-guia-atividade-fisica-para-populacao. Acesso em: 8 ago. 2022.

PITREZ-FILHO et al. Fatores de risco cardiovasculares, metabólicos e inflamatórios e suas relações com obesidade em crianças e adolescentes: fisiopatologia e aspectos clínicos. Boletim Científico de Pediatria, v. 1, n.10, p. 47-51, 2012.

REIS, L. N. et al. Hyperuricemia is associated with low cardiorespiratory fitness levels and excess weight in schoolchildren. Jornal de Pediatria, v. 93, p. 538-543, 2017.

RODULFO, J. I. A. et al. Implicaciones del ácido úrico elevado en el riesgo cardiovascular. Avances Cardiológicos, v. 34, n. 3, p. 239-251, 2014.

ROMUALDO, M. C. S.; NÓBREGA, F. J.; ESCRIVÃO, M. A. M. S. Insulin resistance in obese children and adolescents. Jornal de Pediatria, v. 90, n.100, p. 600-607, 2014.

SBEM – SOCIEDADE BRASILEIRA DE ENDOCRINOLOGIA E METABOLOGIA. Obesidade mais que dobra no país. São Paulo, 2019. Disponível em: https://www.endocrino.org.br/ibge-obesidade-mais-que-dobra-no-pais/. Acesso em: 28 jul. 2022.

SOMMER, A.; TWIG, G. The impact of childhood and adolescent obesity on cardiovascular risk in adulthood: a systematic review. Current Diabetes Reports, v. 18, n. 10, p. 91, 2018.

SOUSA, P. M. L. et al. Association between treatment adherence and quality of life among overweight adolescents. Cadernos de Saúde Pública, v. 33, n. 1, p.e00171815, 2017.

STERGIOU, G. S.; YIANNES, N. G.; RARRA, V. C. Validation of the Omron 705 IT oscillometric device for home blood pressure measurement in children and adolescents: the Arsakion School Study. Blood Pressure Monitoring, v. 11, n. 4, p. 229-234, 2006.

TEBAR, W. R. et al. Obesidade abdominal: prevalência, fatores sociodemográficos e de estilo de vida associados em adolescentes. Journal of Human Growth and Development, v. 27, n. 1, p. 56-63, 2017.

ZIMMET, P. et al. The metabolic syndrome in children and adolescents: an IDF consensus report. Pediatric Diabetes, v. 8, p. 299-306, 2007.