O MUNDO DA SAÚDE

# Metabolic syndrome, consumption of ultra-processed foods and sweetened beverages in adolescents

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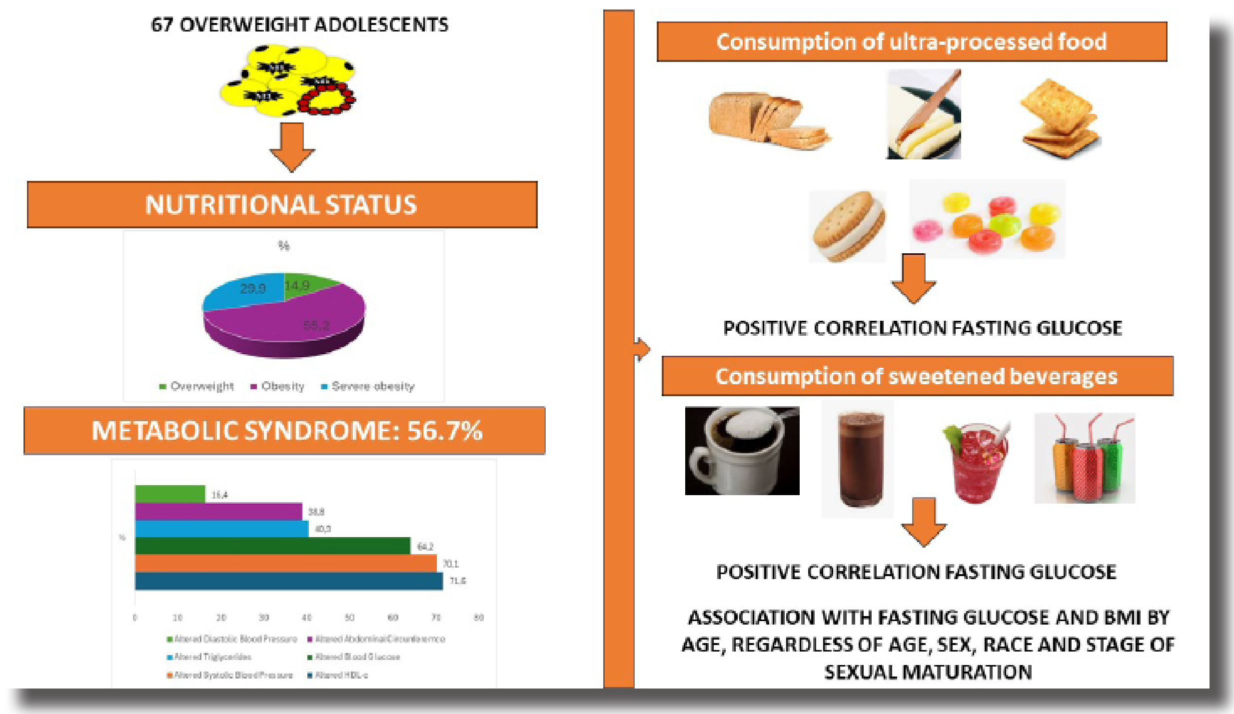
Ingrid Kelly Marinho Salustriano[1] Vânia de Fátima Tonetto Fernandes[1,2] Guido de Paula Colares Neto[1,2] Carolina Costa Figueiredo[2] Nara Michelle de Araújo Evangelista[2] Deborah Cristina Landi Masquio[1]

[1]Centro Universitário São Camilo – CUSC. São Paulo/SP, Brasil.
[2]Hospital Infantil Darcy Vargas. São Paulo/SP, Brasil.
E-mail: deborah.masquio@prof.saocamilo-sp.br

### Graphic Abstract




### Abstract

Metabolic syndrome is characterized by the concomitant presence of changes in blood glucose, dyslipidemia, elevated blood pressure and excessive adiposity, which increase cardiovascular risk. The objective of this study was to analyze the parameters of metabolic syndrome and the association with the consumption of ultra-processed foods and sweetened beverages in overweight adolescents. A cross-sectional study was carried out with 67 overweight adolescents from a pediatric outpatient clinic of a public hospital in the city of São Paulo. The anthropometric assessment consisted of measuring weight, height and waist circumference. Data on glucose, triglycerides, HDL-c, and blood pressure were collected, and metabolic syndrome (MS) was analyzed according to criteria from the Brazilian Association of Nutrology. Food consumption was assessed using the semi-quantitative food frequency questionnaire. The prevalence of metabolic syndrome was 56.7%. The most prevalent parameters were a reduction in HDL-c (71.6%), and an increase in systolic blood pressure (70.1%) and fasting blood glucose (64.2%). Blood glucose was positively associated with the sweetened beverage consumption score and BMI. It is concluded that there is a high prevalence of metabolic syndrome in adolescents, with glycemia being associated with the consumption of sweetened beverages.

**Keywords:** Obesity. Metabolic Syndrome. Ultra-processed Foods. Beverages Sweetened with Sugar. Adolescents.

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## INTRODUCTION

Obesity is defined by the excessive accumulation of adipose tissue, as a result of energy imbalance caused by the influence of multiple environmental and genetic factors. Characterized as a pandemic, which affects millions of children and adolescents around the world. This number has been increasing worryingly in the pediatric population, becoming a relevant factor in public health worldwide[1]. In Brazil, it is estimated that 29.3% of children over five years of age are overweight, of which 4.8% are already severely obese[2]. According to the National School Health Survey (PENSE), conducted in Brazil, the prevalence of excess weight in adolescents aged 13 to 17 is estimated at 23.7% and obesity in 7.8% of the participants assessed[3].

Overweight children and adolescents are more likely to become obese adults and suffer from chronic non-communicable diseases, with fatal cardiovascular outcomes in young adulthood[4]. Obesity in childhood and adolescence is already associated with several comorbidities, such as insulin resistance, high blood pressure, and dyslipidemia. The grouping of these risk factors contributes to the development of metabolic syndrome, which considerably increases the risk of cardiovascular disease and mortality in adulthood[5].

Metabolic syndrome is considered a set of altered biochemical, physiological and clinical factors, which include changes in fasting blood glucose, dyslipidemia, changes in blood pressure and excessive adiposity, especially in the abdominal region[6]. The concomitant presence of these changes increases the risk of developing atherosclerosis, cardiovascular events, type 2 diabetes mellitus and mortality from any cause[5-6].

There are several factors that contribute to the development of obesity and metabolic syndrome in the pediatric phase, such as those related to inadequate nutrition and a sedentary lifestyle[1,6]. A recent systematic review conducted by analyzing ten scientific studies, with approximately 24,281 children and adolescents between 4 and 20 years old, showed a positive association between the intake of ultra-processed foods and the development of obesity[7].

Ultra-processed foods are considered industrial formulations of substances extracted or derived from foods, which contain little or no whole food in their composition and which are typically added with flavors, colorings, emulsifiers and other additives that modify the sensorial attributes of the product. They generally have a high content of added sugar, fat and sodium[8]. However, few studies have evaluated the relationship between this food consumption and the parameters of metabolic syndrome in Brazilian children and adolescents[9-11].

Within the ultra-processed food (UPF) categories are sugary beverages, which refer to any non-alcoholic liquid sweetened with various forms of added sugars. Regarding the consumption of these beverages, systematic review studies indicate a positive association with excess weight in childhood and adolescence[12-13]. Regarding the parameters of metabolic syndrome, the impacts of these beverages on the lipid profile, adiposity in the abdominal region, and changes in blood pressure have already been demonstrated[14-16]. However, few studies have jointly evaluated the relationship between sweetened beverages and metabolic syndrome in overweight children and adolescents[17].

Therefore, we hypothesize that the consumption of ultra-processed foods and sweetened beverages is associated with the parameters of metabolic syndrome in adolescents. Therefore, the objective of this study was to investigate the parameters of metabolic syndrome, and the association with the consumption of ultra-processed foods and sweetened beverages in overweight adolescents.

## METHODS

This is a cross-sectional study, conducted with adolescents treated at a pediatric outpatient clinic of a public hospital, located in the city of São Paulo-SP, between August 2022 and February 2023. The inclusion criteria were the age range between 10 and 19 years of age and diagnosed with overweight and obesity, that is, those who presented a Body Mass Index (BMI) z-score greater than 1 standard deviation, according to the World Health Organization (WHO) reference[18]. The non-inclusion criteria were: adolescents under 10 years of age, or those with specific conditions, such as autoimmune diseases, neurological disorders, food allergies, thyroid disorders, diseases that restrict eating, pregnant women, temporary or permanent mental disabilities.

The number of participants was estimated through sample calculation performed in the GPower 3.1 application (Universität Düsseldorf: Psychologie, Germany). To this end, a power (Beta error) of 80% and a significance level (Alpha error) of 5% were considered. Under these conditions, for an effect size of 0.15, the need for 68 participants was estimated.

Sociodemographic data, such as age, ethnicity and education of those responsible, were collected in interviews. The pubertal staging (breasts-B; pubic hair-P; genitals-G) of the participants was established according to the Tanner criteria[19], being considered pubescent girls with breasts (B2, B3 and B4) and boys with increased testicular volume (G2, G3 and G4), respectively, and post-pubertal those in pubertal stages B5 and G5.

The anthropometric assessment consisted of measuring weight (kg), height (cm) and waist circumference (cm) following the standardization of anthropometric measurements suggested by the Ministry of Health[20]. Participants were weighed barefoot on a digital electronic scale (Toledo® brand), properly calibrated, with a maximum capacity of 200kg. Height was measured using a stadiometer fixed to the wall without a baseboard (Tonelli®), with a millimeter scale and an accuracy of 0.5 cm. Waist circumference was assessed with the participant in an orthostatic standing position, with the abdomen relaxed, using a retractable inelastic measuring tape (Pediatra Nutri Patchwork®), with an accuracy of 0.1 cm, at the height of the umbilical scar[20].

Weight and height data were used to calculate BMI. The nutritional status of adolescents was assessed using the anthropometric BMI-for-age index, with those who presented a z-score ≥ 1 standard deviation, obesity ≥ 2 standard deviation and severe obesity ≥ 3 standard deviation being considered overweight[20]. To calculate the standard deviation, the WHO AnthroPlus software from WHO was used[21].

Biochemical tests were consulted in the participants' medical records, and consisted of fasting blood glucose and lipid profile (total cholesterol, LDL-c, HDL-c and triglycerides), following the standardization of the institution's clinical analysis laboratory. Blood pressure was measured using a 12″ i 120 multiparameter monitor (Alfamed®), with a specific cuff for the pediatric range, with the participant sitting and resting for at least five minutes.

The parameters of metabolic syndrome were analyzed according to the criteria suggested by the Brazilian Association of Nutrology (ABRAN)[6]. Children and adolescents who presented altered values in at least three of the four criteria were considered to have a diagnosis of metabolic syndrome: (1) high waist circumference (according to the age and sex table); (2) high blood glucose (>100 mg/dL) or use of diabetes medication; (3) reduced HDL-c (<45 mg/dL) or high triglycerides (according to the age and sex table), or undergoing drug treatment; (4) elevated systolic or diastolic blood pressure (according to the age and sex table), or use of antihypertensives[6].

Food consumption was assessed using a

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Food Frequency Questionnaire (FFQ) validated for Brazilian adolescents[22]. The questionnaire contained 94 food items. For each participant, a retrospective food frequency record was recorded, referring to the last year or 12 months, completed by the participants themselves, with the help of their guardian. The questionnaire contained seven food frequency categories that could be marked for each food item: (1) never; (2) less than 1x per month; (3)1 to 3x month; (4) 1x per week; (5) 2 to 4x week; (6) 1x day; and (7) 2 or more times per day. Food items were grouped into ultra-processed foods based on the NOVA classification proposed by Monteiro *et al.*[8,23].

To analyze consumption frequencies as a numerical variable, each frequency category was converted into an annual consumption score, following the method proposed by Fornés *et al.*[24]. A weight was assigned to each consumption frequency category, with the value 1 being given as weight for the daily consumption categories, and the others were converted into a score using the equation: (1/365) x [( a+b)/2], where "a" and "b" represent the number of days of minimum and maximum annual consumption, respectively. The following score values were generated for each category: (1) never = 0; (2) less than 1x per month = 0.02; (3) 1 to 3x month= 0.07; (4) 1x per week = 0.13; (5) 2 to 4x week = 0.39; (6) 1x day = 1; and (7) 2 or more x day = 1. Thus, the ultra-processed food consumption score was generated by summing the score values of all food items categorized in this group. The sum of the score for consumption of these foods could vary between 0 and 31, with the higher the score, the greater the frequency of annual consumption. Additionally, the sweetened beverage consumption score was created, considering the sum of the scores for chocolate beverages, soft beverages, yogurts, dairy beverages, sweetened juices, artificial juices, teas and coffee.

This study was approved by the Research Ethics Committee of Centro Universitário São Camilo (nº 5,653,370) and by the Research Ethics Committee of Hospital Infantil Darcy Vargas (nº 5,707,675), and followed the terms of Resolution nº 510/2016 , from the National Health Council. All those responsible and participants agreed and signed the Free and Informed Consent Form (TCLE) and/or the Assent Form.

Statistical analysis was performed using the JAMOVI® software, considering a significance level of $p<0.05$. The Shapiro Wilk normality test was performed. Pearson and Spearman correlations were applied to evaluate the relationship between parametric and non-parametric numerical variables, respectively. Using multiple linear regression analysis, the association between the metabolic syndrome parameters (dependent variables) and other variables, such as the ultra-processed food consumption score, sweetened beverage score and anthropometric data, was investigated.

## RESULTS

In total, data were collected from 82 adolescents, however 15 participants were not included in the analyzes because they did not present all the biochemical tests necessary to identify metabolic syndrome (n=12), because they did not completely complete the FFQ (n=2) and because they had a BMI ≤ 1 standard deviation (n=1). Therefore, the sample for this study consisted of 67 adolescents. In the total sample, the average age was 13.8 ± 2.4 years, with 58.2% being male and 59.7% being white. According to pubertal staging, 58.2% were pubescent. Regarding the profile of those responsible, the average age was 44.4±9.1 and the majority had completed high school (53.7%) (Table 1).

**Table 1** - Sociodemographic profile and pubertal staging of overweight adolescents treated at an outpatient clinic and their guardians. São Paulo, 2023.

| | Adolescents (N=67) |
|---|---|
| **Age (years)** | 13.8 ± 2.40 |
| **Sex (%)** | |
| Female | 28 (41.8) |
| Male | 39 (58.2) |
| **Ethnicity (%)** | |
| White | 40 (59.7) |
| Mixed | 22 (32.8) |
| Black | 5 (7.5) |
| **Pubertal staging (%)*** | |
| Pre-pubescent | 5 (7.5) |
| Pubescent | 39 (58.2) |
| Post-pubescent | 23 (34.3) |
| **Guardians** | |
| **Age (years)** | 44.4 ± 9.12 |
| **Education (%)** | |
| Incomplete primary school | 8 (11.9) |
| Complete primary school | 10 (14.9) |
| Complete high school | 36 (53.7) |
| Complete higher education | 13 (19.4) |

*Pubertal staging according to Tanner criteria: 1 – Pre-pubescent; 2, 3 and 4 – Pubescent and 5 Post-Pubescent12,13.
**Parametric numerical variables are presented as mean ± standard deviation, and non-parametric variables as median (minimum–maximum).
***Categorical variables are presented in absolute and relative frequencies: n (%)

Table 2 presents the anthropometric and metabolic profile of the participants. It was found that the prevalence of obesity was 53.2% and that of severe obesity was 29.9%. The prevalence of metabolic syndrome was 56.7% in adolescents. Regarding the presence of changes in metabolic syndrome parameters, it was observed that 70.1% had changes in systolic blood pressure, 64.2% had changes in blood glucose and 71.6% had changes in HDL-c. Regarding the number of altered parameters of metabolic syndrome, it is worth highlighting that 56.7% of adolescents had three to four criteria present.

Table 3 presents the annual score values for consumption of ultra-processed foods and sweetened beverages. It is noteworthy that the highest scores for ultra-processed foods were for sliced bread, margarine, biscuits without filling, biscuits with filling and candies. Regarding sweetened beverages, higher scores were noted for sweetened coffee, chocolate milk, artificial juices and soft beverages.

**Table 2** - Anthropometric and metabolic profile of overweight adolescents treated at an outpatient clinic. São Paulo. 2023.

| | Adolescents (n=67) |
|---|---|
| **Anthropometric Profile** | |
| Weight (kg) | 79.6 ± 17.3 |
| Height (cm) | 160 ± 11.2 |
| Waist circumference (cm) | 97.4 ± 11.3 |
| BMI (kg/m$^2$) | 30.8 ± 5.26 |
| z-score BMI | 2.73 ± 0.78 |
| **Nutritional status (/%)** | |
| Overweight | 10 (14.9) |
| Obesity | 37 (55.2) |
| Severe obesity | 20 (29.9) |
| **Metabolic Profile** | |
| Blood glucose (mg/dL) | 90 (72 - 139) |
| Triglycerides (mg/dL) | 87 (40 - 588) |
| Total cholesterol (mg/dL) | 151 ( 93 - 342) |
| LDL-c (mg/dL) | 90.9 ± 24.0 |
| HDL-c (mg/dL) | 39 (23 - 73) |
| Systolic Blood Pressure (mmHg) | 126.0 ± 16.7 |
| Diastolic Blood Pressure (mmHg) | 66.5 ± 12.0 |
| **Metabolic syndrome (%)** | 38 (56.7) |
| **Altered Parameters of Metabolic Syndrome (%)** | |
| Alteration in HDL-c (%) | 48 (71.6) |
| Alteration in PAS (%) | 47 (70.1) |
| Alteration in blood glucose (%) | 43 (64.2) |
| Alteration in Triglicérides (%) | 27 (40.3) |
| Alteration in Cintura (%) | 26 (38.8) |
| Alteration in PAD (%) | 11 (16.4) |
| **Number of altered parameters (%)** | |
| 0 | 3 (4.5) |
| 1 | 14 (20.9) |
| 2 | 12 (17.9) |
| 3 | 21 (31.3) |
| 4 | 17 (25.4) |

*Lipoproteínas de Baixa Densidade (LDL-c); Lipoproteínas de Alta Densidade (HDL-c); Pressão Arterial Sistólica (PAS); Pressão Arterial Diastólica (PAD), Índice de Massa Corporal (IMC).
**Variáveis numéricas paramétricas estão apresentadas em média ± desvio padrão, e as variáveis não paramétricas em mediana (mínimo–máximo).
***Variáveis categóricas estão apresentadas em frequência absoluta e relativa: n (%)

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Regarding correlation analyses, the number of altered metabolic syndrome parameters positively correlated with waist circumference (r=0.62, p<0.001), BMI (r=0.51, p<0.001), z-score BMI (r=0.54, p<0.001), SBP (r=0.57, p<0.001), DBP (r=0.39, p=0.001), blood glucose (r=0.41, p=0.001), triglycerides (r=0.25, p=0.004), and negatively with HDL-c (r=-0.25, p=0.043). Additionally, a positive correlation was noted between fasting blood glucose and the consumption of sweetened beverages (r=0.354, p=0.003) and with the ultra-processed food consumption score (r=0.25, p=0.040) (Table 4 ).

To confirm this relationship, the multiple linear regression test adjusted for age, sex, race and stage of sexual maturation revealed that blood glucose was positively associated with the sweetened beverage consumption score and the BMI-for-age z-score. No significant results were found for the ultra-processed food consumption score (Table 5).

**Table 3** - Consumption score of ultra-processed foods and sweetened beverages by overweight adolescents treated at an outpatient clinic. São Paulo. 2023.

| | Adolescents (n=67) |
|---|---|
| **Ultra-processed food score** | **2.99 (0.39 - 16.1)** |
| Loaf bread | 0.31 ± 0.41 |
| Margarine | 0.24 ± 0.40 |
| Biscuits and Crackers | 0.24 ± 0.37 |
| Butter or sandwich cookie | 0.21 ± 0.37 |
| Candy | 0.19 ± 0.33 |
| Cream cheese | 0.14 ± 0.31 |
| Potato chips or snacks | 0.13 ± 0.27 |
| Traditional mayonnaise | 0.13 ± 0.31 |
| Breakfast cereal (cornflakes) | 0.12 ± 0.27 |
| Chocolate Candy | 0.09 ± 0.22 |
| Ice cream | 0.08 ± 0.19 |
| Cheeseburger (bun, patty, cheese) | 0.07 ± 0.19 |
| Deep fried snacks (croquettes and similar) | 0.07 ± 0.21 |
| Instant noodles | 0.07 ± 0.18 |
| Filled Baked Savory Pastries | 0.06 ± 0.18 |
| Hot dogs | 0.06 ± 0.14 |
| Sweet or salty (popped) popcorn | 0.06 ± 0.18 |
| Croissant (ham and cheese, sausage) | 0.04 ± 0.13 |
| Pizza | 0.04 ± 0.13 |
| Cakes/icing. industrialized cake | 0.03 ± 0.05 |
| Desserts like mousse or flan | 0.02 ± 0.05 |
| Cheese bread | 0.15 ± 0.30 |
| **Sweetened beverage score** | 1.27 (0.03 – 7.0) |
| Sweetened coffee | 0.37 ± 0.46 |
| Chocolate powder | 0.27 ± 0.39 |
| Artificial juices | 0.19 ± 0.37 |
| Soda | 0.14 ± 0.31 |
| Fermented milk | 0.11 ± 0.27 |
| Flavored mate tea | 0.11 ± 0.29 |
| Fruit yogurt | 0.10 ± 0.24 |
| Diet soda | 0.02 ± 0.11 |
| Diet yogurt | 0.01 ± 0.05 |

*Valores apresentados em média ± desvio padrão ou em Mediana (mínimo e máximo)

**Table 4** - Correlations between metabolic syndrome parameters, sweetened beverage consumption score and ultra-processed food consumption score in overweight adolescents. São Paulo, 2023.

| | r/rho* | P |
|---|---|---|
| **Number of altered metabolic syndrome parameters** | | |
| Waist circumference (cm) | 0.62 | <0.001 |
| BMI (kg/m$^2$) | 0.51 | <0.001 |
| S-score BMI | 0.54 | <0.001 |
| Systolic blood pressure (mmHg) | 0.57 | <0.001 |
| Diastolic blood pressure (mmHg) | 0.39 | 0.001 |
| Blood glucose (mg/dL) | 0.41 | 0.001 |
| Triglycerides (mg/dL) | 0.25 | 0.004 |
| HDL (mg/dL) | -0.25 | 0.043 |
| **Ultra-processed food consumption score** | | |
| Number of altered parameters | 0.03 | 0.759 |
| Waist circumference (cm) | -0.10 | 0.400 |
| BMI (kg/m$^2$) | -0.13 | 0.294 |
| Z-score BMI | -0.03 | 0.811 |
| Systolic blood pressure (mmHg) | -0.09 | 0.494 |
| Diastolic blood pressure (mmHg) | -0.01 | 0.965 |
| Blood glucose (mg/dL) | **0.25** | **0.04** |
| Triglycerides (mg/dL) | -0.06 | 0.66 |
| HDL (mg/dL) | -0.04 | 0.75 |
| **Sweetened beverage consumption score** | | |
| Number of altered parameters | 0.18 | 0.140 |
| Waist circumference (cm) | 0.13 | 0.308 |
| BMI (kg/m$^2$) | 0.12 | 0.317 |
| z-score BMI | 0.13 | 0.314 |
| Systolic blood pressure (mmHg) | -0.03 | 0.784 |
| Diastolic blood pressure (mmHg) | -0.09 | 0.492 |
| Blood glucose (mg/dL) | **0.35** | **0.003** |
| Triglycerides (mg/dL) | 0.08 | 0.516 |
| HDL (mg/dL) | -0.11 | 0.403 |

*Pearson correlations for parametric variables and Spearman correlations for non-parametric variables.

**Table 5** - Adjusted linear regression analysis to determine factors associated with fasting blood glucose in overweight adolescents treated at an outpatient clinic. São Paulo, 2023.

| **Fasting blood glucose (mg/dL)** | | **Confidence Interval 95%** | | |
|---|---|---|---|---|
| **Predictors** | **Beta** | **Minimum** | **Maximum** | **p** |
| Sweetened beverage score | 2.432 | 0.311 | 4.55 | 0.025 |
| BMI for age (z-score) | 4.808 | 0.321 | 9.29 | 0.036 |
| **Fasting blood glucose (mg/dL)** | | **Confidence Interval 95%** | | |
| **Predictors** | **Beta** | **Minimum** | **Maximum** | **p** |
| Ultra-processed food score | 0.958 | -0.406 | 2.32 | 0.165 |
| BMI for age (z-score) | 5.747 | 0.811 | 10.68 | 0.023 |

*Test adjusted for age, sex, race and sexual maturation.

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## DISCUSSION

One of the most relevant results of our study refers to the high prevalence of metabolic syndrome (56.8%) and severe obesity (29.9%) observed in the sample evaluated. Among the parameters with the greatest changes, a reduction in HDL-c, an increase in systolic blood pressure and fasting blood glucose stand out, and more than half of the participants evaluated. Furthermore, it was noted that fasting blood glucose was positively correlated with the consumption of ultra-processed foods and sweetened beverages.

Recent data from the World Obesity Atlas, published by the World Obesity Federation, indicate alarming trends in the increase in childhood obesity rates annually in Brazil[25]. There are estimates that in 2030 around 22.7% of children and 15.7% of adolescents will be obese in our country[26]. These data are worrying, since metabolic syndrome is a disease that is directly related to the excessive accumulation of visceral adipose tissue, as it is an endocrine organ involved in chronic systemic inflammation and insulin resistance, which are the main mechanisms involved in its pathophysiology[27].

The incidence of this syndrome is increasing, and studies indicate that this clinical condition has been significantly expanding in overweight children and adolescents[5]. In our study, we found that waist circumference and BMI were positively correlated with the number of altered parameters of metabolic syndrome, which reinforces the relationship between abdominal fat, adiposity and metabolic changes. It is important to point out that the literature indicates that the prevalence of metabolic syndrome was 8.8 times higher in children and adolescents with obesity when compared to normal weight individuals[28]. Furthermore, the prevalence of metabolic syndrome is estimated between 17.2% and 37.1% in overweight and obese Brazilian adolescents, respectively[29].

The study conducted by Noubiap *et al.*[5] estimated that the global prevalence of metabolic syndrome in children was 2.8% and in adolescents 4.8% in 2020, which is equivalent to 25.8 million children and 35.5 million adolescents living with this condition. In Brazil, the Study of Cardiovascular Risks in Adolescents (ERICA), which evaluated 37 thousand adolescents, aged between 12 and 17 years, revealed a prevalence of metabolic syndrome of 2.6%. Although this study showed a relatively lower prevalence of this syndrome, the significant occurrence of some of its components stands out, such as reduced HDL-c in 32.7% of those evaluated. It is interesting to note that in the sample of adolescents in our study, this was also the metabolic syndrome parameter with the greatest change (71.6%). It is known that reduced HDL-c concentrations are related to mortality from cardiovascular diseases in the long term[30].

Both obesity and metabolic syndrome are two extremely worrying pathologies in childhood and adolescence, as they result in several serious health consequences, with impacts on quality of life in the short and long term, and contribute to a greater risk of developing cardiovascular diseases and type 2 diabetes mellitus[4,31]. Early signs of vascular dysfunction and subclinical atherosclerosis have also been reported in children with severe obesity[32], which highlights the importance of diagnosing factors related to its development and monitoring such changes early in childhood[1,28,33].

Regarding the consumption of ultra-processed foods, we observed that among the foods consumed most frequently were sliced bread, biscuits, sandwich cookies and candies. It is worth noting that, contrary to our hypothesis, no significant results were found between the ultra-processed food consumption score and the metabolic syndrome parameters in the sample investigated, except for the positive correlation between fasting blood glucose. These foods contain high amounts of added sugar, which, when consumed frequently, can alter carbohydrate metabolism and promote insulin resistance[23].

Above all, it is worth highlighting that studies on the topic proposed in this work are still scarce in the pediatric population. Few published studies have addressed the impact of consuming foods with different levels of processing on the cardiometabolic profile of children and adolescents in Brazil[9-11,34].

In the study conducted by Lima *et al.*[34] it was observed that adolescents with higher consumption of ultra-processed foods (Tertile 3) presented a higher risk of lipid changes, with negative associations being observed with HDL-c concentrations, and positive associations with the high triglycerides and the presence of dyslipidemia. Additionally. Rauber *et al*.[11] found that the consumption of ultra-processed foods were predictors of increased total cholesterol and LDL-c in preschool children (3-4 years), but not in school years (7-8 years). The Brazilian study conducted by Costa *et al.*[10] with 307 children of low socioeconomic status, aged between 4 and 8 years old, revealed an association between consumption of ultra-processed foods and increased waist circumference, but not with glucose concentrations.

Evidence of an association between the consumption of ultra-processed foods and parameters of metabolic syndrome in children and adolescents is still limited and heterogeneous, requiring more robust and longitudinal studies to investigate the outcome of consuming these foods and the impacts on the metabolic and cardiovascular profile. of this public. Additionally, it is worth highlighting that a recent systematic review highlights a positive association between the consumption of ultra-processed foods and BMI, abdominal obesity and body fat in children and adolescents, which may increase the chance of metabolic changes[7]. Another systematic review study published in 2022, which analyzed more than 9,190,718 children and adolescents around the world, showed a 1.71 greater probability of developing severe obesity in the last 15 years in the pediatric age group. These findings elucidate the likely negative impact of a current inadequate lifestyle, including poor diet and sedentary lifestyle, among children[35].

Among the metabolic syndrome parameters analyzed, it was found that high fasting blood glucose was one of the most prevalent changes among adolescents (64.2%). Additionally, a positive association was noted between the consumption of sweetened beverages and fasting blood glucose. When analyzing this association with adjustment variables, it was found that the BMI-for-age z-score was also related to higher blood glucose values.

Corroborating our findings, the study by Seferidi *et al.*[36], carried out with 1,687 children and adolescents, aged between 4 and 18 years, in the United Kingdom, found that the intake of sweetened beverages was associated with a less healthy cardiometabolic profile. Intake of sugar-sweetened beverages and artificially sweetened beverages was associated with higher concentrations of glucose and triglycerides in the blood.

Sweetened beverages are defined as any beverage that contains free sugar in their composition, and are currently considered one of the main contributors to sugar and calorie intake among children and adolescents. It is worth noting that the vast majority of them are considered ultra-processed beverages[37]. Several studies indicate the potential harmful effects of consuming sweetened beverages on the health of adolescents, such as excessive weight gain, obesity, changes in blood pressure levels and lipid profile[12-17].

Data from a systematic review study conducted with adults and the elderly indicated a positive association between the consumption of 1 to 2 servings per day of sweetened beverages and a 26% higher risk of developing type 2 diabetes mellitus, compared to those who consumed none or just one serving of sweetened beverages a day. Associations related to a 20.0% greater chance of developing metabolic syndrome were also observed among those who consumed sweetened beverages more frequently daily[38].

Increasing evidence indicates the positive association between the glycemic imbalance underlying atherosclerosis, arterial hyperten-

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sion and the development of type 2 diabetes mellitus. According to the Global Burden of Disease (GBD) carried out in 2019, it has been identified as one of the dietary risk factors most relevant factors involved in the development of the global burden of chronic diseases and mortality from cardiovascular diseases[39]. Greater visceral adiposity can also affect glucose metabolism, deregulating metabolic functioning and, in the long term, being related to the destruction of pancreas cells, directly causing insulin resistance and hyperglycemia[33]. These mechanisms justify the possible relationship observed between blood glucose, consumption of sweetened beverages and BMI in the present study.

It is worth highlighting that our work was carried out during the COVID-19 pandemic, which may partially justify the higher prevalence of obesity, metabolic syndrome and reduced HDL-cholesterol, possibly linked to a sedentary lifestyle and poor diet, which were intensified during the pandemic period. It is also important to consider during this period, eating habits and lifestyle could meet in a peculiar way[40].

Considering the severity imposed by the scenario of global childhood obesity, as well as its relationship with the development of metabolic syndrome, the importance of tracking and monitoring the risk factors associated with it, encouraging healthy eating and a more active life is highlighted, which constitute the best strategies to reduce the risks of developing chronic diseases that burden the public health system and harm the health of the pediatric public[6].

This study has some limitations, such as the small sample size, which can be considered a bias in relation to the metabolic syndrome parameters not being related to the consumption of ultra-processed foods. Furthermore, it was not possible to adjust the regression model for variables such as family history, history of obesity and chronic diseases, income and level of physical activity, due to the lack of collection of this information in the research. As this is a cross-sectional study, it does not allow establishing a temporal cause and effect relationship between the consumption of ultra-processed foods, sweetened beveragesand the parameters of metabolic syndrome analyzed as an outcome in this study. However, studies with a longitudinal design and larger sample size are suggested to confirm the observed association. Furthermore, the food frequency questionnaire has its limitations, as it is a retrospective method that is subject to participant memory bias, but is widely used in epidemiological research as an instrument for evaluating food consumption and evaluating cardiometabolic outcomes in adolescents[17].

One of the strengths of this study is the investigation of adolescents' food consumption considering the classification of foods according to their level of processing, while part of the studies in the area evaluate food consumption focusing on food groups and nutrients.

## CONCLUSION

Thus, it is concluded that metabolic syndrome had a high prevalence in overweight adolescents. Within the analyzed parameters, fasting glycemia was positively associated with the consumption of sweetened beverages and z-score BMI. Thus, the importance of encouraging healthy eating and lifestyle to control excess weight in the pediatric phase stands out, as well as strategies that emphasize controlling the consumption of sweetened beverages. Such findings show the need for urgent nutritional intervention in adolescents. Additional studies will be needed to investigate the possible relationship between the consumption of ultra-processed foods and metabolic syndrome.

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