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Metabolic syndrome in adolescents and antioxidant nutrient intake: a cross-sectional study

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SUMMARY

OBJECTIVE: To verify the association between metabolic syndrome and its components, and intake of antioxidant nutrients in adolescents.

METHODS: This is a cross-sectional study of the data of 327 adolescents in a high school in Teresina, Piauí, Brazil, pertaining to their socioeconomic background, anthropometric measurements, dietary intake (selenium; copper; zinc; vitamins A, C, and E), hemodynamics, and biochemical tests. The criteria for diagnosing metabolic syndrome in adolescents were applied. Binary logistic regression was used to verify the association between metabolic syndrome and its components, and intake of antioxidants. The level of significance was established at $p<0.05$.

RESULTS: Prevalence of metabolic syndrome was 7.0%, with a significant association between body mass index and blood pressure. Lower tertiles of copper and vitamins A and E intake were associated with high triglyceride and glycemic levels. The association with vitamins A and E remained after adjustment.

CONCLUSIONS: A significant association between lower vitamins A and E intake and metabolic syndrome components (altered triglycerides and glycemic levels) was found. Besides further studies on this issue, the need for health interventions was found, which ensures the appropriate intake of antioxidant nutrients during adolescence.

KEYWORDS: Adolescents. Metabolic syndrome. Antioxidant nutrients.

INTRODUCTION

Metabolic syndrome (MS) is characterized by a set of cardiometabolic changes that elevate the cardiovascular risk in an individual. MS has become a public health challenge, given that the rapid increase in obesity and sedentary lifestyles of children and adolescents can lead to future problems[1]. The prevalence of MS is rising among adolescents, and so it has become essential to identify and examine the risk factors, such as physical inactivity, smoking, and improper eating habits, which predispose adolescents to MS and thus enable early interventions[2].

Adolescents are more susceptible to unhealthy eating habits, such as the intake of excessive high calorie food and insufficient vegetables[3]. Moreover, the intake of poor diet leads to the development of chronic noncommunicable diseases (NCDs) associated with dyslipidemia and high blood pressure levels. Therefore, it is important to monitor the food intake of this

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group, including their intake of antioxidant nutrients that are found in fruits, vegetables, and leafy greens[4].

The frequent intake of antioxidants provides effective protection against organic oxidative processes, the imbalance of which can lead to several NCDs. Antioxidants such as vitamins A and C, which can be found in fruits and vegetables, can maintain the balance between free radical formation and antioxidant defenses. Conversely, the insufficient intake of these micronutrients can lead to an imbalance in antioxidant defenses, which is common in situations such as MS and overweight[5].

Given the rising global prevalence of MS in adolescence, the importance of consuming antioxidants and the lack of studies on the relationship between MS and intake of antioxidants in adolescents, this study analyzes the association between MS (and its components) and intake of antioxidants in adolescents. The hypothesis of this study was that lower intake of antioxidant nutrients was associated with MS and its components in adolescents.

METHODS

Study Characteristics and Ethical Aspects

For this cross-sectional study, the data of adolescents aged between 14 and 19 years enrolled in public and private high schools in Teresina, Piauí, Brazil were used. Data were obtained from the base research project *Saúde na escola: diagnóstico situacional do ensino médio* (translation: School-based health: a situational diagnosis of high school) conducted by the Federal University of Piauí (UFPI), and pertained to students in the first semester of 2016.

The project was approved by the UFPI Research Ethics Committee (Decision No. 1.495.975) under Resolutions 196/96 and 466/2012 of the National Health Council. The adolescents and their parents and/or legal guardians signed the informed consent form for minors.

Sampling Procedures

First, a total of 169 high schools in Teresina were selected. Then, the schools were organized by the type of administration (public/private), geographical areas of city, and size (small: up to 115 students, medium: 116–215 students, large: over 215 students). Both schools, a public and a private, were randomly drawn for each size and geographical area, to obtain a total of 24 institutions, corresponding to 12 schools for each type of administration.

The adolescents were selected through a proportionate stratified sampling method based on the following order: school size, grade level, sex, and age. To calculate the minimum sample, the Epi Info 6.04d software (Centers for Disease Control and Prevention, Atlanta, USA) was used and 40,136 high school students from the 2014 School Census were chosen. A 95% confidence interval (CI), 17.1% prevalence of overweight[6], 5% precision, 1.4 design effect, and 5% significance level were adopted[7]. Thus, the minimum sample required was 316 adolescents. Considering the possible loss of cases, an additional 10% of students from each school were randomly drawn to obtain a sample of 348 adolescents.

Socioeconomic and Demographic Variables

The following socioeconomic and demographic variables: sex, maternal education (≤8 years and >8 years of schooling), and family income (<2 and ≥2 minimum wages) were observed. These data were obtained through a semistructured questionnaire, which was tested prior to the study.

Food Intake Assessment

Information on the adolescents' food intake from a 24-h food record (R24h) based on the "multiple pass method" were collected. A second R24h to 40% of the population after an interval of 2 months to correct any intrapersonal variability was applied[8].

Nutwin software, version 1.6.0.7, of the Federal University of São Paulo, Department of Health Informatics, was used to calculate the amount of micronutrients: zinc (Zn); copper (Cu); selenium (Se); and vitamins A, C, and E. These amounts using the Multiple Source Method software, version 1.0.1 (The German Institute of Human Nutrition Potsdam-Rehbrucke, Department of Epidemiology, Nuthetal, Brandenburg, Germany) were adjusted to determine the usual intake.

Blood Collection and Determining Markers of Lipid Metabolism and Glycemia

Of note, 5 mL of venous blood was collected from the adolescents in the morning, after a 12-h fast, and then placed the blood samples in pre-labeled vacuette® tubes. high-density lipoprotein cholesterol (HDL-C), triglyceride (TG), and glycemic concentrations were determined using the enzymatic colorimetric method (BioSystems 310 Model, Curitiba, Paraná, Brazil) with Labtest® kits.

Anthropometric Assessment

The recommendations of Cameron[9] and Jelliffe and Jelliffe[10] were followed to collect the anthropometric data. The adolescents were weighed on a portable electronic scale (SECA®, model 803, Hamburg, Germany) to a precision of 100 g. Their

heights were measured using a stadiometer (SECA®, messband 206 model, Hamburg, Germany) to a precision of 0.1 cm and these measurements was repeated three times and the mean was calculated.

Body mass index (BMI) of the participants was calculated by the ratio of body weight (kg) to height (m) squared. To classify their nutritional status, the BMI-for-age index, expressed as *z*-scores, was adopted according to the curves provided by the World Health Organization (WHO)[11].

The waist circumference (WC) of the participants was measured at the midpoint between the last rib and iliac crest[12] using an inelastic measuring tape (SECA®, 201 model, Hamburg, Germany) to a precision of 0.1 cm and this procedure was repeated three times and the mean was calculated.

Blood Pressure

The procedures of the *7th Brazilian Guideline of Arterial Hypertension*[13] was adopted by applying a calibrated aneroid sphygmomanometer (Durashock Welch Allyn-Tycos®, model DS-44, New York, USA) and the appropriate cuff size. The average of two measurements, the initial measurement and another measurement after 5 min of rest, were taken. If the difference between the systolic blood pressure and diastolic blood pressure was greater than 5 mmHg, the measurements were repeated two times and mean value was calculated.

Diagnosing Metabolic Syndrome

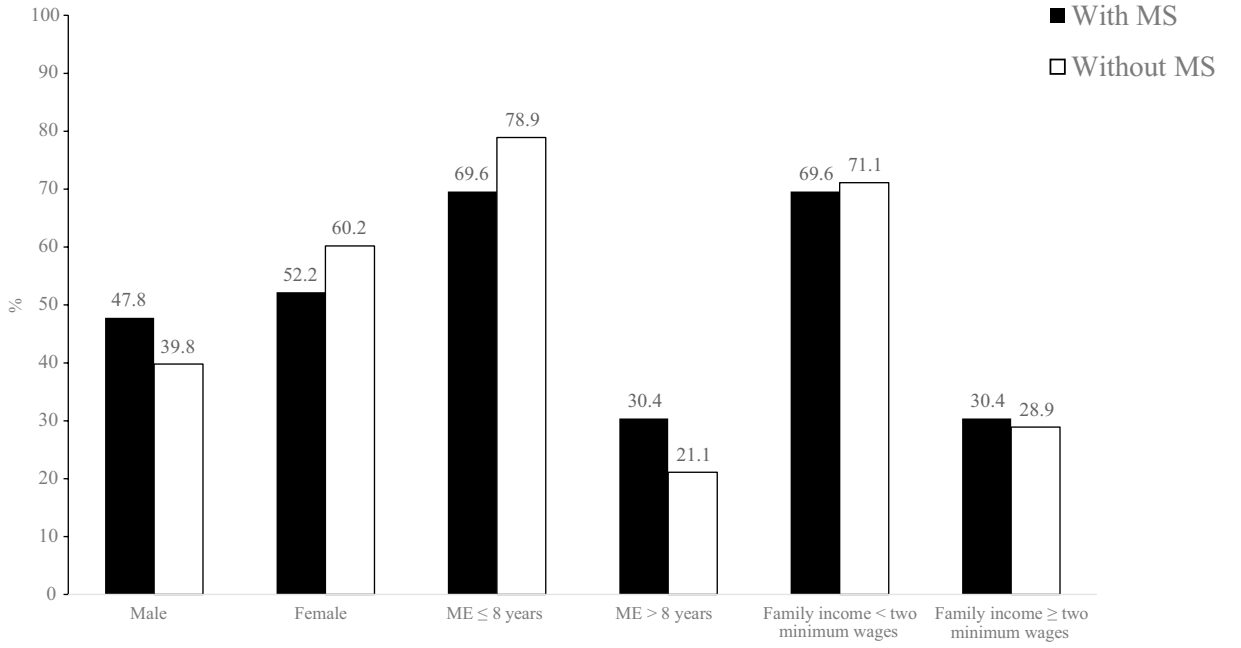
The following cutoff points were employed for the diagnosis of MS: WC ≥90th percentile, blood pressure ≥90th percentile, HDL-C ≤45 mg/dL, TG ≥90 mg/dL, and fasting blood glucose ≥100 mg/dL[14–16]. An adolescent had to have three or more of the aforementioned conditions to be diagnosed for MS[14].

Statistical Analysis

The data in Excel® were organized and exported to the SPSS program (for Windows® version 20.0) for statistical analysis. A bivariate analysis to verify the association between the variables using the 2 × 2 chi-squared test with a 95%CI was used. The results are presented in Figures 1 and 2.

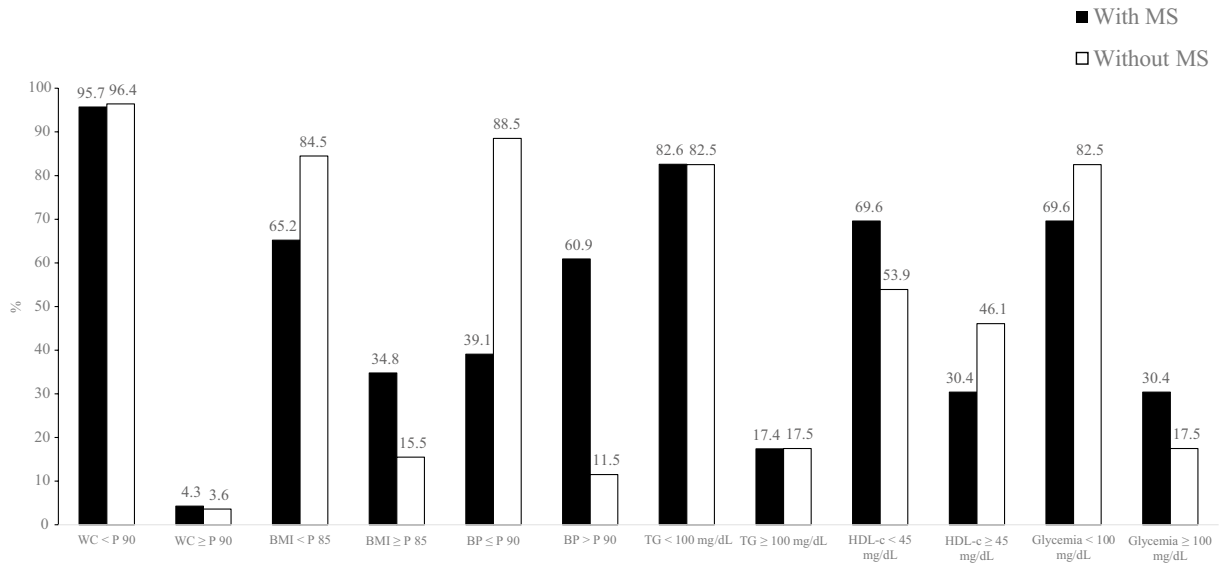
To consider the post-stratification weighting factor and verify the odds ratio (OR) between the dependent and explanatory variables, the variance estimation was used, and the nutrients were expressed as tertiles. The third tertile (highest intake of nutrients) was used as reference for our analyses.

The adjusted binary logistic regression for robust variance as well as adjusted and non-adjusted analyses was used. Variables with a p-value below 0.20 in crude analysis were included in the multivariate analysis calculations. To control the potential confounding factors, these variables were adjusted for sex, age, maternal education, family income, physical activity, and alcohol intake. The level of significance was set at p<0.05.



MS: metabolic syndrome; ME: maternal education. Chi-squared (χ^2) test. Sex: p=0.45; maternal education: p=0.29; Family income: p=0.88.

Figure 1. Socioeconomic characteristics according to the presence or absence of metabolic syndrome.



MS: metabolic syndrome; WC (cm): waist circumference; BMI: Body Mass Index; BP (mmHg): blood pressure; TG: triglyceride; HDL-c: High Density Lipoprotein. Chi-squared (χ^2) test: WC p=0.85; BMI p=0.01; BP p<0.001; TG p=0.99; HDL-c p=0.17; glycemia p=0.12.

Figure 2. Nutritional, pressoric and biochemical characteristics according to the presence or absence of metabolic syndrome.

RESULTS

The final sample included 327 adolescents; 21 participants did not complete the questionnaire or were excluded due to blood hemolysis.

Figures 1 and 2 show the characteristics of the population by socioeconomic, nutritional, blood pressure, and biochemical variables based on MS. The MS prevalence rate was 7%, indicating a statistically significant association between BMI and blood pressure.

Table 1 shows the association between antioxidant intake stratified by tertiles and MS and its components. The lowest tertile of intake of Cu (OR: 2.06, 95%CI: 1.01–4.23), vitamin A (OR: 2.42, 95%CI: 1.07–5.44), and vitamin E (OR: 2.56, 95%CI: 1.04–6.33) had a significant association with high TG concentration. Moreover, a lower intake of vitamins A (OR: 3.59, 95%CI: 1.59–8.13) and E (OR: 2.45, 95%CI: 1.03–5.84) was associated with altered glycemia.

Table 2 shows the results after adjusting the variables for sex, age, maternal education, income, physical activity, and alcohol intake. Antioxidant vitamins A and E maintained their association with high TG concentrations (OR: 9.23, 95%CI: 2.41–35.39 and OR: 4.89, 95%CI: 1.40–17.04, respectively), indicating risk. A lower intake of these vitamins was also linked with altered glycemia (OR: 3.65, 95%CI: 1.26–10.55 and OR: 4.25, 95%CI: 1.17–15.49, respectively).

DISCUSSION

This study found an association between the components of MS and lower intake of antioxidants, which can influence the overall health of adolescents and increase their risk of developing NCDs. Our main findings indicate that lower tertiles of intake of vitamins A and E increased the adolescents' risk of alteration in TG and glycemic concentrations.

This study also indicated a higher MS prevalence compared with the Study of Cardiovascular Risks in Adolescents (ERICA). However, ERICA used different diagnostic criteria[17]. Conversely, a Piauí study of adolescents from private schools showed an MS prevalence of around 3%[18], which is lower than the finding of this study. The MS prevalence detected in our study is comparable with the worldwide prevalence among children and adolescents, which ranges from 1 to 23%[1].

BMI and blood pressure were analyzed as risk markers linked to MS. A previous study using this same sample of adolescents associated overweight and high WC with the risk of altered TG, a component of MS[19]. These associations confirm the importance of monitoring the nutrition of adolescents and support early intervention, specifying the adolescence as a potential period for developing many risk factors for NCDs[20].

The results before and after adjusting the variables for the intake of antioxidant nutrients revealed an association between lower tertiles of intake of vitamins A and E and high

Table 1. Risk analysis between consumption of antioxidant nutrients and metabolic syndrome components (n=327).

Variables	HDL-C ≤40 mg/dL	TG ≥110 mg/dL	Glycemia ≥110 mg/dL	BP ≥90th percentile	MS
	OR (95%CI) p	OR (95%CI) p	OR (95%CI) p	OR (95%CI) p	OR (95%CI) p
Zn					
3rd tertile	1	1	1	1	1
2nd tertile	0.93 (0.56–1.53) 0.77	2.84 (1.45–5.56) 0.02	1.00 (0.52–1.90) 1.00	0.80 (0.39–1.65) 0.55	1.17 (0.46–2.96) 0.74
1st tertile	1.02 (1.58–1.79) 0.94	1.56 (0.69–3.50) 0.28	1.07 (0.52–2.19) 0.86	1.17 (0.55–2.48) 0.68	2.17 (0.59–7.94) 0.23
Cu					
3rd tertile	1	1	1	1	1
2nd tertile	0.94 (0.55–1.61) 0.83	1.37 (0.64–2.92) 0.41	0.78 (0.38–1.61) 0.50	1.27 (0.59–2.72) 0.54	0.67 (0.25–1.84) 0.44
1st tertile	0.80 (0.47–1.36) 0.40	2.06 (1.01–4.23) 0.04	1.29 (0.66–2.50) 0.45	1.37 (0.64–2.91) 0.41	1.15 (0.37–3.56) 0.80
Se					
3rd tertile	1	1	1	1	1
2nd tertile	0.72 (0.42–1.24) 0.23	0.37 (0.16–0.85) 0.01	0.97 (0.47–2.03) 0.94	0.93 (0.41–2.12) 0.87	0.46 (0.14–1.56) 0.20
1st tertile	1.22 (0.63–2.37) 0.56	1.22 (0.63–2.37) 0.56	1.45 (0.72–2.95) 0.29	2.05 (0.97–4.30) 0.05	1.23 (0.46–3.23) 0.67
Vitamin A					
3rd tertile	1	1	1	1	1
2nd tertile	1.09 (0.63–1.89) 0.76	2.65 (1.19–5.90) 0.01	2.34 (1.00–5.45) 0.04	0.85 (0.41–1.75) 0.66	0.90 (0.33–2.43) 0.83
1st tertile	1.15 (0.66–2.00) 0.62	2.42 (1.07–5.44) 0.03	3.59 (1.59–8.13) 0.01	0.53 (0.24–1.19) 0.12	1.63 (0.52–5.18) 0.40
Vitamin C					
3rd tertile	1	1	1	1	1
2nd tertile	0.71 (0.40–1.26) 0.24	1.17 (0.55–2.45) 0.68	0.39 (0.18–0.86) 0.02	0.69 (0.32–1.51) 0.36	0.75 (0.24–2.31) 0.61
1st tertile	0.72 (0.42–1.24) 0.24	1.12 (0.54–2.32) 0.75	0.63 (0.32–1.25) 0.18	0.76 (0.36–1.58) 0.67	1.34 (0.48–3.77) 0.57
Vitamin E					
3rd tertile	1	1	1		1
2nd tertile	1.12 (0.68–1.85) 0.65	1.69 (0.84–3.43) 0.14	1.26 (0.63–2.51) 0.51	1.01 (0.51–2.00) 0.98	1.49 (0.55–4.07) 0.43
1st tertile	1.71 (0.79–3.66) 0.16	2.56 (1.04–6.33) 0.03	2.45 (1.03–5.84) 0.04	0.94 (0.34–2.61) 0.91	1.28 (0.31–5.41) 0.73

MS: metabolic syndrome; HDL-C: high density lipoprotein cholesterol; TG: triglyceride; BP: blood pressure; Zn: zinc; Cu: copper; Se: selenium; OR: odds ratio; 95%CI: 95% confidence interval.

Table 2. Adjusted risk analysis between consumption of antioxidant nutrients and metabolic syndrome components (n=327).

Variables	HDL-C ≤40 mg/dL	TG ≥110 mg/dL	Glycemia ≥110 mg/dL	BP ≥90th percentile	MS
	OR (95%CI) p	OR (95%CI) p	OR (95%CI) p	OR (95%CI) p	OR (95%CI) p
Zn					
3rd tertile	1	1	1	1	1
2nd tertile	–	2.01 (0.88–4.59) 0.09	–	–	–
1st tertile	–	–	–	–	–
Cu					
3rd tertile	1	1	1	1	1
2nd tertile	–	–	–	–	–
1st tertile	–	1.93 (0.77–4.87) 0.16	–	–	–
Se					
3rd tertile	1	1	1	1	1
2nd tertile	–	0.28 (0.08–0.87) 0.03	–	–	–
1st tertile	–	–	–	1.12 (0.37–3.39) 0.84	–
Vitamin A					
3rd tertile	1	1	1	1	1
2nd tertile	–	5.64 (1.62–19.66) 0.00	2.45 (0.83–7.18) 0.10	–	–
1st tertile	–	9.23 (2.41–35.39) 0.01	3.65 (1.26–10.55) 0.01	0.48 (0.16–1.42) 0.48	–
Vitamin C					
3rd tertile	1	1	1	1	1
2nd tertile	–	–	1.07 (0.35–3.25) 0.90	–	–
1st tertile	–	–	1.85 (0.73–4.73) 0.19	–	–
Vitamin E					
3rd tertile	1	1	1		1
2nd tertile	–	1.52 (0.59–3.94) 0.38	–	–	–
1st tertile	1.76 (0.60–5.19) 0.30	4.89 (1.40–17.04) 0.01	4.25 (1.17–15.49) 0.03	–	–

MS: metabolic syndrome; HDL-C: high density lipoprotein cholesterol; TG: triglyceride; BP: blood pressure; Zn: zinc; Cu: copper; Se: selenium; OR: odds ratio; 95%CI: 95% confidence interval. Analyses adjusted for sex, age, maternal education, family income, physical activity, and alcohol consumption.

TG and glycemic concentrations, indicating risk. A study of adolescents showed the association between serum vitamin A, which expresses the food intake or metabolic mobilization of the vitamin, and dyslipidemia[21], thus confirming our findings. Retinoic acid, an active form of vitamin A, stimulates lipolysis and oxidation of fatty acid and reduces TG content, demonstrating its relationship with lipids in the body[22].

However, vitamin E can improve the action of insulin because it is involved in gene expression associated with glucose and lipid metabolism and can influence both dyslipidemia and glycemic changes. A preliminary study has shown that a lower incidence of NCDs corresponds to a higher intake of this nutrient[23]. In addition, vitamin A at the cellular level improves insulin signaling and induces important gene expression for glucose metabolism[22], thus corroborating our findings.

Low serum levels of fat-soluble micronutrients (vitamins A, D, E and carotenoids) have been associated with MS. The optimal levels of these antioxidants in the body can help prevent MS through their antioxidant and anti-inflammatory properties, which are vital to hormone regulation and/or lipid metabolism, besides acting as glucose homeostasis sensors[24].

Studies assessing the association between antioxidant vitamins and MS in adolescents are scarce. Park et al.[25] found that the intake of total vitamins A and C is inversely associated with MS in Korean women. In this study, no significant association between the intake of antioxidant micronutrients and MS was observed, probably due to the low incidence of MS. However, our findings indicate that the intake of antioxidant micronutrients was associated with isolated components of MS. Further investigations, especially studies with a longitudinal design, need to consider the factors that predispose adolescents to MS and examine how the intake of antioxidants can help promote the health of this population.

This study has some limitations. As this is a cross-sectional study, the findings are limited to the level of association, and the cause and effect interpretations are not possible. Therefore, the longitudinal studies for a better understanding of this issue are suggested. Other limitations arise from the use of R24h, such as the variance in the intake of nutrients and its over- or under-reporting of ingestion. In this study, these errors were reduced through intrapersonal variability adjustments.

These results are relevant because the sample used is representative of public and private high school students in the municipality of Teresina, Piauí. Furthermore, these results clarify the relationship between the intake of antioxidants and MS during adolescence, and demonstrate the need for effective health intervention strategies such as including the sources of antioxidant nutrients in adolescents' diet.

CONCLUSIONS

This study could find no association between MS and the tertiles of the intake of antioxidant nutrients. However, the association between lower tertiles of the intake of vitamins A and E and altered MS components (TG and glycemia), which indicates risk, was observed. These findings can help shed light on the relationship between the intake of antioxidant nutrients and MS during adolescence and can lead to further health interventions and future studies.

AUTHORS' CONTRIBUTION

CCB: Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **LMN:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – review & editing. **LCRSL:** Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **BGMR:** Investigation, Visualization, Writing – original draft, Writing – review & editing. **VC:** Supervision, Visualization, Writing – review & editing. **KMGF:** Conceptualization, Formal analysis, Methodology, Supervision, Visualization, Writing – review & editing.

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