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ORIGINAL

The influence of ultra-processed food consumption in anthropometric and atherogenic indices of adolescents

Influência do consumo de alimentos ultraprocessados em índices antropométricos e aterogênicos de adolescentes

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ABSTRACT

Objective

To investigate the influence of ultra-processed food consumption on anthropometric and atherogenic indices.

Methods

A cross-sectional study was conducted with 327 adolescents aged 14 to 19 years. Sociodemographic, anthropometric, biochemical, and food consumption data were evaluated. The ratios of atherogenic indices were calculated using the Castelli I (Total Cholesterol/High Density Lipoprotein Cholesterol), Castelli II (Low Density Lipoprotein Cholesterol/High Density Lipoprotein Cholesterol), and estimated Low Density Lipoprotein Cholesterol particle size (Atherogenic Index of

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Plasma=Triglycerides/High-Density Lipoprotein Cholesterol) indices. Logistic regression was used for the unadjusted and adjusted analysis between ultra-processed foods consumption, anthropometric, and atherogenic indices. The level of significance was 5%.

Results

Most participants were female (59.3%). Girls had a higher consumption of ultra-processed foods (26.6% *vs*. 20.5%). Of the total number of adolescents, 16.5% were overweight and 65.7% were from public schools. Adolescents with altered values for the Castelli I and II Index, and for the Atherogenic Index of Plasma had significantly higher weights, Waist Circumference, Waist Circumference/ Height and Body Mass Index/ Age values. The adjusted analysis identified a significant association (Odds ratio=2.29; 95% Confidence interval: 1.23-4.28) between the high consumption of ultra-processed foods and the Castelli II index.

Conclusion

The associations between atherogenic indices and anthropometric indices and the consumption of ultra-processed foods highlight the negative influence of these foods on adolescents' cardiovascular health.

Keywords: Adolescence. Cardiovascular risk. Food consumption. Processed foods.

RESUMO

Objetivo

Verificar a influência do consumo de alimentos ultraprocessados em índices antropométricos e de aterogenicidade.

Métodos

Estudo transversal com 327 adolescentes na faixa etária de 14 a 19 anos. Avaliaram-se dados sociodemográficos, antropométricos, bioquímicos e de consumo alimentar. As razões dos índices de aterogenicidade foram calculadas por meio do Índice de Castelli I (Colesterol Total/Lipoproteína de Alta Densidade), Índice de Castelli II (Lipoproteína de Baixa Densidade/Lipoproteína de Alta Densidade) e da estimativa do tamanho da partícula de Lipoproteína de Baixa Densidade (Índice Aterogênico do Plasma=Triglicerídeos/Lipoproteína de Alta Densidade). A regressão logística foi utilizada para a análise bruta e ajustada entre consumo de alimentos ultraprocessados, indicadores antropométricos e índice de aterogenicidade. O nível de significância foi de 5%.

Resultados

A maioria dos adolescentes que participaram do estudo era do sexo feminino (59,3%). As meninas apresentaram maior consumo de alimentos ultraprocessados (26,6% vs. 20,5%). Do total de participantes, 16,5% estavam com excesso de peso e 65,7% eram de escolas públicas. Adolescentes com valores alterados para o Índice Castelli I e II e para o Índice Aterogênico do Plasma apresentaram valores de peso, Circunferência da Cintura, Circunferência da Cintura/Altura e Índice de Massa Corporal/Idade significantemente superiores. A análise ajustada identificou associação significante (Razão de possibilidades=2,29; Intervalo de confiança 95%:1,23-4,28) entre o elevado consumo de alimentos ultraprocessados e o índice de Castelli II.

Conclusão

As associações entre os índices aterogênicos com os índices antropométricos e com o consumo de alimentos ultraprocessados ressaltam a influência negativa desses alimentos na saúde cardiovascular de adolescentes.

Palavras-chave*: Adolescência. Risco cardiovascular. Consumo alimentar. Alimentos industrializados.*

INTRODUCTION

Lipid changes and excess weight are risk factors for the development of Cardiovascular Diseases (CVD). They usually appear during childhood and adolescence and may contribute to the development of CVD in adulthood [1]. Plasma lipid control is associated with CVD prevention, whose major risk factors are related to changes in Total Cholesterol (TC), Triglycerides (TG), and High Density Lipoprotein Cholesterol (HDL-c) and Low Density Lipoprotein Cholesterol (LDL-c) particle size (Atherogenic Index of Plasma, AIP). Small LDL-c particles are linked to the atherosclerotic process due to reduced affinity for LDL-c receptors, resulting in their incorporation into the intima layer of the blood vessel. Studies have shown that the Castelli I (TC/HDL-c) and Castelli II (LDL-c/HDL-c) indices, and the AIP (TG/HDL-c) may help assess cardiovascular risk [2-4].

The prevalence of CVD and obesity has increased concomitantly with the production and consumption of Ultra-Processed Foods (UPF). Major changes in the food patterns of developing countries involve the replacement of natural/minimally processed foods of vegetable origin and culinary preparations based on such foods with ready-to-eat industrialized products. These changes have led to an unbalanced nutrient supply and excessive consumption of calories, favoring lipid changes [5,6].

Among the few dietary assessment tools that differentiate foods according to their level of processing, the NOVA classification is considered the most systematic and consistent [7]. According to NOVA, all foods are classified into: unprocessed and minimally processed foods, processed culinary ingredients, processed foods and ultra-processed foods. The latter category comprises a group of industrial formulations made with various ingredients and a series of processes [8].

Based on this explanation, this research highlights the following question: does the consumption of ultra-processed foods influence anthropometric atherogenic indices? Due to the fact that UPF consumption is indicated as a risk factor for the increase of obesity and lipid alterations among adolescents, considered potential risk factors for the development of CVD, the present study has the objective of investigating the influence of UPF consumption in anthropometric and atherogenic indices.

METHODS

This cross-sectional study was carried out with adolescents aged between 14 and 19, enrolled in the public and private education network of the city of *Teresina*, in the state of *Piauí*, in 2016. Before starting the data collection, a 5-day pilot study was carried out to test the data collection and logistics instruments for anthropometric and biochemical data collection.

The minimum required sample was 316 adolescents from public and private schools. In view of possible losses, additional 10% were included in the sample size, totalizing a sample of 348 adolescents; however, considering the losses due to refusals and blood hemolysis, the final sample consisted of 327 adolescents.

The study's participants were students from regular or integral high school in private and public schools. Accordingly, 101 of the 155 existing public schools met the inclusion criteria, 31 in the 4th Regional School Management (GRE, as per the Portuguese acronym for *Gerenciamento Regional Escolar*), 31 on the 19th, 21 on the 20th, and 18 on the 21st GRE. Moreover, 67 out of 163 private schools met the inclusion criteria, with 28 in the area corresponding to the 4th GRE, 10 to the 19th, 24 to the 20th, and 05 to the 21st GRE. The distribution of private schools was made by the researchers, since they are not managed by the state government. Considering that there was a list of public schools distributed throughout the four GREs, after locating the private schools on a map, we obtained the distribution of all 168 schools that were part of the population of schools to be sampled.

The selection of the participating schools was done with simple random sampling. The random drawing of schools guaranteed equal chances of participation in the study for all schools. The municipality was organized in four areas and for each area the same number of schools was drawn by size and type of management. Initially, schools were grouped by size, small (up to 115 students), medium (116 to 215 students), and large (more than 215 students), depending on the number of students enrolled and attending high school in the first semester of 2016. One public and one private school of each size were drawn for the geographical area corresponding to each GRE, totaling 12 publics and 12 private schools, with 06 schools per GRE. In case of refusal of the school chosen, another school was selected of the same size, type of management, and GRE as the first.

Proportional stratified probability sampling was used to select the adolescents. The minimum sample was calculated using Epi Info software version 6.04d (Centers for Disease Control and Prevention, Atlanta, USA), considering the total population of 40,136 high school students from state and private public schools, according to data from the School Census of 2014, and adopting a confidence interval of 95%, prevalence of overweight of 17.1%, accuracy of 5.0%, effect of the design of 1.4, and significance level of 5.0%. The sample was distributed in schools drawn in proportion to the number of students in public and private schools in the municipality. Next, the sample was arranged according to the size of the school, to the grade of high school, to sex, and proportional to age, in that order. These draws were carried out by making available the list of students enrolled and active in 2016, in each school drawn which accepted to participate in the research (Figure 1). More details can be found in the article by Gomes *et al*. [9].

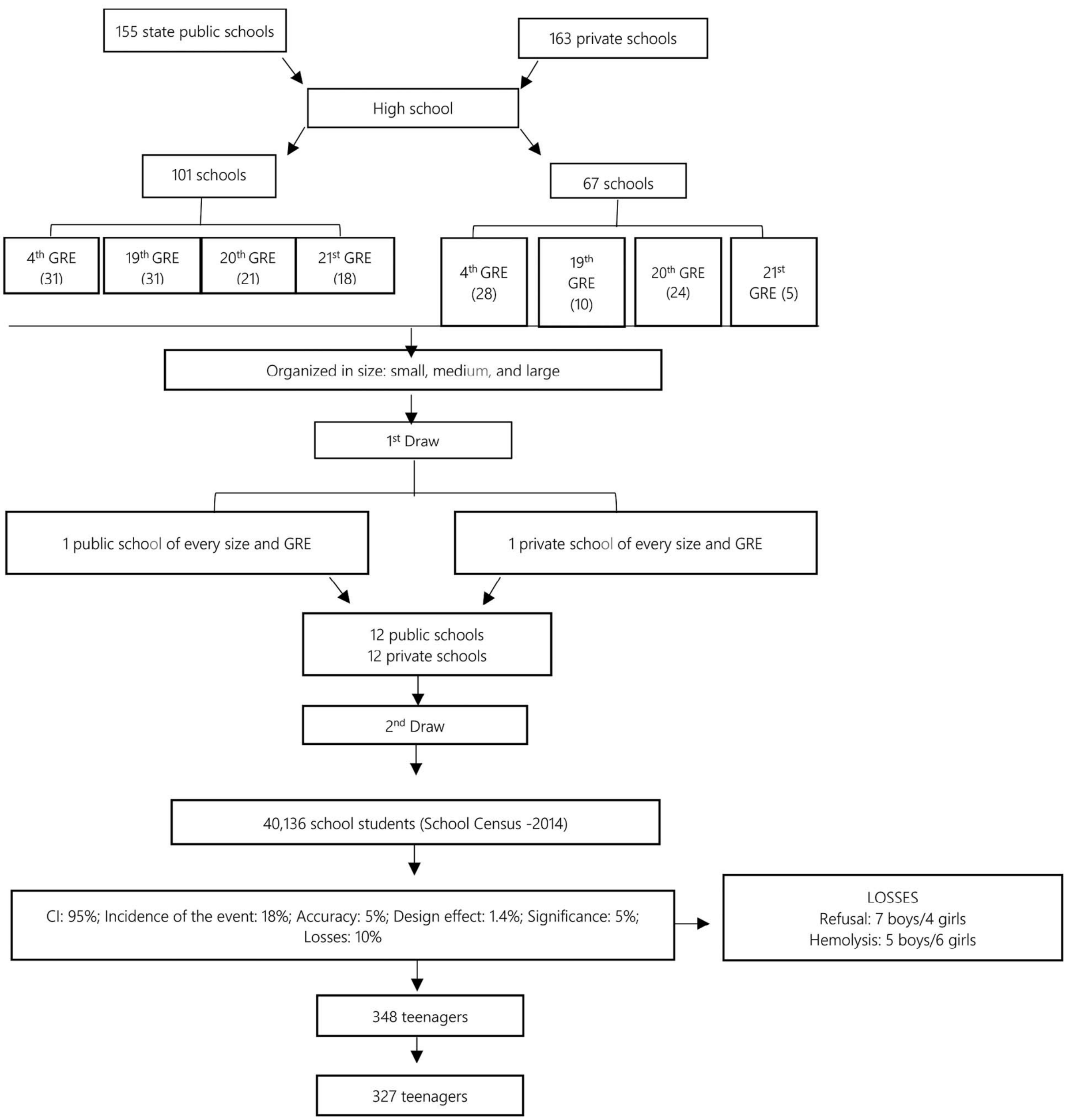

Figure 1 – Flowchart of the study sample selection.

This study included adolescents between 14 and 19 years-old who were duly enrolled in high school at the educational institution where the study was conducted, whose students and/or parents/guardians accepted their participation in the research by signing the Term of Consent, Informed Assent, and/or Informed Consent Term, respectively. Those who did not meet the above requirements were considered ineligible, as well as the ones who had triglycerides greater than 400mg/dL, who did not respect the fasting period, and/or pregnant adolescents, and/or who had a disability that would prevent anthropometric assessment.

Anthropometry was performed according to the recommendations of Cameron and Jelliffe & Jelliffe [10]. A portable electronic scale (SECA®, model 803, Hamburg, Germany) with a precision of 100g, and a stadiometer (SECA®, model messband 206, Hamburg, Germany) with an accuracy of 0.1cm were used to weigh the adolescents. The Body Mass Index (BMI) was expressed as a Z-score and classified according to the World Health Organization [11].

The Waist Circumference (WC) of the teenagers was measured with the technique of Callaway *et al*. [12], using an inelastic tape measure (SECA®, Model 201, Hamburg, Germany) with a precision of 0.1cm. Measurements were compared using the curve of Fredriks *et al*. [13], considering the percentile ≥90 as cutoff value for obesity. The Waist-Height ratio (WHR) was obtained by measuring the WC and height of the participants, and the cutoff value was 0.50. This value was used as the proposed limit for the diagnosis of excess abdominal fat in adolescents [14].

The determination of serum lipid levels was performed through the collection of blood sample (5mL) by nurses in the school facilities after a 12-hour fast. At the time of sensitization, the adolescents were instructed about fasting for blood collection and the day before the collection, messages were sent through an application on a mobile device, in which the adolescents were reminded of the fasting period and other pertinent guidelines for the collection. The concentrations of Total Cholesterol (TC), HDL-c and TG were determined according to the enzymatic colorimetric method. The fraction of LDL-c was calculated according to the Friedewald *et al*. [15] formula.

The Castelli index I was calculated with the formula CT/HDL-c, for which the cutoff point of less than 4.4 indicates normal values. The Castelli II index was calculated with the formula LDL-c/HDL-c, whose reference value considered normal was less than 2.9. The estimated LDL-c particle size (AIP) was evaluated using the TG/HDL-c formula; for this parameter, values less than 2mg/dL are considered normal [3,16-18].

The food consumption of adolescents was obtained through a 24-hour dietary recall (24h-R), which was followed by guidelines about the multiple pass method [19]. A second 24h-R was applied to 40% of the population, in an interval of two months, where the same procedures that were used during the first interview were applied in order to correct intrapersonal variability. For this new assessment, the adolescents were selected by lot in each school that was visited. The replication rate was chosen based on the research by Verly-Júnior *et al*. [20], on which it can be observed that the application of a second 24h-R in 40% of the sample did not mean a loss in precision for estimating food consumption, regardless of the sample size.

The classification of food items according to their degree of industrial processing followed the NOVA classification. Group 1 referred to unprocessed or minimally processed foods; Group 2 to processed culinary ingredients; Group 3 to processed foods; and Group 4 to ultra-processed foods. However, this study analyzed only Group 4, composed of foods with industrial formulations typically made with five or more ingredients [21].

For this study, Group 4 was used as the main object, whereas food consumption was classified into four groups. Then, only the group of Ultra-Processed Foods was selected for a detailed analysis of the amounts of energy. The average of the recalls was used, calculated by the Nutwin software, version 1.6.0.7, from the *Departamento de Informatica em Saúde* of the *Universidade Federal de São Paulo* UNIFESP, through the use of data from the Brazilian Table of Food Composition (TACO) [22], Table of Nutritional Composition of Food Consumed in Brazil [23], and the United States Department of Agriculture (USDA) Table Food Search for Windows, version 1.0, SR23 [24]. This analysis made it possible to verify the contribution of

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ultra-processed foods in relation to the total caloric value of the diet, which was categorized into terciles of consumption for association with the dependent variables (anthropometric and atherogenic indices).

In order to adjust the nutrients for intrapersonal variability, the statistical modeling technique of the Multiple Source Method (MSM) software (version 1.0.1, 2011, Department of Epidemiology of the German Institute of Human Nutrition Potsdam-Rehbrucke, Nuthetal, Brandenburg, Gemany) was used, through estimates of usual consumption [25].

The SPSS software (IBM®, version 20.0) was used for the statistical analyses; descriptive analysis of the data was based on means and standard deviations. The Kolmogorov-Smirnov test was used to analyze the distribution of data, and Student's *t*-test and the Mann-Whitney test were used to compare measures of central tendency. The nutrients were expressed in thirds. Unadjusted and adjusted linear regressions were applied to estimate the association between ultra-processed food consumption, anthropometric, and atherogenic indices. The variables used for adjustment were sex, age, and income. The level of significance was 5%.

This research is part of a project entitled "Health at the school: situational diagnosis in high school", of the *Universidade Federal do Piauí*. The study was approved by the Research Ethics Committee of the *Universidade Federal do Piauí* (n° 1,459,975) and by the Secretariat of Education and Culture of Piauí, in accordance with Resolution 466/2012 of the National Health Council [10]. Adolescents and parents and/or guardians who agreed to participate in the study signed the Informed Assent Form and the Informed Consent Form, respectively.

RESULTS

A total of 327 adolescents participated in the study. Table 1 shows their sociodemographic characteristics and nutritional statuses, besides the adolescents' consumption of ultra-processed foods. The majority were female and students of public schools, with a family income of less than 2 minimum wages. Regarding BMI, 16.5% of the participants were overweight. Table 1 also shows that around 60% of the adolescents had altered atherogenic indices (Castelli Indices I and II and LDL-c particle size – AIP). The study showed that the median consumption of UPF was 26.6% of the Total Caloric Value (TCV) for girls and 20.5% of the TCV for boys.

Table 2 shows that the mean values of weight, WC, WC/height, and BMI/I were significantly higher among adolescents with altered Castelli I Index, Castelli II Index, and AIP.

Table 3 shows the absolute and relative frequencies between the anthropometric parameters and the indices evaluated for each tercile of consumption of ultra-processed foods. There was an increase in most anthropometric indicators and atherogenicity indexes as the terciles of consumption of ultra-processed foods also grew.

The results of the unadjusted and adjusted analyses of association between ultra-processed food consumption, anthropometric indicators, and atherogenic indices are presented in Table 4. It was noted that there was a significant association between high consumption of ultra-processed foods (Tercile 3, whose median was 35.6% of the TCV) and the Castelli II index after adjustment. In this table, it is also evident that some of the other results followed a tendency showing that the greater the consumption of ultra-processed foods, the greater was the risk of presenting altered atherogenic indices.

Table 1 – Sociodemographic, anthropometric, and food consumption characteristics of adolescents.

Risk factors	Female		Male		Total	
	n	%	n	%	n	%
Sample	196	59.9	131	40.1	327	100
Age (years)						
14-16	101	60.8	65	39.2	166	50.8
17-19	95	59.0	66	41.0	161	49.2
Type of school						
Public	135	62.8	80	37.2	215	65.7
Private	61	54.5	51	45.5	112	34.2
Mother's education (years)						
Illiterate	5	45.5	6	54.5	11	3.4
≤8	74	63.8	42	36.2	116	35.5
9-12	79	61.2	50	38.8	129	39.4
≥13	38	53.5	33	46.5	71	21.7
Monthly family income (BMMW)						
<2	144	62.1	88	37.9	232	70.9
≥2	52	54.7	43	45.3	95	29.1
BMI (Weight/height^2)						
Eutrophy	166	60.8	107	39.2	273	83.5
Overweight	30	55.5	24	44.5	54	16.5
WC						
<percentile 90	189	61.6	118	38.4	307	93.9
≥percentile 90	7	35.0	13	65.0	20	6.1
WC/Height						
<0.50	32	62.7	19	37.3	51	15.6
≥0.50	164	59.4	112	40.6	276	84.4
Castelli Index I						
<4.4	65	61.3	41	38.7	106	32.5
≥4.4	131	59.5	89	40.5	220	67.5
Castelli Index II						
<2.9	70	62.5	42	37.5	112	34.3
≥2.9	126	58.6	89	41.4	215	65.7
AIP (mg/dL)						
<2	56	56.6	43	43.4	99	31.6
≥2	132	61.7	82	38.3	214	68.4
	Median	*p*25-*p*75	Median	*p*25-*p*75		
TCV (Kcal/day)	1,832.5	1,609.5-2,124.0	2,232	1,942.0-2527.0*	1,988	1,705-2,326
UPF (Kcal/day)	491.0	334.9-653.4	434.3	227.9-626.0	479.9	322.7-639.6
UPF (% do TCV)	26.6	18.2-33.7	20.5	13.9-28.4*	23.9	15.8-31.9

Note: *Mann-Whitney's test $p<0,05$. AIP (Atherogenic Index of Plasma)=TG/HDL-c; BMI: Body Mass Index; BMMW: Brazilian Monthly Minimum Wage; Castelli Index I=TC/HDL-c; Castelli Index II=LDL-c/HDL-c; Eutrophy: >Score-Z -2 and <Score-Z +1; Overweight: >Score-z +1; CV: Total Caloric Value; UPF: Ultra-Processed Foods; WC: Waist Circumference.

DISCUSSION

This is the first study to investigate the influence of the consumption of ultra-processed foods on anthropometric and atherogenic indices in adolescents. For that, we considered the level of food processing according to the NOVA classification. The Brazilian Family Budget Survey carried out in 2017-2018 classifies the northeastern region of Brazil as the second region with the lowest consumption of ultra-processed

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Table 2 – Anthropometric variables according to different atherogenicity indexes in adolescents.

Anthropometric variables	Atherogenicity indexes											
	Castelli Index I				Castelli Index II				AIP			
	Normal		Elevated		Normal		Elevated		Normal		Elevated	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Weight (kg)	57.7	11.3	60.7	13.5*	57.6	11.4	60.8	13.3*	57.8	11.7	60.9	13.2*
WC (cm)	71.9	10.2	75.3	10.7	71.7	10.1	75.4	10.7*	71.5	10.6	75.9	9.9*
WC/Height (cm/cm)	0.4	0.0	0.4	0.1*	0.4	0.0	0.5	0.06*	0.4	0.0	0.5	0.1*
BMI (Z-score)	-0.10	0.07	0.15	0.11	-0.13	0.07	0.18	0.11*	-0.10	0.07	0.19	0.11*

Note: AIP (Atherogenic Index of Plasma) TG/HDL-c: <2.0; BMI: Body Mass Index; Castelli Index I (TC/HDL-c): <4.4; Castelli Index II (LDL-c/HDL-c): <2.9; SD: Standard Deviation; Student's *t* test *$p<0.05$; WC: Waist Circumference.

Table 3 – Absolute and relative frequencies of exposed and unexposed of anthropometric variables and cardiovascular risk among terciles of consumption of ultra-processed foods.

Variables	Ultra-Processed Food Consumption (% TCV)					
	Tercile 1		Tercile 2		Tercile 3	
	Median	*p25-p75*	Median	*p25-p75*	Median	*p25-p75*
UPF	13.3	10.1-15.8	23.9	22.0-26.3	35.6	31.9-42.0
Variables	n	%	n	%	n	%
WC						
<percentile 90	102	93.6	99	90.8	106	97.2
≥percentile 90	7	6.4	10	9.2	3	2.8
WC/Height						
<0.50	19	17.4	18	16.5	14	12.8
≥0.50	90	82.6	91	83.5	95	87.2
BMI						
Eutrophy	89	81.6	90	82.6	94	86.2
Overweight	20	18.4	19	17.4	15	13.8
Castelli Index I						
<4.4	39	35.8	36	33.0	31	28.7
≥4.4	70	64.2	73	67.0	77	71.3
Castelli Index II						
<2.9	44	40.4	35	32.1	33	30.3
≥2.9	65	59.6	74	67.9	76	69.7
AIP						
<2	33	32.0	36	34.3	30	28.6
≥2	70	68.0	69	65.7	75	71.4

Note: AIP: Atherogenic Index of Plasma; BMI: Body Mass Index; Castelli Index I: CT/HDL; Castelli II Index: LDL/HDL; TCV: Total Caloric Value; UPF: Ultra-Processed Foods; WC: Waist Circumference.

foods in the country [26]. In Brazilian households, 18.4% of the total calorie consumption comes from these foods. In the northeast region of the country, ultra-processed foods account for 14.4% of the total caloric value. Moreover, in the northern and northeastern regions, the share of fresh or minimally processed foods and culinary ingredients is well above the average of the country.

The lower consumption of ultra-processed foods in the northeastern region may reflect the lower prevalence of overweight in adolescents (16.5%) in the present study. Similarly, the study by Carneiro *et al*. [27] found prevalence of overweight in 14.4% of adolescents in the city of *Goiânia*, in midwestern Brazil. On the other hand, the National Study of Cardiovascular Risk in Adolescents (ERICA), which presents a multicentric approach, found a national prevalence of overweight of 25.5% [28]. Ultra-processed foods increase overweight markers because these foods are low in dietary fibers, have low satiety power, and high caloric density [29].

Table 4 – Unadjusted and adjusted coefficients of the association between ultra-processed food intake, anthropometric, and atherogenicity indices.

Unadjusted Analysis						
Ultra-Processed Food Consumption (% of TCV)						
Variables	Tercile 1		Tercile 2		Tercile 3	
UPF	Median	p25-p75	Median	p25-p75	Median	p25-p75
	13.3	10.1-15.8	23.9	22.0-26.3	35.6	31.9-42.0
			OR	95%CI	OR	95%CI
WC	1 Reference		1.47	0.53-4.01	0.41	0.10-1.63
WC/ Height	1 Reference		1.09	0.54-2.22	1.40	0.66-2.97
BMI	1 Reference		1.05	0.53-2.10	1.38	0.66-2.86
Castelli Index I	1 Reference		1.07	0.61-1.86	1.41	0.79-2.5
Castelli Index II	1 Reference		1.35	0.78-2.35	1.58	0.90-2.78
AIP	1 Reference		0.85	0.48-1.52	1.20	0.66-2.18
Adjusted Analysis						
Ultra-Processed Food Consumption (% of TCV)						
	Tercile 1		Tercile 2		Tercile 3	
	Median	*p*25-*p*75	Median	*p*25-*p*75	Median	*p*25-*p*75
UPF	13.3	10.1-15.8	23.9	22.0-26.3	35.6	31.9-42.0
Variables			OR	95%CI	OR	95%CI
WC	1 Reference		1.73	0.62-4.84	0.47	0.11-1.96
WC/ Height	1 Reference		1.08	0.52-2.23	1.68	0.77-3.66
BMI	1 Reference		0.93	0.46-1.90	0.67	0.31-1.45
Castelli Index I	1 Reference		1.31	0.72-2.37	1.87	0.99-3.51
Castelli Index II	1 Reference		1.75	0.96-3.18	2.29	1.23-4.28
AIP	1 Reference		0.89	0.49-1.61	1.25	0.67-2.35

Note: Adjustment variables: sex. age. income and school type; AIP: Atherogenic Index of Plasma; BMI: Body Mass Index; Castelli I Index: CT/HDL; Castelli II Index: LDL/HDL; CI: Confidence Interval 95%; OR: Odds Ratio 95%; TCV: Total Caloric Value; WC: Waist Circumference.

In Brazil, a study with a representative sample of adolescents and adults showed a positive association between the consumption of ultra-processed foods and drinks and obesity [30]. Enes, Camargo, and Justino [29] carried out a study in *Campinas*, in the state of *São Paulo*, Brazil, and found a high prevalence of overweight (64.5%) in adolescents, as well as a greater contribution of ultra-processed foods in their total caloric consumption (50.6%). In addition, the low percentage of overweight (16.5%) in adolescents in the present study can be explained by the type of school. The majority of adolescents were from public schools and had low income, which can influence the lower consumption of ultra-processed foods. Overweight also correlates with other environmental and lifestyle factors that were not investigated in this research, such as the practice of physical activity and its intensity.

A high prevalence of inadequacy in the WC/height ratio was found. According to Barroso *et al*. [31], a high WC/height ratio correlates with lipid changes. This is because the accumulation of adipose tissue is responsible for the release of free fatty acids, which in turn increase the production of triacylglycerols and Very Low Density Lipoprotein (VLDL) [32]. This evidence is confirmed by the high percentage of inadequacy in the plasma atherogenic index (TG/HDL-c) in these adolescents. Sapunar *et al*. [33] evaluated the risk of atherogenesis based on this index (PAI) in a sample of schoolchildren. The authors showed that 54.3% of the students had a high atherogenic risk according to PAI. This finding corroborates the present study, in which the risk for atherogenesis was 68.4%.

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Furthermore, the averages of anthropometric measures or indices (weight, WC, WC/height, and BMI) were significantly higher when the adolescents were in altered categories for the Castelli I and II and PAI indexes. This association shows the great influence of nutritional status on metabolic parameters.

High Castelli I and II indices indicate a higher cardiovascular risk since these indices often correlate with hypertriglyceridemia, hypertension, glucose intolerance, and insulin resistance [34]. In the present study, only the Castelli II index correlated significantly with the highest tercile of consumption of ultra-processed foods (median of 35.6% UPF); the odds ratio of presenting this altered index was 2.29 times higher for those adolescents in the highest tercile of consumption of UPF. Lima *et al*. [6] and Rauber *et al*. [35] showed that ultra-processed foods correlate with a negative metabolic profile, including changes in LDL-c and HDL-c and in total cholesterol levels in adolescents and preschoolers, respectively. As these lipid parameters are used in the composition of the Castelli II index, such evidence is confirmed in this study.

A systematic review investigated the relationship between dietary patterns and cardiometabolic risk factors in children and adolescents [36]. The review showed that unhealthy eating patterns characterized by the consumption of ultra-processed foods correlate positively with cardiometabolic changes. These results point to the negative health consequences caused by the consumption of these foods since the typical dietary pattern of adolescents includes excessive consumption of soft drinks, foods rich in simple carbohydrates, fast food, reduced consumption of fruits and vegetables, adoption of monotonous diets, and the absence of some meals [37].

Moreover, ultra-processed foods are products rich in nutrients such as saturated and trans fats, which are closely related to lipid concentrations and correlate with a proatherogenic lipid profile. Saturated fats increase LDL-c and trans-fat levels. In addition to increasing this lipid fraction, these fats reduce HDL-c concentrations, which may explain the positive association between the Castelli II index and the highest tercile of ultra-processed food consumption among adolescents [38].

Thus, the results presented in this research highlight the importance of food and nutritional education actions based on dietary guidelines. In this context, emphasis should be given to the adoption of dietary standards based on fresh or minimally processed foods, which are necessary to reduce and prevent chronic non communicable diseases such as cardiovascular disease.

Some limitations of this study include its cross-sectional design, which restricts the findings to the level of associations. Therefore, a broader analysis of risk factors in adolescents and the practice of physical activity is necessary. This is a very important factor both for nutritional status and for metabolic changes, which can be assessed using atherogenicity indices. The recording of food consumption was another limitation. The study considered a 24-hour recall, and the information depended substantially on the memory of the adolescents, which could underestimate the food intake, food ingredients added to meals, brands, and quantities of servings of ultra-processed foods. However, to alleviate these concerns, two dietary recalls were performed at two-month intervals, with adjustments for intrapersonal variability. Different food consumption tables were also used to make the analysis program more comprehensive.

CONCLUSION

Adolescents showed changes in atherogenic indices and anthropometric parameters were higher in those adolescents with such altered indices. The importance of healthy eating habits is emphasized, since ultra-processed foods have a negative influence on the health of individuals, besides being associated with high atherogenic indices, which, in turn, may increase cardiovascular risk. Therefore, actions that encourage adolescents to seek strategies to improve food choices and thus reduce consumption of ultra-processed foods are needed.

CONTRIBUTORS

LM NASCIMENTO contributed to data collection, statistical analysis and interpretation of data, and review. CRLS IBIAPINA contributed to data interpretation and review. NVN MONTEIRO contributed to data interpretation and review. TM VILAR contributed to data interpretation and review. KMG FROTA contributed to the conception and design, analysis, interpretation of data, review, and approval of the final version of the article.

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