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Relationship between ultra-processed foods and metabolic syndrome in adolescents from a Brazilian Family Doctor Program

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Abstract

Objective: To estimate the association between food intake and metabolic syndrome (MetS).

Design: Cross-sectional design conducted from July 2006 to December 2007.

Setting: Adolescents assisted by the Family Doctor Program (FDP) in Niterói, a metropolitan area in Rio de Janeiro State, Brazil.

Subjects: Survey of 210 adolescents. Individuals with three or more of the following components of MetS were classified as having this syndrome: TAG ≥ 110 mg/dl; HDL cholesterol < 50 mg/dl for girls aged 12–19 years and boys aged 12–14 years or <45 mg/dl for boys aged 15–19 years; waist circumference ≥75th percentile; serum glucose >100 mg/dl; and blood pressure ≥90th percentile. A semi-quantitative FFQ was used, and foods were grouped as: unprocessed or minimally processed foods (Group 1), processed culinary and food industry ingredients (Group 2) and ultra-processed foods (Group 3). The associations between food consumption and MetS were adjusted for sociodemographic, behavioural and family history covariates and were estimated using generalized estimation equations with the Poisson regression model.

Results: MetS was diagnosed in 6·7 % of the adolescents; the most frequent diagnostic criteria included the reduction of HDL cholesterol (46·7 %), elevated serum glucose (17·1 %) and the elevation of waist circumference (16·7 %). Crude analysis showed higher average daily intakes of energy, carbohydrates and ultra-processed foods among adolescents with MetS. After statistical adjustment, the intake of ultra-processed foods (≥3rd quartile) remained associated with MetS (prevalence ratio = 2·5; $P = 0·012$).

Conclusions: High consumption of ultra-processed foods was associated with the prevalence of MetS in this adolescents group.

Keywords
Metabolic syndrome
Adolescent
Food intake
Ultra-processed foods

Metabolic syndrome (MetS) is defined as the association of obesity, arterial hypertension, alterations in glucose metabolism, and low HDL cholesterol (HDL-C) and high TAG levels[1]. The cardiovascular risk related to MetS appears to persist from childhood to young adulthood[2]. The prevalence of MetS varies during childhood and adolescence[3,4]. Regardless of the classification criteria, studies corroborate the increased prevalence of MetS among overweight and obese adolescents[5–8].

The prevalence of overweight and obesity is increasing in Brazilian adolescents[9], as is the regular consumption of unhealthy diet markers and high-energy products, such as candies/sweets and soft drinks[10–12]. Diets including large amounts of ultra-processed foods, such as cakes, pastries, soft drinks, burgers and chips, are nutritionally unbalanced and unhealthy[13,14].

No studies have examined the association between dietary intake and MetS in Brazilian adolescents. Therefore, the present study aimed to estimate the association between characteristics of food consumption and MetS in adolescents assisted by the Family Doctor Program (FDP) in a medium-sized city – Niterói, a metropolitan area of Rio de Janeiro State, in Brazil.

Methods

Study population

The study was cross-sectional, based on data from the CAMELIA (cardio-metabolic-renal) project conducted between 2006 and 2007, and included adults with hypertension and/or diabetes mellitus and controls

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(non-hypertensive and non-diabetic), and their living biological children aged 12–30 years, assisted by the FDP in Niterói, Rio de Janeiro State, Brazil. Eligible participants in the present analysis were children aged 12–19 years, coming from 185 families. There were 247 adolescents in the study sample, but we included in the analysis only those with food consumption and MetS data (n 210).

Study variables

Information on age, skin colour, educational level, household income per capita, smoking, physical activity and time spent watching television and videos was collected by a structured questionnaire. Physical activity was assessed as activities performed in the last 15 d – type, number of times per week and time spent[15].

Weight, height and waist circumference (WC) measurements followed the Lohman approach[16]. BMI was used to classified adolescents as underweight, normal weight, overweight or obese[17]. WC above the 75th percentile for age was considered inadequate[18].

Hypertension was defined as systolic and/or diastolic blood pressure above the 90th percentile for age, gender and height[19]. Serum glucose, HDL-C and TAG were assessed after a 12 h fast.

Food consumption

Diet was assessed by a semi-quantitative FFQ, designed and validated for adolescents in Rio de Janeiro, containing ninety food items and seventeen questions about eating habits[20,21]. These data were transformed into daily frequencies[22] and multiplied by the weight of the household measurement used in the FFQ to convert the values to grams or millilitres. We used the US official food composition table[23] to estimate daily energy intake (1 kcal = 4·184 kJ), carbohydrates (g), protein (g), lipids (g) and fibre (g).

Foods (measured in grams or millilitres) were classified into three groups according to the extent and purpose of the industrial processing applied to them, as proposed by Monteiro[13]: unprocessed/minimally processed foods (Group 1); processed culinary ingredients (Group 2); or ultra-processed ready-to-eat or ready-to-heat food products (Group 3).

Metabolic syndrome assessment

MetS classification was based on the definition proposed by De Ferranti *et al.*[24], adapting the cut-off of hyperglycaemia[25]. Adolescents were classified as having MetS when three or more of the following components were altered: (i) serum glucose ≥ 100 mg/dl; (ii) systolic blood pressure (SBP) and/or diastolic blood pressure (DBP; mmHg) >90th percentile; (iii) HDL-C < 50 mg/dl for girls (12–19 years) and boys (12–14 years) or <45 mg/dl for boys (15–19 years); (iv) TAG ≥ 100 mg/dl; and (v) WC (cm) ≥ 75th percentile.

The presence of components of Mets in parents was classified according to the definition proposed by the National Cholesterol Education Program's Adult Treatment Panel III[26].

Statistical analysis

Descriptive data were expressed as mean and standard deviation for continuous variables or as number and percentage for categorical ones. Student's t test and the Mann–Whitney test were used for continuous variables. Correlation was performed by Spearman and Pearson coefficients. For categorical variables, we used the χ^2 test. One-way ANOVA was used for comparisons of food intake by the number of MetS components present (0, 1–2, ≥3), with a *post hoc* Scheffé test.

Considering the possibility of familial aggregation for MetS (25 % of the sample is composed of teens and their siblings), we used the model of generalized estimating equations (GEE) which produces efficient estimates for regression parameters with correlated data[27]. We estimate crude and adjusted associations between dietary intake and MetS. We included sociodemographic, behavioural and family history covariates as possible confounders. Data for energy, macronutrients, fibre and the food groups were categorized according to quartile of daily intake. High consumption (≥3rd quartile) and lower consumption (≤3rd quartile) were compared to verify association with MetS. Prevalence ratios (PR) were estimated by Poisson regression, and the variables statistically significant ($P < 0{\cdot}10$) were included in individually adjusted models. The final model included variables significant ($P < 0{\cdot}05$) in previous models. The SPSS for Windows statistical software package version 17·0 (SPSS Inc., Chicago, IL, USA) was used for analysis.

Results

The characteristics of the participants, globally and according to MetS status, are shown in Table 1.

Regarding nutritional status, 66·2 % were normal weight and 31·4 % were overweight. The most common metabolic disturbances were: reduction of HDL-C (46·7 %), elevation of plasma glucose (17·1 %), increased WC (16·7 %), abnormal blood pressure (14·3 %) and increased TAG (11·4 %). We found no significant differences in the prevalence of MetS between boys and girls.

MetS was diagnosed in 6·7 % of the study participants. Only 1·4 % of normal-weight adolescents had MetS, compared with 18·2 % of overweight adolescents. Those with MetS had significantly higher values for mean BMI, WC, SBP, TAG, HDL-C and serum glucose ($P < 0{\cdot}001$).

Adolescents with MetS had higher average total daily energy and macronutrient intakes, with a significant difference in mean daily consumption of energy and carbohydrates ($P < 0{\cdot}05$), compared with adolescents without the syndrome. Regarding food groups, the intake of ultra-processed foods (Group 3) was higher among

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Table 1 Sociodemographic, behavioural, anthropometric and biochemical characteristics of adolescents assisted by FDP, Niterói, Rio de Janeiro State, Brazil, 2006–2007

	Total				Without MetS (*n* 196)				MetS (*n* 14)				
Variable	*n*	%	Mean	SD	*n*	%	Mean	SD	*n*	%	Mean	SD	*P* value*
Sex													
Female	110	52·4			105	53·6			5	35·7			0·310
Male	100	47·6			91	46·4			9	64·3			
Age (years)			15·0	2·1			15·0	2·1			14·6	2·1	0·512
Skin colour†													
White	51	24·6			47	24·4			4	28·6			0·750
Brown or black	156	75·4			146	75·6			10	71·4			
Income per capita (Brazilian Real)‡			234·9	156·4			236·9	159·1			207·1	110·9	0·801
Physically active													
Yes	51	24·3			47	24·0			4	28·6			0·748
No	159	75·7			149	76·0			10	71·4			
Sedentary activities§													
<2 h/d	28	14·1			26	14·0			2	16·7			0·680
≥2 h/d	170	85·9			160	86·0			10	83·3			
Smoking‖													
No	202	97·1			190	97·9			12	85·7			0·054
Yes	6	2·9			4	2·1			2	14·3			
BMI (kg/m^2)			21·9	4·5			24·5	4·2			27·4	5·2	0·000
Underweight	5	2·4			5	2·6			0	0			0·000
Normal weight	139	66·2			137	69·9			2	14·3			
Overweight	36	17·1			33	16·8			3	21·4			
Obese	30	14·3			21	10·7			9	64·3			
WC (cm)			71·4	9·5			70·4	8·5			85·5	12·3	0·000
Adequate	175	83·3			172	87·8			3	21·4			0·000
Inadequate	35	16·7			24	12·2			11	78·6			
SBP (mmHg)			110·7	11·9			110·0	11·4			120·4	14·8	0·007
DBP (mmHg)			65·5	9·3			65·3	9·1			68·0	11·0	0·301
Blood pressure													
Adequate	180	85·7			173	88·3			7	50·0			0·000
Inadequate	30	14·3			23	11·7			7	50·0			
Glucose (mg/dl)			91·6	9·7			91·0	9·5			100·0	8·5	0·001
Adequate	174	82·9			167	85·2			7	50·0			0·003
Inadequate	36	17·1			29	14·8			7	50·0			
TAG (mg/dl)			64·2	32·4			61·2	28·3			106·0	52·9	0·000
Adequate	186	88·6			179	91·3			7	50·0			0·000
Inadequate	24	11·4			17	8·7			7	50·0			
HDL-C (mg/dl)			50·5	10·2			51·1	10·2			42·0	4·3	0·000
Adequate	112	53·3			111	56·6			1	7·1			0·000
Inadequate	98	46·7			85	43·4			13	92·9			

FDP, Family Doctor Program; MetS, metabolic syndrome; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; HDL-C, HDL cholesterol.
*Mann–Whitney test or χ^2 test.
†*n* 207.
‡*n* 203.
§*n* 198.
‖*n* 208.

those with MetS (1331 g/d) compared with those who had no component (930 g/d, $P = 0{\cdot}035$) or one/two components (889 g/d, $P = 0{\cdot}012$). There were no differences in average consumption of Group 1 and Group 2 foods between adolescents with and without MetS (Table 2).

We observed a significant association between MetS and the consumption of ultra-processed foods (crude PR = 3·04; $P < 0{\cdot}05$) and smoking (crude PR = 5·61; $P < 0{\cdot}05$). The following variables had $P \geq 0{\cdot}05$ and $< 0{\cdot}10$: a high intake of carbohydrates (crude PR = 2·28), high energy consumption (crude PR = 2·28) and a family history of hypertriacylglycerolaemia (crude PR = 6·00).

No association was found between the presence of MetS and sociodemographic and behavioural variables, except smoking; likewise, no association was found between MetS and intakes of protein, lipids, fibre, foods from Group 1 and foods from Group 2 ($P > 0{\cdot}10$).

The associations between dietary variables and MetS were estimated by adjusted models and included variables that had $P < 0{\cdot}10$ in the crude analysis (Table 3). In the first model the association between MetS and dietary variables (carbohydrates, energy and ultra-processed food) was adjusted for smoking status (model 1), in the second model by family history of hypertriacylglycerolaemia (model 2), in the third model by energy consumption (model 3) and in the final model they were adjusted by the former variables simultaneously (model 4).

The consumption of carbohydrates showed a significant association only in model 2. Energy intake remained significant in both models 1 and 2. Ultra-processed foods

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Table 2 Mean daily intakes of energy, macronutrients, fibre and food groups according to the number of MetS components in adolescents assisted by FDP, Niterói, Rio de Janeiro State, Brazil, 2006–2007

	Number of components of MetS			
Energy, nutrients and food groups	0 (*n* 66)	1–2 (*n* 130)	≥3 (*n* 14)	*P* value*
Energy (kJ)	11 753	11 113[a]	14 205[a]	0·038
Carbohydrates (g)	418	400[b]	521[b]	0·032
Protein (g)	91	85	103	0·075
Lipid (g)	90	84	106	0·063
Fibre (g)	21	20	23	0·346
Group 1 (g)	1283	1209	1499	0·147
Group 2 (g)	67	64	76	0·543
Group 3 (g)	930[c]	889[d]	1331[c,d]	0·012

MetS, metabolic syndrome; FDP, Family Doctor Program.
Group 1: unprocessed or minimally processed foods.
Group 2: processed culinary and food industry ingredients.
Group 3: ultra-processed food products.
[a,b,c]$P \leq 0{\cdot}05$; [d]$P < 0{\cdot}01$.
*One-way ANOVA test for means, with Scheffé *post hoc* test.

Table 3 Prevalence ratio (PR) for the association between food consumption and MetS, adjusted for sociodemographic and behavioural variables in adolescents assisted by FDP, Niterói, Rio de Janeiro State, Brazil, 2006–2007

	Food consumption*					
	Energy		Carbohydrates		Ultra-processed foods	
	PR	*P* value†	PR	*P* value†	PR	*P* value†
Crude	2·279	0·077	2·279	0·077	3·038	0·016
Model 1‡	2·498	0·049	2·498	0·143	3·337	0·006
Model 2§	2·780	0·037	2·625	0·037	3·350	0·012
Model 3‖	–	–	1·541	0·315	2·612	0·031
Model 4¶	–	–	1·760	0·193	2·486	0·012

*High consumption (≥3rd quartile).
†Generalized estimation equations.
‡Adjusted for smoking.
§Adjusted for family hypertriacylglycerolaemia.
‖Adjusted for energy intake.
¶Adjusted for smoking, family hypertriacylglycerolaemia and energy intake.

showed a significant association in all models. Prevalence of MetS was higher among adolescents with a high consumption of ultra-processed foods (≥3rd quartile). The daily consumption of more than 1245 g of ultra-processed foods was associated with the presence of MetS (PR = 2·486, $P = 0{\cdot}012$).

Discussion

Despite different classification criteria for MetS, the prevalence of the syndrome and its isolated components is high among adolescents. The most prominent components of metabolic syndrome in our study were overweight and low HDL-C. This profile is also found in national and international studies[3,4,28].

The contribution of ultra-processed foods to the total energy purchased by Brazilian families increased by more than 200 % between 1974 and 2003[13,14], and there is evidence of a high consumption among Brazilian adolescents[10–12]. Diets that include a large amount of ultra-processed foods tend to be nutritionally unbalanced and are harmful to one's health. Ultra-processed foods, created to be sold ready- or semi ready-to-eat, are distributed worldwide and have increased in production and consumption in recent decades[13,14].

International research[29,30] corroborates our finding that those with MetS have higher intakes of carbohydrates and ultra-processed foods. The intake of foods rich in simple carbohydrates is responsible for the increase in MetS components. In adolescents, a dietary pattern characterized by consumption of flour, pizza, hamburgers, snacks and sweets was associated with a higher prevalence of abdominal obesity, changes in plasma TAG and glucose[31]. The consumption of sugary drinks is higher in individuals with one or more components of MetS than in those without any risk factor[32]. According to a classification based on the extent and purpose of food processing, all of these food sources of simple carbohydrates are part of the ultra-processed foods group. In addition to simple carbohydrates, ultra-processed foods also have high concentrations of lipids[13].

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Strengths and limitations

To our knowledge, the present study is the first of the relationship between food intake and MetS in Brazilian adolescents. It is also the first to use the classification of foods according to the extent and purpose of the industrial processing applied to them in order to evaluate adolescents' food intake.

Since the study participants were not a representative sample, the prevalence of MetS found in our study cannot be extrapolated to all Brazilian adolescents. However, we believe that the findings of the association between food consumption and MetS are valid.

Another limitation was the use of a cross-sectional design, which generally does not suggest causal relationships. A further point is the possibility of measurement bias: the FFQ may have been less accurate as adolescents sometimes have difficulty in estimating portion sizes and servings of food intake[33]. It is also possible that participants with a greater number of MetS risk factors may have underestimated their food consumption because this practice has been observed in people with excess weight[34,35], and it may cause the association of MetS and diet to be underestimated.

Being overweight or having a family history of CVD is associated with a higher prevalence of MetS in adolescence; therefore, we expected a high prevalence of MetS in our study population. The associations would be even greater in a population with a similar socio-economic profile but with a lower prevalence of chronic diseases.

In the present study, the criteria for MetS used lower cut-off points, with more sensitivity and less specificity[24]. This is adequate as a screening programme, but we could have included false-positive MetS in our analysis.

Conclusions

Our results suggest an association of MetS with some aspects of the food intake of Brazilian adolescents assisted by an FDP in a medium-sized urban city in Brazil. A balanced diet, emphasizing the intake of minimally processed foods and a low consumption of ultra-processed foods, should be encouraged and incorporated into the habits of teenagers. These recommendations should be incorporated into the protocol of the FDP in this city and can be extended to similar populations.

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