Association of dietary patterns and body phenotypes in Brazilian adolescents

Ana Elisa Madalena Rinaldi [1]
https://orcid.org/0000-0003-0154-554X

Carla Cristina Enes [3]
https://orcid.org/0000-0002-4634-4402

Wolney Lisboa Conde [2]
https://orcid.org/0000-0003- 0493-134X

[1] Postgraduate Program in Health Sciences. School of Medicine. Federal University of Uberlândia. Uberlândia, MG, Brazil.
[2] Postgraduate Program in Nutrition in Public Health. School of Public Health. University of Sao Paulo. São Paulo, SP, Brazil.
[3] Postgraduate Program in Health Sciences. School of Life Sciences. Pontifical Catholic University of Campinas. Campinas, SP, Brazil. John Boyd Avenue (no number). Campinas, SP, Brazil. Zip Code 13.060-904. E-mail: cacenes@gmail.com

Abstract

Objectives: to investigate the association between dietary patterns, physical activity, and body phenotypes in adolescents.

Methods: this school-based cross-sectional study involved 1,022 adolescents aged ten to 19 years. Dietary patterns and body phenotypes were defined using a principal component analysis. Body phenotype was defined using anthropometry, body composition, biochemistry, sexual maturation, and dietary patterns from 19 food groups, using a food frequency questionnaire. The association between the dietary patterns and body phenotypes was assessed using a linear regression model.

Results: five body phenotypes ($BP1_{adiposity}$, $BP2_{puberty}$, $BP3_{biochemical}$, $BP4_{muscular}$, $BP5_{lipids\_biochemical}$) *and five dietary patterns* ($DP1_{ultraprocessed\_foods}$, $DP2_{fresh\_foods}$, $DP3_{bread\_rice\_beans}$, $DP4_{culinary\_preparations}$, $DP5_{cakes\_rice\_beans}$) *were identified. There were higher* $BP_{\_adiposity}$ *scores for obese adolescents, but energy expenditure was similar for obese and non-obese adolescents. Physical activity was positively associated with BMI,* $BP_{\_adiposity}$, *and* $BP_{\_puberty}$. *We observed a negative association between* $DP_{\_ultraprocessed\_foods}$ *and BMI, and a positive association between* $DP_{\_fresh\_food.\ DP\_fresh\_foods}$ *was positively associated with* $BP_{\_adiposity}$; $DP_{\_ultraprocessed\_foods}$ *and* $DP_{\_culinary\_preparations}$ *were negatively associated with this phenotype.* $BP_{\_biochemical}$ *was negatively associated with* $DP_{\_fresh\_foods}$.

Conclusion: we identified a negative association between a dietary pattern composed mainly of ultra-processed foods, fresh foods, and $BP_{\_adiposity}$. *These associations need to be better explored, especially in adolescents, as both dietary patterns and phenotypes were defined using multivariate analysis.*

Key words *Body phenotype, Dietary pattern, Adolescent, Obesity*

http://dx.doi.org/10.1590/1806-9304202400000416-en

Introduction

Healthy eating practices during adolescence can have profound effects on the immediate and long-term health of adolescents and may limit harmful behaviors contributing to the epidemic of non-communicable diseases (NCDs) in adulthood.[1,2] In 2016, considering that nutrition is a central health, economic, and sustainable development challenge, the United Nations implemented the Decade of Action on Nutrition (2016-2025), which aimed to mobilize all governments to accelerate actions to eradicate all forms of malnutrition (undernourishment, micronutrient deficiencies, and overweigh/ obesity).[3]

Current dietary practices of adolescents have been characterized by increased intake of foods with high total and saturated fats, sugars, and salt, and low intake of fruits and vegetables.[4] Thus, the adoption of inappropriate dietary practices seems to be a determinant of health and nutritional status. In Brazil, as in many countries worldwide, youth obesity is growing concern in public health and nationally representative studies indicate obesity reaches approximately 8% of adolescents.[5,6] Physical inactivity, which also contributes to increased body weight, is also very prevalent among young people in Brazil, so that 84% of adolescents between 11 and 17 years old do not practice one hour of physical activity a day, as recommended by international organizations.[7]

The use of traditional analyses that investigate the isolated effect of food consumption,[8] physical activity, and body composition instead of a joint and dynamic assessment of behavioral profiles, dietary patterns (DPs), and the main influencers of adolescents in social and psychosocial contexts can impede a broader understanding of adolescent health.

Dietary pattern analysis has emerged as a practical way to deliver information to the public and to implement policies in contrast to investigations of dietary risk factors focused on food groups or nutrients.[9] In fact, this approach allows for the evaluation of dietary implications with different food groups and correlates with clinical conditions more completely than the analysis of isolated nutrients or specific food types.

The nutritional status of adolescents also has an important impact on their health and is usually assessed using isolated indicators (anthropometry, body composition, or biochemical markers) that are analyzed separately with social and psychosocial predictors, hindering a broader understanding of the health situation of adolescents.[10] These indicators are unable to address the complexity of body composition changes during puberty. An alternative to this limitation is the use of multivariate analysis for the definition of body phenotypes (BPs) that are the sum of the specificities that characterize an individual.[11]

The use of BPs in the assessment of nutritional status in adolescents is an innovative approach, demonstrated by the simultaneous analysis of anthropometric dimensions, body composition, and biochemical parameters in a multivariate model. Previous studies[12,13] have proposed and described BPs using anthropometric, sexual maturation, body composition, and biochemical variables in multivariate analyses.

In our study we applied these BPs as outcomes to understand their association with dietary patterns, physical activity, and sociodemographic characteristics. Therefore, the aim of our study was to investigate the association between DPs and physical activity, and BPs in adolescents.

Methods

We performed a cross-sectional study using data from a school-based study entitled "Determinants of the risk of obesity among adolescents from a survey of schoolchildren with a mixed sample: transversal and longitudinal" (IAP-SP). The IAP-SP corresponds to a third wave of surveys conducted with school adolescents in the city of Piracicaba, São Paulo state, Brazil. This is a probabilistic sample of schools, using two stratification criteria: geographic (central and peripheral districts) and school administration type (public and private). Subsequently, the sample was stratified by school grade and the clusters were analyzed in two stages. In the first stage, the primary sampling units were all the public and private schools; and in the second stage, the secondary sampling units were all the grades in each school. The study enrolled 1,022 adolescents aged ten to 19 years.

BPs was defined using anthropometric (weight, height, skinfolds, waist circumference), body composition (phase angle), biochemical (total cholesterol, triacylglycerol, glucose, and hemoglobin), sexual maturation (pubic hair, genitals, and breasts) variables, and age (years). The same variables have been used in previous studies.[12,13] Body mass index (BMI) was defined as ratio the weight (kilograms) of a person to the square of the height (meters). Based on BMI, we classified the nutritional status of adolescents according to age and sex (Z scores), considering the cut-off point: underweight (Z score < -2), eutrophic (Z score from -2 and $<+1$), overweight (Z score $\geq+1$ and $<+2$), and obese (Z score ≥ 2).

All anthropometric measurements were performed in duplicate by trained researchers using standard techniques, considering the mean between values. The phase angle was calculated as the arc tangent of the ratio of reactance to resistance. Resistance and reactance were measured with a bioimpedance analyzer (BIA) (model 0358T, RJL Systems, Clinton Township, USA). All procedures were performed according to recommendations in the manufacturer's manual. All variables were continuous.

The sexual maturation assessment was based on breast development and pubic hair growth in girls, and genital development and pubic hair growth in boys. All adolescents classified themselves into one of the five maturation stages, according to line drawings representing the five different Tanner stages. Adolescents aged ≥15 years did not complete the assessment of sexual maturation. Furthermore, when the girls were asked about their age at menarche, we understood that they had completed the sexual maturation process. Therefore, we classified all girls aged 15 years as Tanner stage 5. For boys, 16% were aged 16 years and older, and they were also considered to be at Tanner stage 5.

Blood samples were collected in the morning, after 12 hours of fasting. Triglycerides, glucose (fasting glycemia), hemoglobin, total cholesterol, and lipoprotein fractions values were determined in plasma. The total cholesterol / LDL cholesterol ratio was used.

The usual food intake assessment was performed by applying the validated Semi-Quantitative Food Frequency Questionnaire (SQFFQ) for adolescents.[14] This tool provides seven consumption choices for 58 food items over the past three months. Trained fieldworkers conducted face-to-face structured interviews and filled out questionnaires at the schools. We classified the 58 original food items into 19 groups based on the similarity of nutrient profiles or culinary usage among foods, and some individual food items were classified individually if their composition differed substantially from that of other foods; the resulting classification is as follows: fruits; vegetables; meat/poultry/fish/eggs; processed meat/sausage; snacks; fast foods; breads; fried tubers; dairy foods; fatty foods; sugary drinks; sugar/pastries; ice cream; cookies; bakery foods; cakes; side dishes; rice/beans; and potatoes/corn (Table 1).

Sociodemographic variables included age, sex, ethnicity, school administration (public or private), and socioeconomic status. The household asset score is applied as a proxy of wealth. Scores for each component were also calculated. A list of household assets and schooling of the household head was compiled using the Brazilian Economic Classification Criteria.[15] These variables were modelled using principal component analysis (PCA), and only the first component was selected to summarize the data, which was partitioned into tertiles. We also assessed the usual physical activity (during the last 12 months) using a validated questionnaire for adolescents.[16] The intensity of physical activity was expressed in metabolic equivalents (METs) using data on the type of physical activity, duration (hours), and weight (in kilograms). We classified METs according to the World Health Organization in three intensity categories, which were as follows: low intensity (1 to 1.9 METs), moderate intensity (3 to 5.9 METs), and vigorous intensity (more than 6 METs).[17] METs were also used as continuous variable in the logarithmic scale (log).

BPs were defined by PCA based on anthropometrics, body composition, biochemical variables, and sexual maturation. Components with an eigenvalue ≥ 1.0 were

Table 1

Description of food groups defined from semiquantitative food frequency questionnaire. Piracicaba, São Paulo, Brazil, 2012.

Food groups	Original foods
Fruits	Apple; mango/papaya; orange/tangerine; strawberry/pineapple; banana; fruit juices
Vegetables	Tomato; pumpkin/carrot; broccoli; lettuce; beet; chayote
Meat/poultry/fish/eggs	Fried meat, pork, chicken and fish; grilled meat, pork, chicken and fish; fried eggs/scrambled eggs/omelet
Processed meat/sausage	Sausages
Snacks	Snacks
Fast foods	Hot dog; burguer, sandwichs
Breads	White bread; loaf bread
Fried tubers	French fries/fried manioc
Dairy foods	Yoghurts; cheese; whole milk; creamy cheese
Fatty foods	Margarine; butter; olive oil/oil
Sugary drinks	Soft drinks; carbonated drinks; nectar juices
Sugar/pastries	Sugar; chocolate poder; goodies; jam/fruits in syrup
Ice-cream	Ice-cream; popsicle
Cookies	Filled cookies; non-filled cookies
Bakery foods	Baked, pizza,
Cakes	Cakes; cake mixes
Side dishes	Potate salad with mayonnaise; pasta with tomato sauce; pasta with tomato sauce and meat; risoto with chicken or fish
Rice/beans	Rice and beans (Brazilian dish)
Potatoes/corn	Boiled potatoes; boiled corn

retained and factor loadings > 0.2 were used to describe the phenotypes. The Kaiser-Meyer-Olkin (KMO) test was used to assess sampling adequacy in relation to the degree of correlation among variables. Further details on the construction of BPs have been presented elsewhere.[12,13]

Dietary patterns (DPs) were defined from 19 food groups using PCA. Components with eigenvalues higher than 1.0 were retained, and eigenvectors (factor loadings) higher than 0.2 were used to describe the DP. After that, the Kaiser-Meyer-Olkin (KMO) test was used to analyze the compliance of variables with the PCA. Each adolescent received a standardized score for each DP identified. The value of the score represents the proximity of the adolescent to each DP.

We performed a scatter plot to describe the relationship between energy expenditure according to MET and BP scores. The association between BPs and DPs, adjusted by sex, age, and socioeconomic status, was assessed using a linear regression model. The 95% confidence interval was considered to assess significance level of model. All analyses were carried out using Stata SE 13.0 software.

The study enrolled 1,022 adolescents aged ten to 19 years. The study was approved by the Ethics Committee of the University of São Paulo (protocol number 02546612.5.0000.5421).

Results

A total of 1,022 adolescents were included in this study. The main differences between adolescents from private and public schools are there ethnicity and wealth. The percentage of girls was higher than that of boys (55.9% vs. 44.1%), and most of the adolescents were under the age of 15 from public (65.2%) and private schools (66.1%). The percentage of adolescents classified as white was higher in private schools (83.3%), mixed race (28.9%) and black (17.6%) in the public ones. Most adolescents in public schools were classified in the lower tertiles of wealth (44.8%), and the private ones were the higher ones (80.4%). The percentage of excess weight (overweight and obese) and low physical activity (MET) was 37.9% (37.2% public *versus* 40.8% private) and 50.0% (53.9% public *versus* 54.85 private), respectively (data not shown in tables).

Five BPs were defined: $BP1_{adiposity}$, characterized by positive loadings for the skinfold, body mass, and waist circumference variables; $BP2_{puberty}$, characterized by positive loadings for stages of pubic hair and breasts in girls, or pubic hair and genitals in boys, height, and age; $BP3_{biochemical}$, characterized by positive loadings for triglycerides and glucose; $BP4_{muscule}$, characterized by positive loadings for phase angle and hemoglobin; and $BP5_{lipids\_biochemical}$ with negative loadings for phase angle and positive ones for triglycerides and the total cholesterol/LDL cholesterol ratio. The KMO value was high (0.8096) (Table 2).

The relationship between the intensity of physical activity (METs) and BP according to sex and obesity diagnosis is described in Figure 1. For all BPs, it was possible to define mainly two groups of adolescents – physically inactive (energy expenditure < 1.0) and physically active (energy expenditure ≥ 3.0). Higher scores of $BP_{\_adiposity}$ are presented for obese adolescents, but energy expenditure (log) was similar for both obese and non-obese adolescents.

Table 2

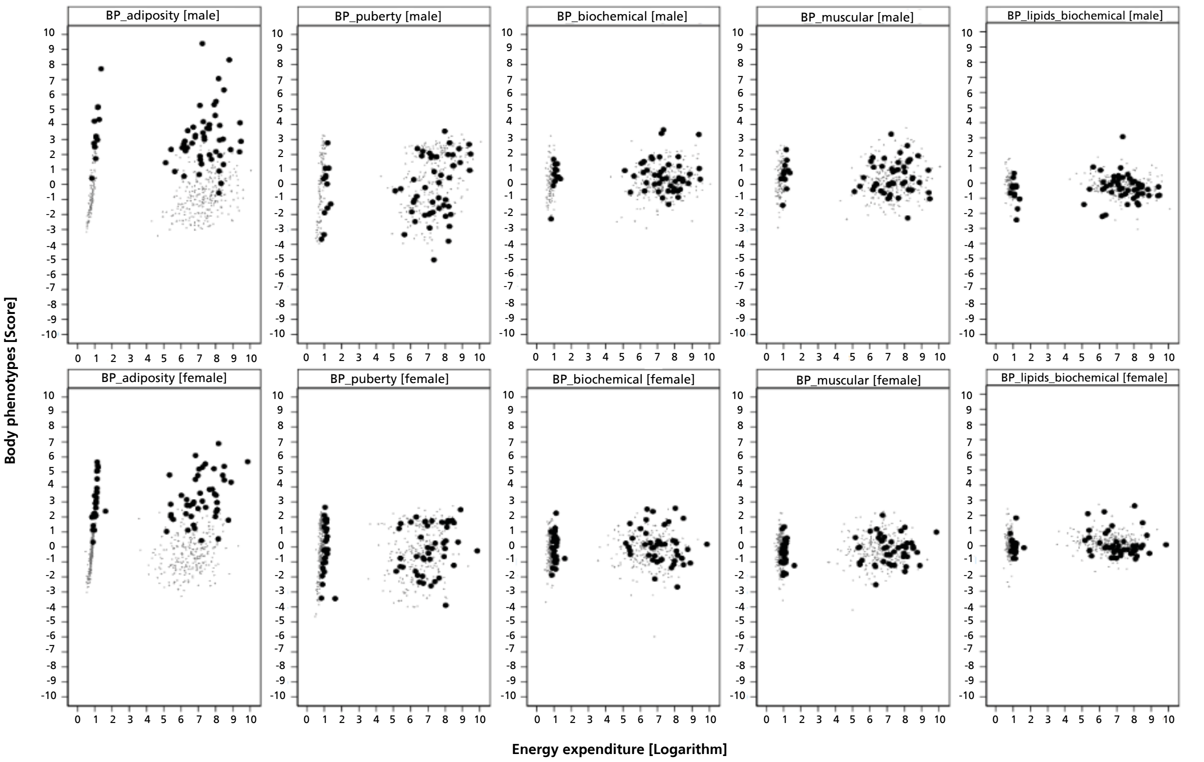
Body phenotypes defined from demographic, anthropometric, body composition and biochemical variables for adolescents. Piracicaba, São Paulo, Brazil, 2012.

Variables	Eigenvalues				
	BP_adiposity	**BP_puberty**	**BP_biochemical**	**BP_muscular**	**BP_lipids_biochemical**
Weight (kg)	0.4313				
Height (cm)		0.3840			
Triciptal skinfold (mm)	0.4897				
Subscapular skinfold (mm)	0.5165				
Waist circunference (cm)	0.5017				
Phase angle (°)				0.2538	-0.3623
Pubic hair (sexual maturation)		0.5099			
Gonads and breast (sexual maturation)		0.5126			
Hemoglobin (mg/dL)				0.9204	
Triglycerides (mg/dL)			0.2360		0.2932
Glucose (mg/dL)			0.9270		
Total cholesterol/LDL-chol					0.8664
Age (years)		0.5079			
KMO	**0.8096**				

BP= Body phenotypes; KMO= Kaiser-Meyer-Olkin test.

Figure 1

Characterization of energy expenditure and all five body phenotypes scores according to sex and obesity classification (bold dots). Piracicaba, São Paulo, Brazil, 2012.



Highlighed (black)= obese; BP=body phenotypes.

Five DPs were defined for food groups and each DP was named taking into account the foods that most contributed to the formation of each main component, since higher values indicate greater importance. The first DP (ultra-processed foods) was composed mainly of ultra-processed foods; the second (fresh foods) with fresh foods and culinary preparations; the third (bread_rice_beans) was made up mostly of rice and beans (a typical Brazilian dish) and bread with butter or margarine (typical foods for breakfast); the fourth (culinary_preparation) consisted of culinary preparations such as cakes, rice, beans and potatoes, and corn; and the fifth (cakes_rice_beans) included rice and beans, and cakes (Table 3).

Table 3

Description of dietary patterns of adolescents. Piracicaba, São Paulo, Brazil, 2012.

Food groups	Eigenvalues				
	DP_ultraprocessed	DP_fresh_foods	DP_bread_ rice_beans	DP_culinary_ preparation	DP_cake_rice_ beans
Fruits	0.2026	0.3858		-0.2922	
Vegetables		0.5671			
Meat/poultry/fish/eggs	0.2695			-0.3262	
Processed meat/sausage	0.2631			-0.3946	
Snacks		-0.3213			
Fast foods	0.2363	-0.2564			
Breads			0.4429		
Fried tubers	0.2249				
Dairy foods	0.2381			0.2745	-0.5600
Fatty foods	0.2176		0.3655		
Sugary drinks	0.2383			-0.4395	
Sugar/pastries	0.2016	-0.2837	0.2908		-0.4547
Ice-cream	0.2303		-0.2580		
Cookies	0.2419				
Bakery foods	0.2801		-0.2149		
Cakes				0.3711	0.2785
Side dishes	0.3443	0.2220			
Rice and beans			0.4314	0.2335	0.4669
Boiled potato and corn	0.2590	0.3157	-0.2532	0.3137	
KMO			**0.8579**		

DP= dietary patterns; KMO= Kaiser-Meyer-Olkin test.

We verified the association between sociodemographic variables, physical activity and DPs, and BMI and BP scores (Table 4). Physical activity was positive associated with BMI, $BP_{—adiposity}$, and $BP_{—puberty}$. Female sex was positively associated with $BP_{—adiposity}$ and $BP_{—lipids\_biochemical}$, while male sex was positively associated with $BP_{—puberty}$, $BP_{—lipids\_biochemical}$ and $BP_{—muscule}$. We observed a negative association between $DP_{—ultraprocessed}$ and BMI, and a positive one for $DP_{—fresh\_foods}$. Three DPs were associated with $BP_{—adiposity}$; $DP_{—fresh\_foods}$ was positively associated with $BP_{—adiposity}$; $DP_{—ultraprocessed}$ and $DP_{—culinary\_preparation}$ were negatively associated with $BP_{—adiposity}$; and $BP_{—biochemical}$ was negatively associated with $DP_{—fresh\_foods}$.

Table 4

Association of body mass index, body phenotypes scores and dietary patterns scores, physical activity and sociodemographic variables. Piracicaba, São Paulo, Brazil, 2012.

Variables	Outcomes (scores)					
	BMI (score)	BP_adiposity	BP_puberty	BP_biochemical	BP_muscular	BP_lipids_ biochemical
$DP_{\_ultraprocessed}$	-0.08 (-0.11;-0.05)	-0.08 (-0.13;-0.03)	-0.01 (-0.02;0.04)	0.02 (-0.01;0.04)	0.01 (-0.02;0.04)	0.02 (-0.01;0.05)
$DP_{\_fresh\_foods}$	0.09 (0.04;0.14)	0.09 (0.003;0.17)	0.009 (-0.045;0.062)	-0.05 (-0.10;-0.004)	0.01 (-0.04;0.06)	-0.04 (-0.09;0.01)
$DP_{\_bread\_rice\_beans}$	-0.06 (-0.13;-0.00)	-0.06 (-0.16;0.03)	0.078 (0.017;0.139)	0.04 (-0.02;0.09)	0.02 (-0.03;0.07)	-0.01 (-0.07;0.04)
$DP_{\_culinary\_preparation}$	-0.06 (-0.13;0.01)	-0.15 (-0.24;-0.04)	-0.04 (-0.11;0.03)	-0.03 (-0.09;0.03)	-0.02 (-0.08;0.04)	-0.002 (-0.06;0.06)
$DP_{\_cake\_rice\_beans}$	-0.02 (-0.08;0.05)	0.01 (-0.10;0.12)	0.02 (-0.05;0.08)	0.03 (-0.04;0.09)	0.01 (-0.06;0.07)	-0.03 (-0.09;0.04)
Physical activity	0.24 (0.16;0.32)	0.29 (0.16;0.41)	0.11 (0.03;0.19)	0.03 (-0.04;0.10)	0.03 (-0.05;0.10)	-0.06 (-0.14;0.01)
Age (years)						
10 -14	0.00 (Ref)	0.00 (Ref)	0.00 (Ref)	0.00 (Ref)	0.00 (Ref)	0.00 (Ref)
15-19	-0.20 (-0.34;-0.05)	0.66 (0.43;0.89)	2.72 (2.57;2.86)	-0.17 (-0.30;-0.04)	0.08 (-0.05;0.21)	-0.07 (-0.14;0.12)
Sex						
Male	0.00 (Ref)	0.00 (Ref)	0.00 (Ref)	0.00 (Ref)	0.00 (Ref)	0.00 (Ref)
Female	0.09 (-0.06;0.24)	0.41 (0.18;0.63)	-0.29 (-0.43;-0.14)	-0.46 (-0.59;-0.33)	-0.50 (-0.63;-0.37)	0.37 (0.24;0.50)
Wealth (score)	-0.01 (-0.05;0.03)	0.02 (-0.04;0.08)	0.003 (-0.04;0.04)	-0.05 (-0.08;-0.01)	0.05 (0.01;0.08)	0.02 (-0.01;0.06)

BP= body phenotypes; DP= dietary patterns; BMI= body mass index.

Discussion

In this study, we applied a multivariate analysis to estimate the outcomes (BPs) and smain predictors (DPs). We identified five profiles of BP namely as $BP1_{adiposity}$, $BP2_{puberty}$, $BP3_{biochemical}$, $BP4_{muscule}$, and $BP5_{lipids\_biochemical}$. We highlighted the first two BPs that explain the major data variability, express adiposity and body volume, and explain linear growth (chronological axis of adolescence). Five DPs were identified. The first was composed mainly of ultra-processed foods, and in three of them rice and beans were identified. $DP_{—ultraprocessed}$ and $DP_{—fresh\_foods}$ were negatively associated with $BP_{—adiposity,}$ and $DP_{\_culinary\_preparation}$ was positively associated with $BP_{—adiposity}$ in girls, and adolescents aged 15 - 19 years. $DP_{—fresh\_foods}$ was negatively associated with $BP_{—biochemical}$ for girls and wealth score.

The multivariate analysis applied in our study may be considered an innovative approach to assess nutritional status. This proposal based on the multidimensionality of parameters of nutritional status (BPs) allowed us to explore multiple interactions among anthropometric, body composition, and biochemical variables.[12,13] Also, a positive aspect of multivariate analysis is the absence of cut-off point for anthropometric measurements, body composition, and biochemical data. These biological measurements were used in our analysis without assumptions, and BP analysis is reproducible in other adolescent populations.[18]

The perspective of analysis to investigate the relationship between DPs and nutritional status indicators presented in our study is still recent and unprecedented in the type of proposal presented here. The use of DPs to examine the association between diet and health outcomes is innovative. Studies linking specific DPs to chronic diseases, including obesity and related phenotypes such as body composition and cardiometabolic markers[19,20] are growing. However, most studies still prioritize the use of BMI or obesity phenotypes (weight, waist, and lipid levels) in isolation to assess nutritional status.

A study carried out in China in 2009, including 5267 children and adolescents (six to 13 years old), found a positive association between the western dietary pattern and higher levels of triglycerides and glucose. However, mean triglycerides and glucose values are similar between healthy and western dietary patterns. There was no association between DPs and the presence of hypertriglyceridemia or elevated glucose.[21] In another study, carried out in England in 2014, using data from Avon Longitudinal Study of Parents and Children (ALSPAC), higher scores for healthy eating patterns were associated with lower glucose levels.[22]

Several studies have already investigated the relationship between eating behaviors and nutritional status indicators in both young people[23-24] and adults.[25,26] The results of these studies showed in general that unhealthy eating practices, characterized by the presence of ultra-processed foods, high in free sugar, saturated and trans fat, depleted in protein, fiber, and most micronutrients; these refined products increase the risk of elevated body weight. In contrast, the presence of fruits, vegetables, whole grains, and nuts are protective against gains in body fat. It is important to note that the relationship between DPs and the indicators of nutritional status is better established among adults. In children and adolescents, some reviews[27,28] have highlighted that the results are inconsistent in cross-sectional studies.

Contrary to expectations, our study identified a negative association between DP marked by the presence of ultra-processed foods and culinary preparations, and a positive association between DP marked by fresh food and the adiposity phenotype. $DP_{\text{—ultraprocessed}}$ was the first principal component in our study, and we observed a high percentage of adolescents who consumed ultra-processed foods identified in this DP such as processed meat, fast foods, and sugary drinks. In a study conducted in 2010 with adolescents in the city of São Paulo, Brazil, the ‘healthy’ DP was also associated with the obesity profile.[29] In a study carried out in the United States of America in 2012 using data from Project EAT – Eating Among Teens, a positive association was observed between the “sweet and salty snacks pattern” and the risk of overweight / obesity in boys, and higher scores for the “fruit pattern” were positively associated with risk of overweight / obesity in younger boys (mean age = 12.9 years); for girls, these associations were the opposite. The authors hypothesized that the food frequency questionnaire might not reflect all the foods consumed by adolescents included in the study; therefore, DPs did not show a clear association with weight status. Perhaps the use of multiple 24-hour recalls, considered the standard tool for assessing dietary intake, could better reflect the eating habits of the adolescents under study. Another hypothesis raised was that food consumption was not the main determinant of weight status in adolescents.[30]

In a systematic review and meta-analysis study, the authors reported higher scores for unhealthy DPs, and higher values for cardiometabolic risk factors (body weight, waist circumference, lipid profile, and blood glucose). However, healthy patterns were also associated with higher values of BMI and waist circumference. The authors highlighted publication bias in their study, and due to an unexpected or implausible association between healthy patterns and higher cardiometabolic risk, and unhealthy patterns and lower cardiometabolic risk, it may not be published.[30] Also, the protective effect of healthy DPs in adolescents may be unclear and more studies are necessary to understand the relationship of diet and nutritional status outcomes.

The main strength of our study was its originality. To the best of our knowledge, this is possibly the first study to address both the domain of food consumption and nutritional status in a multidimensional manner and the first to analyze the association between BPs as latent variables in the model. In addition, the food frequency questionnaire used to assess food consumption was validated t the study population. We also highlighted the adjusted regression analysis by energy expenditure, sex, age, and wealth status.

Among the limitations of the present study, we highlight a cross-sectional design that prevents the attribution of causality between variables and presents the possibility of the occurrence of reverse causality, as can be seen in this study and; b) the absence of some foods in the list of the food frequency questionnaire and the presence of ultra-processed and processed foods in the same food groups (i.e., pasta and noodles, and homemade cake and industrialized cake). It is important to note that when the questionnaire was developed, there was no classification based on the extent and purpose of industrial food processing, this is a recent proposal for food classification; and c) the overestimation of physical activity by adolescents. Our questionnaire included a list of all types of physical activity, and adolescents may have been overestimated. In contrast to our study, the prevalence of physically active Brazilian adolescents (with 300 min or more of exercise per a week) in 2012 and 2015 was low (21% and 20.7%, respectively). Furthermore, overweight and obese adolescents could practice physical activity to lose their body weight. Finally, we highlighted possible residual confounding effects, even after adjusting for the main factors (age, sex, wealth, and energy expenditure).

We identified a negative association between dietary patterns composed mainly of ultra-processed foods, fresh foods, and $BP_{\text{\_adiposity}}$. These associations need to be better explored, especially in adolescents, as both dietary patterns and phenotypes were defined using a multivariate analysis. Little is known about the association of DPs with relation to obesity, metabolic risk, or both among young people in emerging economies such as Brazil. Thus, multidimensional analysis of the parameters of nutritional status and its relationship with DPs should be further explored for a better understanding of this association, as it is an innovative approach.

Author's contribution

Rinaldi AEM contributed to the study design, analysis and interpretation of data, writing and critical review of the article. Enes CC contributed to the interpretation of data, writing and critical review of the article. Conde WL contributed to the writing and critical review of the article. All authors approved the final version and declare no conflict of the interest.

References

1. Ruiz LD, Zuelch ML, Dimitratos SM, Scherr RE. Adolescent Obesity: Diet Quality, Psychosocial Health, and Cardiometabolic Risk Factors. Nutrients. 2019; 12 (1): 43.
2. Tandon K, Adhikari N, Adhikari B, Pradhan PMS. Co-occurrence of non-communicable disease risk factors and its determinants among school-going adolescents of Kathmandu Metropolitan City. PLoS One. 2022; 17 (8): e0272266.
3. United Nations System Standing Committee on Nutrition (UNSCN). The UN decade of action on nutrition 2016-2025. [*Internet*]. [access in 2022 August 20]. Available from: https://www.unscn.org/en/topics/un-decade-of-action-on-nutrition
4. World Health Organization (WHO). Health for the World's Adolescents: A Second Chance in the Second Decade. Geneva: WHO; 2014. [access in 2022 May 5]. Available from: http://apps.who.int/iris/bitstream/10665/112750/1/WHO_FWC_MCA_14.05_eng.pdf
5. Bloch KV, Klein CH, Szklo M, Kuschnir MCC, Abreu GA, Barufaldi LA, *et al.* ERICA: prevalências de hipertensão arterial e obesidade em adolescentes brasileiros Rev Saúde Pública. 2016; 50 (Supl. 1): 9s.
6. Instituto Brasileiro de Geografia e Estatística (IBGE). Pesquisa nacional de saúde: 2019. Percepção do estado de saúde, estilos de vida, doenças crônicas e saúde bucal. Brasil e grandes regiões. IBGE, Coordenação de Trabalho e Rendimento. Rio de Janeiro: IBGE; 2020. [access in 2022 May 5]. Available from: https://biblioteca.ibge.gov.br/visualizacao/livros/liv101764.pdf
7. Guthold R, Stevens GA, Riley LM, Bull FC. Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1.6 million participants. Lancet Child Adolesc Health. 2020; 4: 23-35.
8. Andrade VMB, Santana MLP, Fukutani KF, Queiroz ATL, Arriaga MB, Conceição-Machado MEP, *et al*. Multidimensional Analysis of Food Consumption Reveals a Unique Dietary Profile Associated with Overweight and Obesity in Adolescents. *Nutrients.* 2019; 11 (8): 1946.
9. Tapsell LC, Neale EP, Satija A, Hu FB. Foods, Nutrients, and Dietary Patterns: Interconnections and Implications for Dietary Guidelines. Adv Nutr. 2016; 7: 445-54.
10. Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. Pediatr Obes. 2012; 7: 284-94.
11. Gage TB. The evolution of human phenotypic plasticity: age and nutritional status at maturity. Hum Biol. 2003; 75: 521-37.
12. Cumpian Silva J, Rinaldi AEM, Mazzeti CMS, Conde WL. Body phenotypes in adolescence and sexual maturation. Cad Saúde Pública. 2018; 34 (3): e00057217.
13. Cumpian Silva J, Rinaldi AEM, Conde WL. Body phenotypes in adolescence: is it necessary to adjust body mass index according to sexual maturation stages? Cad Saúde Pública. 2020; 36 (7): e00072719.
14. Voci SM, Enes CC, Slater B. Validation of a Food Frequency Questionnaire by food groups for the adolescent population. Rev Bras Epidemiol. 2008; 11 (4): 561-72.
15. Associação Brasileira de Empresas de Pesquisa (ABEP). Critério Brasil 2015 e atualização da distribuição de classes para 2016. [access in 2022 August 20]. Available from: https://www.abep.org/Servicos/Download.aspx?id=09
16. Florindo AA, Romero A, Peres SV, Silva MV, Slater B. Development and validation of a physical activity assessment questionnaire for adolescents. Rev Saúde Pública. 2006; 40 (5): 802-9.
17. World Health Organization (WHO). Guidelines on physical activity and sedentary behaviour. Geneva: WHO; 2020. [access in 2022 August 20]. Available from: https://www.who.int/publications/i/item/9789240015128
18. Cumpian Silva J, Rinaldi AEM, Vasconcelos FAG, Assis MAA, Mazzeti CM, Oliveira MH, *et al*. Body phenotypes and sexual maturation in Brazilian and US adolescents: evidence for a change in body mass index Category. Public Health Nutr. 2021 Nov; 24 (16): 5387-99.

19. Smith AD, Emmett PM, Newby PK, Northstone K. Dietary patterns and changes in body composition in children between 9 and 11 years. Food Nutr Res. 2014; 58.

20. Fernandez-Alvira JM, Bammann K, Eiben G, Hebestreit A, Kourides YA, Kovacs E, *et al*. Prospective associations between dietary patterns and body composition changes in European children: The IDEFICS study. Public Health Nutr. 2017; 20: 3257-65.

21. Shang X, Li Y, Liu A, Zhang Q, Hu X, Du S, *et al.* Dietary pattern and its association with the prevalence of obesity and related cardiometabolic risk factors among Chinese children. PLoS One. 2012; 7 (8): e43183.

22. Ambrosini GL, Emmett PM, Northstone K, Jebb SA. Tracking a dietary pattern associated with increased adiposity in childhood and adolescence. Obesity. 2014; 22: 458-65.

23. Gutiérrez-Pliego LE, Camarillo-Romero E, Montenegro-Morales LP, Garduño-Garcia JJ. Dietary patterns associated with body mass index (BMI) and lifestyle in Mexican adolescents. BMC Public Health. 2016; 850.

24. Arenaza L, Huybrechts I, Ortega FB, Ruiz JR, Henauw S, Manios Y, *et al.* Adherence to the Mediterranean diet in metabolically healthy and unhealthy overweight and obese European adolescents: the HELENA study. Eur J Nutr. 2019; 58: 2615-23.

25. Rauber F, Steele EM, Louzada MLC, Millett C, Monteiro CA, Levy RB. Ultra-processed food consumption and indicators of obesity in the United Kingdom population (2008-2016). PLoS ONE. 2020; 15 (5): e0232676.

26. Rautiainen S, Wang L, Lee IM, Manson JE, Buring JE, Sesso HD. Higher Intake of Fruit, but Not Vegetables or Fiber, at Baseline Is Associated with Lower Risk of Becoming Overweight or Obese in Middle-Aged and Older Women of Normal BMI at Baseline. J Nutr. 2015; 145 (5): 960-8.

27. Leech RM, McNaughton SA, Timperio A. The clustering of diet, physical activity and sedentary behavior in children and adolescents: a review. Int J Behav Nutr Phys Act. 2014; 11: 4.

28. Cunha CM, Costa PRF, Oliveira LPM, Queiroz VAO, Pitangueira JCD, Oliveira AM. Dietary patterns and cardiometabolic risk factors among adolescents: Systematic review and meta-analysis. Br J Nutr. 2018; 119: 859-79.

29. Salvatti AG, Escrivao MAMS, Taddei JAAC, Bracco MM. Padrões alimentares de adolescentes na cidade de São Paulo. J Nutr. 2011; 24 (5): 703-13.

30. Cutler G, Flood A, Hannan P, Slavin J, Neumark-Sztainer D. Association between major patterns of dietary intake and weight status in adolescents. Br J Nutr. 2012; 108 (2): 349-56.

Received on January 24, 2023
Final version presented on November 27, 2023
Approved on December 11, 2023

Associated Editor: Pricila Mullachery