ORIGINAL ARTICLE

‘MEAT AND EGGS’ DIETARY PATTERN IN OVERWEIGHT AND OBESE ADOLESCENTS AND ITS RELATIONSHIP WITH CARDIOMETABOLIC MARKERS

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Highlights: (1) 'Meat and eggs' dietary pattern associated with low HDL and high triacylglycerols levels. (2) 'Meat and eggs' dietary pattern was dominant in overweight adolescents. (3) 'Meat and eggs' dietary pattern increases the risk of high triacylglycerols by 2.76 times.

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‘MEAT AND EGGS’ DIETARY PATTERN IN OVERWEIGHT AND OBESE ADOLESCENTS AND ITS RELATIONSHIP WITH CARDIOMETABOLIC MARKERS

ABSTRACT

To associate dietary patterns with cardiometabolic markers in overweight and obese adolescents. A cross-sectional study was conducted with 227 adolescents aged 10 to 19 years, who were attending six public healthcare services in a city in Southern Brazil. A semi-quantitative food frequency questionnaire was administered. Dietary patterns were identified using principal component analysis followed by orthogonal Varimax rotation. Independent associations between dietary patterns and marker values (glucose, fasting insulin, Homeostatic Model Assessment index, total cholesterol, triacylglycerols, Low-Density Lipoprotein, High-Density Lipoprotein, cholesterol not transported by HDL, C-reactive protein, and blood pressure) were tested using quantile regression. The scores of dietary patterns were categorized into tertiles and associated with the outcomes of altered cholesterol transported by HDL or triacylglycerols levels due to their significant associations. A significance level of $p<0.05$ was considered. Five dietary patterns were identified: ‘Meat and eggs’, ‘Coffee, dairy, and vegetables’, ‘Breads and processed meats’, ‘Sugar and fat’, and ‘Soup and cereals’. The ‘Meat and eggs’ pattern, characterized by red meat, white meat, and eggs, was the most representative and showed a negative association with cholesterol transported by HDL and a positive association with triacylglycerols. The ‘Soup and cereals’ pattern had a positive association with triacylglycerols. Adolescents belonging to the third tertile of the ‘Meat and eggs’ pattern had 2.76 times higher odds of elevated triacylglycerols. Greater adherence to the ‘Meat and eggs’ pattern was associated with lower levels of cholesterol transported by HDL and higher plasma triacylglycerols.

Keywords: Adolescent; overweight; obesity; dietary patterns; lipoproteins; cardiometabolic risk factors.

RESUMO

Associar padrões alimentares a marcadores cardiometabólicos em adolescentes com pré-obesidade e obesidade. Foi realizado um estudo transversal com 227 adolescentes com idades entre 10 e 19 anos, que frequentavam seis serviços públicos de saúde em uma cidade no sul do Brasil. Foi aplicado um questionário semiquantitativo de frequência alimentar. Os padrões alimentares foram identificados por meio de análise de componentes principais seguida de

rotação ortogonal Varimax. Associações independentes entre os padrões alimentares e os valores dos marcadores (glicose, insulina em jejum, índice de avaliação do modelo homeostático, colesterol total, triacilgliceróis, lipoproteína de baixa densidade, lipoproteína de alta densidade, colesterol não transportado por HDL, proteína C reativa e pressão arterial) foram testadas por meio de regressão quantílica. As pontuações dos padrões alimentares foram categorizadas em tercis e associadas aos resultados de níveis alterados de colesterol transportado por HDL ou triacilgliceróis devido a suas associações significativas. Foi considerado um nível de significância de $p<0,05$. Foram identificados cinco padrões alimentares: "Carne e ovos", "Café, laticínios e vegetais", "Pães e carnes processadas", "Açúcar e gordura" e "Sopa e cereais". O padrão "Carne e ovos", caracterizado por carne vermelha, carne branca e ovos, foi o mais representativo e mostrou uma associação negativa com o colesterol transportado por HDL e uma associação positiva com os triacilgliceróis. O padrão "Sopa e cereais" teve uma associação positiva com os triacilgliceróis. Os adolescentes pertencentes ao terceiro tercil do padrão "Carne e ovos" tiveram 2,76 vezes mais chances de triacilgliceróis elevados. A maior adesão ao padrão "Carne e ovos" foi associada a níveis mais baixos de colesterol transportado por HDL e triacilgliceróis plasmáticos mais elevados.

Palavras-chave: Adolescente; sobrepeso; obesidade; padrões alimentares; lipoproteínas; fatores de risco cardiometabólicos.

INTRODUCTION

The term ‘cardiometabolic risk factors’ refers to the association between conventional cardiovascular risk factors and changes in the metabolic syndrome.[1]Assessment of these factors, including blood lipids, fasting glucose, blood pressure (BP), and high-sensitivity C-reactive protein (CRP), helps to determine the risk of metabolic dysregulation and the development of cardiovascular disease.[1]This association appears to establish a cardiovascular continuum from childhood to adolescence, in which pathological processes are initiated by the interaction of various risk factors. Over time, these factors progressively lead to anatomic and functional changes that trigger cardiovascular complications later in life.[2]

Obesity is associated with multiple comorbidities, including cardiometabolic disorders.[3] The presence of chronic low-grade inflammation[4,5] and reduced insulin sensitivity[4]

physiopathologically contributes to the development of cardiometabolic risk factors such as dyslipidemia and dysglycemia. High levels of total cholesterol, low-density lipoprotein (LDL) and triacylglycerols, and low levels of high-density lipoprotein (HDL), associated with hyperglycemia, increase cardiovascular risk.[5] There is a high prevalence of cardiovascular and atherogenic risk in overweight and obese adolescents.[6] A significant proportion of overweight and obese adolescents have insulin resistance, dyslipidemia, and chronic low-grade inflammation, conditions that increase the long-term risk of morbidity and mortality from cardiovascular disease.[4,6]

Dietary quality has been recognized as a major factor in the etiology of several metabolic disorders.[7] Studies have shown associations between dietary patterns and metabolic and inflammatory markers in adolescents,[8-11] but there is no consensus on the findings.[12,13] A systematic review pointed to the need for more studies investigating the relationship between dietary patterns and cardiometabolic markers in children and adolescents, given the limited information available in this specific population.[14]

This study was carried out due to the lack of consistency in the associations found between dietary patterns and cardiometabolic markers in overweight and obese adolescents. In addition, different dietary patterns are influenced by cultural, regional, economic, and individual preferences. The objective of our study was to analyze the association between dietary patterns and cardiometabolic risk markers in overweight and obese adolescents.

METHODS

Study design, population, and sample

This study used a quantitative, cross-sectional, retrospective design with analysis of secondary data collected between 2013 and 2018 from the Adolescent Health in Chronic Condition study. The study population consisted of adolescents aged 10 to 19 years with overweight or obesity, based on the z-score of the Body Mass Index for Age and Sex (BMI/A),[15] who attended medical consultations at six health care facilities, including primary and secondary care, within the Unified Health System (SUS) in a southern Brazilian city. Exclusion

criteria included cognitive deficits, genetic syndromes, neurological diseases, endocrine disorders, short stature (height z-score less than -2), dietary restrictions due to illness, incomplete anthropometric data, and incomplete responses to the Adolescent Food Frequency Questionnaire (AFFQ).

The Adolescent Health in Chronic Condition study was approved by the Ethics Committee for Human Research of the Regional University of Blumenau (CAAE: 37003820.2.0000.5370), according to the criteria established in Resolution 510 of April 7, 2016, of the National Health Council (CNS).

Data Collection Methods

Sociodemographic, anthropometric, dietary intake, and cardiometabolic marker data were collected. Sociodemographic data included gender, age, and family income. Family income was classified as low (equal to or less than R$ 2.673.00), medium (from R$ 2.674.00 to R$ 9.896.00), and high (greater than R$ 9.897.00).[16]Anthropometric data, including weight and height, were collected using standardized techniques and calibrated equipment by previously trained researchers. Weight was measured in kilograms (kg) using a digital scale with a capacity of 150 kg and an accuracy of 0.05 kg, while height was measured in meters using a wall-mounted stadiometer with a scale in millimeters (mm).

Food consumption data were collected using the AFFQ. This semi-quantitative instrument consists of 94 food items with seven frequency options (never, less than once a month, one to three times a month, once a week, two to four times a week, once a day, and two or more times a day).[17] Each frequency of consumption has a corresponding equivalent for daily intake.[18] Dietary patterns were derived from the frequency of consumption variable. Foods in the AFFQ were grouped into 14 food groups based on similarities in nutrient composition, ingredients, and culinary preparation. Adequacy of sample size with respect to the food groups formed was verified prior to analysis.[19]

Cardiometabolic markers of dysglycemia included fasting glucose and insulin, and the homeostatic model assessment index (HOMA-IR). Glycemia < 100 mg/dL was considered

normal, and ≥ 100 mg/dL was considered elevated.[20] Fasting insulin classified with specific cut-off points (µg/dL) age and sex group.[21] HOMA-IR was calculated as the product of fasting glucose (mg/dL) and fasting insulin (µg/dL) divided by 405.[22] HOMA-IR values greater than 3.16 were considered indicative of insulin resistance.[23] Total cholesterol, triacylglycerols, HDL cholesterol, LDL cholesterol, and non-HDL cholesterol were used to assess dyslipidemia. Total cholesterol levels < 150 mg/dL were considered normal and ≥ 150 mg/dL were considered elevated.[20] Triacylglycerols levels < 100 mg/dL were considered normal and ≥ 100 mg/dL were considered elevated.[20] HDL-cholesterol levels < 45 mg/dL were considered low and ≥ 45 mg/dL were considered desirable.[20] LDL cholesterol (mg/dL) was calculated using the formula LDL = total cholesterol - HDL - (triacylglycerols/5),[24] with a cutoff of < 100 (normal) and ≥ 100 (elevated).[20] Non-HDL cholesterol (mg/dL) was obtained by subtracting HDL cholesterol from total cholesterol, with a cutoff of < 120 (normal) and ≥ 120 (elevated).[20] BP (mmHg) was considered elevated if systolic blood pressure (SBP) was ≥ 130 mm Hg and/or diastolic blood pressure (DBP) was ≥ 85 mmHg.[25] CRP (mg/dL) was used as an inflammatory marker and was categorized as < 1 (low risk for noncommunicable chronic diseases (NCDs)) and ≥ 1 (intermediate or high risk for NCDs/chronic low-grade inflammation).[26]

Statistical Analysis

The statistical software used for analysis was Stata 14. Descriptive statistics included absolute and relative frequencies, mean ± standard deviation, depending on data normality. Normality of quantitative variables was assessed using the Kolmogorov-Smirnov test.

Dietary patterns were extracted using principal component analysis (PCA) followed by orthogonal varimax rotation. The correlation matrix among the 14 food groups showed sample adequacy for component analysis, as indicated by the Kaiser-Meyer-Olkin measure (KMO = 0.7619) and statistically significant Bartlett's test of sphericity (BTS) ($p < 0.001$), indicating the suitability of the correlation between variables in the data model.[19,27]

The number of retained components (dietary patterns) was determined by combining the following criteria: eigenvalue > 1, Cattel's Scree plot, and interpretability of the identified

patterns.[19,27] Dietary patterns were interpreted and labeled based on the composition of food groups with a component loading > 0.30, indicating a significant contribution to the dietary pattern.[19,27] If a food group had a component loading > 0.30 in more than one component, the component with the highest loading was used to label the dietary pattern; negative component factor loadings were not considered. Each individual received a factor score for each dietary pattern.

Component scores for each of the generated dietary patterns on cardiometabolic markers were adjusted for sex and age using median quantile regression with standard errors estimated by 100 bootstrap replications. Regression coefficients and corresponding 95% confidence intervals (CI) are presented.

Logistic regression models were used to assess the odds ratios (OR) of altered HDL-cholesterol and triacylglycerols with dietary pattern scores categorized into tertiles, with the first tertile representing lower dietary pattern adherence and the third tertile representing higher dietary pattern adherence. The first tertile was taken as the reference point. This analysis was performed for HDL cholesterol and triacylglycerols, which showed an association with dietary patterns. Models were run without adjustment and with adjustment for sex and age. A significance level of 5% was used.

RESULTS

A total of 227 adolescents of both sexes were examined. The majority were classified as obese (61.3%). Most participants were classified with high total cholesterol and insulin levels, had intermediate or high CRP values (75.1%) as well as insulin resistance according to HOMA-IR (Table 1).

Table 1. Characteristics of overweight and obese adolescents. Blumenau, Santa Catarina, Brazil, 2023.

Variables	*n* (%)	Mean (SD)	Minimun	Maximum
Gender				
Male	114 (50.2)	-	-	-
Female	113 (49.8)	-	-	-
Age (years)	-	13.5 (2.12)	10	18
Age				
10 to 14 years	170 (74.9)	-	-	-
15 to 19 years	57 (25.1)	-	-	-
Family Income				
Low	75 (40.3)	-	-	-
Medium	66 (35.5)	-	-	-
High	1 (0.5)	-	-	-
Nutritional status				
Overweight	88 (38.8)	-	-	-
Obesity	95 (41.9)	-	-	-
Severe Obesity	44 (19.4)	-	-	-
Total cholesterol (mg/dL)	-	158.23 (29.85)	84	238.9
Total cholesterol				
Normal	75 (42.1)	-	-	-
High	103 (57.9)	-	-	-
HDL-cholesterol (mg/dL)	-	49.47 (8.73)	25	84
HDL-cholesterol				
Normal	131 (73.2)	-	-	-
Low	48 (26.8)	-	-	-
LDL-cholesterol (mg/dL)	-	87.31 (26.59)	31.8	165.56
LDL-cholesterol				
Normal	121 (68.8)	-	-	-
High	55 (31.3)	-	-	-
Non-HDL cholesterol (mg/dL)	-	109.39 (28.6)	45	190.1
Non-HDL cholesterol				
Normal	109 (62.6)	-	-	-
High	65 (37.4)	-	-	-
Triacylglycerols (mg/dL)	-	100.50 (52.28)	29	486

Triacylglycerols				
Normal	106 (58.2)	-	-	-
High	76 (33.5)	-	-	-
Insulin (µU/mL)	-	19.93 (14.61)	1.05	131
Insulin category				
Normal	68 (42.5)	-	-	-
High	92 (57.5)	-	-	-
Glycemia (mg/dL)	-	82.66 (9.84)	63	109
Glycemia	-	-	-	-
Normal	174 (95.6)	-	-	-
High	8 (4.4)	-	-	-
HOMA- IR	-	4.08 (3.11)	0.21	27.79
HOMA- IR category				
Normal	73 (45.6)	-	-	-
Insulin resistance	87 (54.4)	-	-	-
SBP (mmHg)	-	115.59 (13.76)	80	168
DBP (mmHg)	-	71.87 (9.39)	50	90
BP category				
Normal	149 (79.7)			-
High	38 (20.3)			-
CRP (mg/L)	-	4.73 (25.95)	0.00	295
CRP				
Low	32 (25)	-	-	-
Medium	56 (43.8)	-	-	-
High	40 (31.3)	-	-	-

Abbreviations: SD: Standard Deviation; HDL: High-Density Lipoprotein; LDL: Low-Density Lipoprotein; HOMA-IR: Homeostatic Model Assessment; BP: Blood Pressure; DBP: diastolic blood pressure; SBP: systolic blood pressure; CRP: C-reactive protein; µU/ml: micro-unit per milliliter; mg/dL: milligram per deciliter; mg/L: milligram per liter.

Source: Adolescent Health in Chronic Conditions Study, 2013 to 2018, Blumenau, Santa Catarina, Brazil.

Five main dietary patterns were derived using PCA, which together explained 59.2% of the total variance in dietary intake among the sample. The dietary patterns were named ‘Meat and eggs’, ‘Coffee, milk and vegetables’, ‘Bread and processed meat’, ‘Sugar and fat’, and ‘Soup and cereals’ according to their constituent food groups. The ‘Meat and eggs’ pattern explained the largest proportion of the total variance (25.3%). Table 2 describes the food groupings used in the factor analysis, the factor loading matrix, and the variance explained by each pattern identified.

Table 2. Food groups and factor loading matrix of the identified dietary patterns.

Food Groups	Food items	Dietary patterns				
		Meat and eggs	**Coffee, dairy and vegetables**	**Breads and processed meats**	**Sugar and fat**	**Soup and cereals**
Red meat	Boiled meat (steak, roll), Steak (fried/breaded), pork (steak, loin)	**0.69**				
Fish, poultry and eggs	Chicken (boiled/roasted), fish (fried), eggs and omelet	**0.75**				
Dairy products	Milk (whole/skimmed), fermented milk, yogurt (natural/diet), cheese, cottage cheese.		**0.50**			
Oils and fats	Butter, margarine and traditional mayonnaise, olive oil		**0.44**			
Vegetables	Lettuce, chard/cabbage, watercress/rucola, cauliflower, beet, carrots, spinach/cabbage, peas, green corn, cucumber, tomato		**0.57**			
Fruit and fruit juices	Fresh fruit, various fruit juices sweetened with sugar		**0.62**			
Coffee and tea	Coffee, tea and *mate*		**0.68**			
Breads	Breads (French/shaped/whole meal)			**0.80**		
Cold cuts and processed meats	Ham, turkey breast, mortadella, salami, hot dog sausage e sausage			**0.65**		
Fatty foods and preparations	Snacks such as chips, potato chips, fried snacks, popcorn, cheese/potato bread, croissants (ham and cheese), pasta (lasagna, ravioli), mayonnaise salad, cheeseburger, hot mix, hot dog, pizza, natural sandwiches				**0.44**	
Foods and preparations high in sugar	Chocolate, sweets, chocolate powder, ice cream and popsicles, cookies, cake, cereal (sucrose and cereal bar), chocolate croissants, artificial juices, soft drinks, added sugar, desserts.				**0.86**	

Beans	Beans (brown or black type)				**0.58**	
Soup	Soup					**0.85**
Cereals	Cassava flour, rice, instant noodles, potatoes, *polenta* (boiled/fried), boiled cassava, *pamonha* (sweet/salty)					**0.48**
% of variance explained		25.3	9.9	8.7	8.0	7.2

*Entries in bold are component loadings > 0.30, which are considered important contributors to the standards. Negative loadings were not considered.

Source: research data.

Quantile regression analysis in the unadjusted model showed that the ‘Meat and eggs’ pattern had a significant negative association with low HDL-cholesterol; the ‘Soup and cereals’ pattern had a positive association with elevated triacylglycerols levels and categories; and the ‘Bread and processed meats’ pattern had a positive association with elevated glycemia categories. In the model adjusted for age and sex, the ‘Meat and eggs’ dietary pattern retained negative associations with low HDL-cholesterol and showed a positive association with elevated triacylglycerols categories. The ‘Soup and cereals’ pattern maintained a significant positive association with elevated triacylglycerols levels and categories (Table 3). No statistically significant associations were observed between the other dietary patterns and cardiometabolic markers.

Table 3. Unadjusted and age- and sex-adjusted quantile association between dietary patterns and cardiometabolic markers of overweight and obese adolescents.

		¥MODEL 1				
Cardiometabolic markers		Meat and eggs	Coffee, dairy and vegetables	Breads and processed meats	Sugar and fat	Soup and cereals
Total cholesterol (mg/dL)	Coef.	-0.001	-0.002	-0.003	-0.006	0.000
	(95% CI)	(-0.01 a 0.00)	(-0.01 a 0.00)	(-0.01 a 0.00)	(-0.02 a 0.00)	(-0.00 a 0.00)
	p	0.6	0.6	0.3	0.2	0.8
Total cholesterol (category)	Coef.	-0.091	- 0.122	-0.162	-0.134	-0.126
	(95% CI)	(-0.47 a 0.29)	(-0.35 a 0.11)	(-0.68 a 0.36)	(-0.67 a 0.40)	(-0.44 a 0.19)
	p	0.6	0.3	0.5	0.6	0.4
HDL-cholesterol (mg/dL)	Coef.	0.002	-0.010	-0.008	0.003	-0.004
	(95% CI)	(-0.01 a 0.02)	(-0.03 a 0.01)	(- 0.03 a 0.01)	(-0.03 a 0.03)	(-0.02 a 0.01)
	p	0.8	0.2	0.5	0.9	0.6
HDL-cholesterol (category)	Coef.	- 0.303	0.016	0.111	0.134	-0.057
	(95% CI)	(-0.55 a - 0.05)	(-0.28 a 0.31)	(-0.41 a 0.63)	(-0.39 a 0.66)	(-0.36 a 0.25)
	p	**0.0 ***	0.9	0.7	0.6	0.7
LDL-cholesterol (mg/dL)	Coef.	- 0.002	- 0.003	-0.002	-0.006	0.000
	(95% CI)	(-0.01 a 0.00)	(-0.01 a 0.00)	(-0.01 a 0.01)	(-0.01 a 0.00)	(-0.01 a 0.01)
	p	0.4	0.3	0.6	0.1	0.9
LDL-cholesterol (category)	Coef.	-0.276	- 0.102	-0.132	-0.146	0.013
	(95% CI)	(-0.64 a 0.09)	(-0.35 a 0.14)	(-0.65 a 0.39)	(-0.52 a 0.23)	(-0.28 a 0.30)
	p	0.1	0.4	0.6	0.4	0.9
Non HDL-cholesterol (mg/dL)	Coef.	- 0.001	-0.001	-0.003	-0.006	0.002
	(95% CI)	(-0.01 a 0.01)	(-0.01 a 0.00)	(-0.01 a 0.00)	(-0.01 a 0.00)	(-0.00 a 0.01)

	p	0.7	0.6	0.4	0.2	0.5
Non HDL-cholesterol (category)	Coef.	- 0.233	-0.023	-0.249	-0.228	0.077
	(95% CI)	(-0.57 a 0.11)	(-0.38 a 0.34)	(-0.72 a 0.22)	(-0.74 a 0.28)	(-0.21 a 0.36)
	p	0.2	0.9	0.3	0.4	0.6
Triacylglycerols (mg/dL)	Coef.	0.001	0.001	-0.001	-0.003	0.004
	(95% CI)	(-0.00 a 0.00)	(-0.00 a 0.00)	(-0.00 a 0.00)	(-0.01 a 0.00)	(0.00 a 0.01)
	p	0.4	0.5	0.5	0.3	**0.0 ****
Triacylglycerols (category)	Coef.	0.334	0.010	0.010	0.094	0.374
	(95% CI)	(-0.00 a 0.67)	(-0.22 a 0.24)	(-0.58 a 0.60)	(-0.28 a 0.47)	(0.10 a 0.65)
	p	0.1	0.9	1	0.6	**0.0 *****
Insulin (µU/ml)	Coef.	-0.003	0.008	-0.002	-0.005	0.005
	(95% CI)	(-0.02 a 0.01)	(-0.01 a 0.02)	(-0.015 a 0.011)	(-0.02 a 0.01)	(-0.00 a 0.01)
	p	0.7	0.3	0.8	0.5	0.3
Insulin (category)	Coef.	0.030	0.045	-0.058	0.019	0.155
	(95% CI)	(-0.39 a 0.45)	(-0.23 a 0.32)	(-0.57 a 0.45)	(-0.38 a 0.42)	(-0.13 a 0.44)
	p	0.9	0.7	0.8	0.9	0.3
Glycemia (mg/dL)	Coef.	0.009	-0.002	0.015	0.013	-0.008
	(95% CI)	(-0.01 a 0.03)	(-0.01 a 0.01)	(-0.01 a 0.04)	(-0.01 a 0.03)	(-0.02 a 0.00)
	p	0.4	0.8	0.2	0.2	0.2
Glycemia (category)	Coef.	-0.065	0.122	0.924	0.634	0.191
	(95% CI)	(-1.17 a 1.04)	(-0.20 a 0.44)	(0.00 a 1.85)	(-0.40 a 1.67)	(-0.28 a 0.66)
	p	0.9	0.5	**0.0 ******	0.2	0.4
HOMA-IR	Coef.	0.011	0.023	-0.008	-0.022	0.021
	(95% CI)	(-0.07 a 0.09)	(-0.04 a 0.09)	(-0.08 a 0.06)	(-0.09 a 0.04)	(-0.03 a 0.07)
	p	0.8	0.5	0.8	0.5	0.4

HOMA-IR (category)	Coef.	-0.168	0.095	0.319	0.012	-0.013
	(95% CI)	(-0.52 a 0.19)	(-0.18 a 0.37)	(-0.21 a 0.85)	(-0.46 a 0.48)	(-0.31 a 0.28)
	p	0.4	0.5	0.2	1	0.9
SBP (mmHg)	Coef.	-0.006	0.002	0.001	-0.000	-0.006
	(95% CI)	(-0.01 a 0.00)	(-0.01 a 0.01)	(-0.01 a 0.01)	(-0.01 a 0.01)	(-0.01 a 0.00)
	p	0.1	0.6	0.9	1	0.1
DBP (mmHg)	Coef.	-0.004	0.007	-0.011	-0.005	-0.010
	(95% CI)	(-0.02 a 0.01)	(-0.01 a 0.02)	(-0.03 a 0.01)	(-0.03 a 0.02)	(-0.02 a 0.00)
	p	0.6	0.4	0.3	0.7	0.2
BP (category)	Coef.	-0.179	0.036	0.163	-0.048	0.037
	(95% CI)	(-0.52 a 0.16)	(-0.20 a 0.27)	(-0.31 a 0.64)	(-0.56 a 0.47)	(-0.47 a 0.54)
	p	0.3	0.8	0.5	0.9	0.9
CRP (mg/L)	Coef.	- 0.002	-0.001	-0.003	-0.002	0.002
	(95% CI)	(-0.09 a 0.09)	(-0.09 a 0.09)	(-0.05 a 0.05)	(-0.08 a 0.08)	(-0.04 a 0.05)
	p	1	1	0.9	1	0.9
CRP (category)	Coef.	0.214	-0.020	-0.095	-0.095	-0.061
	(95% CI)	(-0.07 a 0.50)	(-0.29 a 0.25)	(-0.39 a 0.20)	(-0.47 a 0.28)	(-0.35 a 0.22)
	p	0.1	0.9	0.5	0.6	0.7
				¥¥**MODEL 2**		
Total cholesterol (mg/dL)	Coef.	-0.000	-0.002	-0.003	-0.006	-0.001
	(95% CI)	(-0.01 a 0.01)	(-0.01 a 0.00)	(-0.01 a 0.00)	(-0.01 a 0.00)	(-0.01 a 0.00)
	p	0.9	0.3	0.4	0.2	0.7
Total cholesterol (category)	Coef.	-0.085	-0.167	0.000	-0.124	-0.105
	(95% CI)	(-0.56 a 0.39)	(-0.40 a 0.06)	(-0.49 a 0.49)	(-0.59 a 0.34)	(-0.39 a 0.18)
	p	0.7	0.1	1	0.6	0.5

HDL-cholesterol (mg/dL)	Coef.	0.004	-0.009	-0.005	0.005	-0.003
	(95% CI)	(-0.02 a 0.02)	(-0.03 a 0.01)	(-0.02 a 0.01)	(-0.02 a 0.03)	(-0.02 a 0.01)
	p	0.7	0.3	0.6	0.8	0.7
HDL-cholesterol (category)	Coef.	-0.315	0.173	-0.002	0.134	-0.038
	(95% CI)	(-0.57 a -0.06)	(-0.16 a 0.50)	(-0.52 a 0.51)	(-0.34 a 0.61)	(-0.40 a 0.32)
	p	**0.0** †	0.3	1	0.6	0.8
LDL-cholesterol (mg/dL)	Coef.	-0.004	-0.003	-0.000	-0.007	-0.001
	(95% CI)	(-0.01 a 0.00)	(-0.01 a 0.00)	(-0.01 a 0.01)	(-0.02 a 0.00)	(-0.01 a 0.00)
	p	0.2	0.3	1	0.1	0.6
LDL-cholesterol (category)	Coef.	- 0.340	-0.155	-0.060	-0.155	-0.064
	(95% CI)	(-0.81 a 0.13)	(-0.38 a 0.07)	(-0.57 a 0.46)	(-0.56 a 0.25)	(-0.35 a 0.23)
	p	0.2	0.2	0.8	0.4	0.7
Non HDL-cholesterol (mg/dL)	Coef.	-0.000	-0.002	-0.003	-0.006	0.000
	(95% CI)	(-0.01 a 0.00)	(-0.01 a 0.00)	(-0.01 a 0.00)	(-0.01 a 0.00)	(-0.00 a 0.01)
	p	0.9	0.4	0.4	0.1	0.9
Non HDL-cholesterol (category)	Coef.	-0.340	-0.096	-0.181	-0.293	-0.058
	(95% CI)	(-0.78 a 0.10)	(-0.35 a 0.16)	(-0.63 a 0.27)	(-0.70 a 0.11)	(-0.35 a 0.23)
	p	0.1	0.5	0.4	0.2	0.7
Triacylglycerols (mg/dL)	Coef.	0.002	0.001	-0.000	-0.003	0.004
	(95% CI)	(-0.00 a 0.00)	(-0.00 a 0.00)	(-0.00 a 0.00)	(-0.01 a 0.00)	(0.00 a 0.01)
	p	0.2	0.3	0.8	0.2	**0.0**††
Triacylglycerols (category)	Coef.	0.413	0.029	-0.048	0.063	0.312
	(95% CI)	(0.07 a 0.76)	(-0.23 a 0.29)	(-0.69 a 0.59)	(-0.42 a 0.54)	(0.04 a 0.59)
	p	**0.0** †††	0.8	0.9	0.8	**0.0**††††
Insulin (µU/ml)	Coef.	-0.005	0.011	-0.000	-0.006	0.004
	(95% CI)	(-0.03 a 0.01)	(-0.00 a 0.02)	(-0.01 a 0.01)	(-0.02 a 0.01)	(-0.01 a 0.01)

	p	0.6	0.1	1	0.4	0.4
Insulin (category)	Coef.	-0.089	0.063	0.073	-0.037	0.113
	(95% CI)	(-0.55 a 0.37)	(-0.26 a 0.38)	(-0.42 a 0.57)	(-0.52 a 0.45)	(-0.15 a 0.37)
	p	0.7	0.7	0.8	0.9	0.4
Glycemia (mg/dL)	Coef.	0.009	-0.001	0.013	0.013	-0.010
	(95% CI)	(-0.01 a 0.03)	(-0.01 a 0.01)	(-0.01 a 0.04)	(-0.01 a 0.04)	(-0.03 a 0.00)
	p	0.5	0.9	0.3	0.3	0.2
Glycemia (category)	Coef.	-0.057	0.094	0.816	0.597	0.271
	(95% CI)	(-1.17 a 1.06)	(-0.19 a 0.38)	(-0.14 a 1.78)	(-0.43 a 1.62)	(-0.26 a 0.81)
	p	0.9	0.5	0.1	0.3	0.3
HOMA-IR	Coef.	-0.013	0.042	-0.002	-0.028	0.020
	(95% CI)	(-0.11 a 0.08)	(-0.02 a 0.11)	(-0.07 a 0.07)	(-0.98 a 0.04)	(-0.02 a 0.06)
	p	0.8	0.2	1	0.4	0.4
HOMA-IR (category)	Coef.	-0.207	0.164	0.238	-0.076	-0.036
	(95% CI)	(-0.64 a 0.22)	(-0.14 a 0.47)	(-0.24 a 0.72)	(-0.50 a 0.35)	(-0.26 a 0.19)
	p	0.3	0.3	0.3	0.7	0.8
SBP (mmHg)	Coef.	-0.005	0.002	0.002	-0.002	-0.006
	(95% CI)	(-0.01 a 0.00)	(-0.01 a 0.01)	(-0.01 a 0.02)	(-0.02 a 0.02)	(-0.01 a 0.00)
	p	0.3	0.5	0.8	0.8	0.2
DBP (mmHg)	Coef.	-0.001	0.001	0.000	-0.012	-0.011
	(95% CI)	(-0.02 a 0.02)	(-0.01 a 0.02)	(-0.03 a 0.03)	(-0.04 a 0.01)	(-0.03 a 0.00)
	p	1	0.09	1	0.3	0.1
BP (category)	Coef.	-0.156	-0.079	0.305	-0.101	0.002
	(95% CI)	(-0.56 a 0.25)	(0.37 a 0.21)	(-0.25 a 0.86)	(-0.50 a 0.30)	(-0.38 a 0.38)
	p	0.5	0.6	0.3	0.6	1

CRP (mg/L)	Coef.	-0.001	-0.002	-0.003	-0.002	0.001
	(95% CI)	(-0.11 a 0.11)	(-0.09 a 0.09)	(-0.07 a 0.07)	(-0.08 a 0.08)	(-0.06 a 0.06)
	p	1	1	0.9	1	1
CRP (category)	Coef.	0.169	-0.042	0.094	0.001	-0.054
	(95% CI)	(-0.10 a 0.44)	(-0.35 a 0.27)	(-0.25 a 0.44)	(-0.39 a 0.39)	(-0.28 a 0.17)
	p	0.2	0.8	0.6	1	0.6

¥Model 1 unadjusted; *p*-value < 0.05 *p= 0.018; ** p= 0.016; *** p= 0.008; **** p= 0.049; ¥¥ Model 2 adjusted for age and sex; † p= 0.016; †† p= 0.014; ††† p= 0.020; †††† p= 0.027. Abbreviations: HDL: High-Density Lipoprotein; LDL: Low-Density Lipoprotein; HOMA-IR: Homeostatic Model Assessment; BP: blood pressure; DBP: diastolic blood pressure; SBP: systolic blood pressure; CRP: C-reactive protein; µU/ml: micro-unit per milliliter; mg/dL: milligram per deciliter; mg/L: milligram per liter; Coef.: coefficient; 95 % CI: 95 % confidence interval.

Source: research data.

Table 4 presents the results of logistic regression analyses, which indicate that in the unadjusted model, adolescents with higher ‘Meat and eggs’ pattern adherence had higher odds of elevated triacylglycerols levels (OR=2.37; 95% CI: 1.14 - 4.93). After adjustment for age and sex, the significance became even more consistent, showing that individuals in the third tertile of ‘Meat and eggs’ pattern scores had higher odds of elevated triacylglycerols compared to those with lower adherence (OR=2.76; 95% CI: 1.29 - 5.91 and OR=1.38; 95% CI: 0.65 - 2.96).

Table 4: Adjusted and unadjusted odds ratio and 95% confidence interval of the association between dietary patterns and cardiometabolic markers of overweight and obese adolescents.

Food Patterns	Model Without Adjustment						Model With Adjustment *					
	Altered HDL			Altered TGL			Altered HDL			Altered TGL		
	OR		95% CI	OR		95% CI	OR		95% CI	OR		95% CI
Meat and eggs												
1 tertile	1.0	Ref.		1.0	Ref.		1.0	Ref.		1.0	Ref.	
2 tertile	0.78		0.36 -1.71	1.24		0.59-2.60	0.74		0.33 –1.63	1.38		0.65 – 2.96
3 tertile	0.54		0.24 – 1.26	2.37		1.14 –4.93	0.52		0.22 –1.20	2.76		1.29 – 5.91
p-value		0.155			**0.021**			0.124			**0.009**	
Coffee, dairy products and vegetables												
1 tertile	1.0	Ref.		1.0	Ref.		1.0	Ref.		1.0	Ref.	
2 tertile	0.86		0.38-1.94	0.89		0.43-1.83	0.85		0.37-1.93	0.91		0.44-1.89
3 tertile	1.04		0.46-2.32	0.85		0.41- 1.75	1.07		0.48-2.40	0.80		0.38-1.67
p-value		0.923			0.653			0.871			0.546	
Breads and processed meats												
1 tertile	1.0	Ref.		1.0	Ref.		1.0	Ref.		1.0	Ref.	
2 tertile	0.61		0.27-1.41	0.53		0.25-1.10	0.60		0.26 –1.37	0.56		0.26-1.18
3 tertile	0.86		0.39-1.89	0.94		0.46-1.92	0.84		0.38 –1.86	0.98		0.47-2.03
p-value		0.709			0.877			0.676			0.973	
Sugar and fat												
1 tertile	1.0	Ref.		1.0	Ref.		1.0	Ref.		1.0	Ref.	
2 tertile	0.90		0.40-2.01	1.32		0.64-2.70	0.93		0.41-2.10	1.19		0.57-2.48
3 tertile	0.82		0.37-1.85	0.93		0.45-1.94	0.82		0.36 –1.85	0.94		0.45 – 1.97
p-value		0.639			0.853			0.637			0.869	
Soup and cereals												
1 tertile	1.0	Ref.		1.0	Ref.		1.0	Ref.		1.0	Ref.	
2 tertile	0.92		0.41-2.07	0.75		0.36-1.58	0.91		0.40 –2.06	0.81		0.38-1.71
3 tertile	1.20		0.53-2.67	1.95		0.94-4.03	1.22		0.54 –2.73	1.98		0.94-4.14
p-value		0.667			0.075			0.636			0.072	

* Adjusted for sex and age; Abbreviations: Ref., reference values; OR- odds ratio; 95 % CI = 95 % confidence interval; HDL - high-Density Lipoprotein; TGL- triacylglycerols. Source: research data.

DISCUSSION

Five dietary patterns were identified in this group of overweight and obese adolescents, with the 'Meat and eggs' pattern explaining most of the total variance. The dietary patterns 'Meat and eggs' and 'Soup and cereals' showed associations with cardiometabolic markers. Higher adherence to the 'Meat and eggs' pattern was positively associated with triacylglycerols levels and negatively associated with HDL-cholesterol levels, whereas the 'Soup and cereals' pattern had a significant positive association with triacylglycerols levels and categories. In the analysis adjusted for age and sex, these associations remained consistent. However, in the logistic regression analysis, only the 'Meat and eggs' pattern remained associated with hypertriglyceridemia.

The number of dietary patterns identified in this study was similar to those found in other studies.[28-30] The percentage of dietary patterns found was 59.2%, higher than that reported in other studies of adolescents, which ranged from 24% to 53.98%[8,31,32]. The pattern that best represented adolescent dietary consumption was labeled 'Meat and eggs', with high component loadings for the food groups fish, poultry, and eggs, and red meat (beef and pork).

Similar dietary patterns in nomenclature and components to the 'Meat and eggs' pattern have been identified in other groups of adolescents living in southern Brazil,[33] France,[30] and China.[34] However, it is often observed that red meat is a component of dietary patterns labeled as Western, which are considered unhealthy in studies conducted with adolescents.[13,29] Differences in the composition and nomenclature of dietary patterns may be due to the inherent subjectivity of the PCA method used to derive dietary patterns[27]and should be taken into account when comparing studies. From a nutritional perspective, meat in general is a source of high-quality protein, B vitamins, iron, zinc, phosphorus and magnesium.[35] The nutritional composition and associations between consumption and cardiometabolic markers vary depending on the type of meat and how it is prepared.[36] Fish, poultry, and eggs are often part of healthy dietary patterns,[8,29,31] while red and processed meats are typically part of dietary patterns considered unhealthy.[33,37]In this study, adolescents with higher adherence to the dietary pattern labeled 'Meat and eggs' were 2.76 times more likely to experience an increase in plasma triacylglycerols levels compared with those with lower adherence.

Associations between cardiometabolic markers and adherence to meat-based dietary patterns have been reported in studies of adolescents. In France, the *High protein and animal fat* dietary pattern, characterized by high consumption of red meat, animal fat, milk, and yogurt, was positively associated with higher plasma triacylglycerols concentrations in all models after adjustment for sex and age.[8] In obese adolescents aged 14-19 years from São Paulo, Brazil, the *Traditional* dietary pattern, consisting of rice and pasta, beans, red meat, processed meat, oils, and sweets, and the *Transitional* dietary pattern, consisting of fish, poultry, eggs, bread, butter, milk and dairy products, vegetables, fruits, fruit juices, and refined sugar, showed a positive association with plasma insulin, glucose, and triglyceride levels and a negative association with HDL cholesterol levels, with adjustment for maternal income, maternal education, and adolescent body mass index.[10] Similarly, the *Western* dietary pattern, consisting of rice, fish, red meat, and dark and light vegetables, was associated with higher plasma concentrations of glucose, LDL-cholesterol, and triacylglycerols in Chinese children[11] Overweight and obese Iranian adolescents who were in the highest tertile of consumption of the Western dietary pattern, consisting of processed and red meats, organ meats, poultry, dairy products, potatoes, refined grains, pizzas, snacks, sweets, desserts, soft drinks and oils and fats, also had higher levels of BP, insulin, triacylglycerols and HOMA-IR and lower levels of HDL cholesterol.[37]

In addition to the association with triacylglycerols levels, this study also found an inverse association between the 'Meat and eggs' dietary pattern and plasma HDL-cholesterol levels. It seems that high in sugars and saturated and *trans* fats dietary patterns are negatively associated with HDL-cholesterol.[10,11] Higher adherence to the *Processed meat and fast-food* dietary pattern was associated with lower HDL-cholesterol levels in adolescent females from Pelotas, southern Brazil.[33]

Metabolic and physiological mechanisms may explain the potential effect of a meat-based dietary pattern on serum lipid concentrations, manifested by elevated triacylglycerols levels and low HDL cholesterol levels. Components of meat and its preparations, such as cholesterol, saturated fatty acids, *trans* fatty acids, L-carnitine, and heme iron, have effects on lipid metabolism and an increased risk of cardiovascular events.[38] Cholesterol, when incorporated into lipoproteins and leading to increased hepatic production of very low-density lipoproteins (VLDL), may contribute to elevated plasma triacylglycerols levels. Excess saturated and *trans* fats play an important role in lipid alterations by stimulating hepatic

secretion of VLDL. In plasma, enzymes and transfer proteins remodel VLDL and other lipoproteins, potentially interfering with the activity of enzymes responsible for the removal of circulating triacylglycerols.[39] *Trans* fatty acids have the additional metabolic effect of reducing HDL cholesterol levels by inhibiting its synthesis.[39] L-carnitine and iron, particular components of red meat products, may also explain changes in the lipid profile. High concentrations of L-carnitine may result in increased transport of fatty acids into cells, leading to lipid accumulation and elevated triacylglycerols.[38] Iron, on the other hand, has pro-oxidant effects, leading to oxidative stress and lipoprotein oxidation.[38]

Excessive consumption of animal protein, especially red and processed meat, has been associated with an increase in adiposity and hypertension.[34,40] However, red meat and processed meat should be distinguished when examining associations with health problems.[38] In this study, the ‘Bread and processed meat’ dietary pattern did not show an association with the cardiometabolic markers studied. It is important to note that the influence of individual food consumption on chronic diseases cannot be easily extrapolated to the analysis of dietary patterns, as they represent a combination of foods.[38] The association found between the ‘Meat and eggs’ dietary pattern and cardiometabolic markers in adolescents may have been influenced by various factors, such as food amount, type of animal protein, method of preparation, and interaction with other foods, since effects on disease result from the interaction of multiple dietary components rather than from isolated food components. Understanding dietary components is essential to understanding results completely.

However, high consumption of meat in diets deserves attention, as it is associated with an unfavorable cardiometabolic profile. This scenario is influenced by the local culinary tradition in southern Brazil, which emphasizes the frequent consumption of beef, such as *charque* and *churrasco*, characterized by high saturated fat and sodium content, as well as the widespread use of lard in food preparation. Therefore, understanding these dietary nuances is crucial for a comprehensive assessment of health-related outcomes.

As a limitation, dietary intake is subject to recall bias and social desirability bias, which may lead to underreporting of food consumption by overweight and obese adolescents and result in inaccurate reports of dietary intake. The PCA statistical method may also be subjective, as decisions made by the researcher during the analysis process, such as the combination of

food groups, the number of components retained, and the criteria for labeling identified patterns, may influence the results. Strengths include the use of a validated dietary assessment tool for adolescents and a representative sample to derive dietary patterns using the PCA method, a method accepted for this purpose in nutritional epidemiology.

CONCLUSION

The ‘Meat and eggs’ dietary pattern, which best represented the consumption pattern of this sample of overweight and obese adolescents, was associated with lower HDL cholesterol and higher triacylglycerols levels, with an increased risk of elevated triacylglycerols based on tertiles of adherence to the pattern.

These findings highlight the importance of ongoing nutritional interventions to promote healthy and balanced eating habits, as pathological processes may be initiated during childhood and adolescence due to the association of various risk factors, including obesity.

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