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Association between magnesium, selenium and zinc consumption and lipid profile of brazilian adolescents

Asociación entre el consumo de magnesio, selenio y zinc y el perfil lipídico de los adolescentes brasileños

ABSTRACT

The study aims to evaluate the association between inadequate consumption of antioxidant minerals and plasma lipoprotein concentrations in adolescents. We conducted a cross-sectional study that evaluated sociodemographic and anthropometric data, information on intake of magnesium, selenium and zinc and lipid profile. Student's t-test was used to compare means between the groups and logistic regression to verify the strength of the association between the independent variables and lipid profile. Inadequate zinc consumption was associated with a higher chance of low HDL-c levels and lower chance of hypertriglyceridemia and high LDL-c levels. Inadequate selenium intake was associated with a lower chance of high total cholesterol and of high triglyceride concentrations and a higher chance of low HDL-c levels. Inadequate magnesium consumption was associated with a higher chance of high cholesterol and triglyceride levels, a lower chance of high LDL-c levels and with a higher chance of low HDL-c. We observed an association between inadequate consumption of magnesium, zinc and selenium and changes in the lipid profile of adolescents.

Keywords: Adolescents; Magnesium; Lipid metabolism; Selenium; Zinc.

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RESUMEN

El estudio tiene como objetivo evaluar la asociación entre el consumo inadecuado de minerales antioxidantes y las concentraciones plasmáticas de lipoproteínas en adolescentes. Estudio transversal que evaluó datos sociodemográficos y antropométricos, información sobre ingesta de magnesio, selenio y zinc y perfil lipídico. Se utilizó la prueba t de Student para comparar medias entre los grupos y regresión logística para verificar la fuerza de la asociación entre las variables independientes y el perfil lipídico. El consumo inadecuado de zinc se asoció con una mayor probabilidad de niveles bajos de HDL-c y una menor probabilidad de hipertrigliceridemia y niveles altos de LDL-c. La ingesta inadecuada de selenio se asoció con una menor probabilidad de colesterol total alto y de altas concentraciones de triglicéridos y una mayor probabilidad de niveles bajos de HDL-c. El consumo inadecuado de magnesio se asoció con una mayor probabilidad de niveles altos de colesterol y triglicéridos, una menor probabilidad de niveles

altos de LDL-c y una mayor probabilidad de niveles bajos de HDL-c. El estudio muestra una asociación entre el consumo inadecuado de magnesio, zinc y selenio y los cambios en el perfil lipídico de los adolescentes.

Palabras clave: Adolescentes; Magnesio; Metabolismo de los lípidos; Selenio; Zinc.

INTRODUCTION

Dyslipidemia is characterized by changes in lipoprotein metabolism, standing out as a relevant risk factor for the development of atherosclerotic cardiovascular diseases¹. Changes in lipid profile in childhood and adolescence require prophylactic actions, as they contribute to the increased risk of atherosclerosis, a relevant factor for the occurrence of myocardial

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infarction and cerebrovascular accidents in adulthood².

Familial hypercholesterolemia is characterized by high cholesterol levels early in life and when untreated it is associated with prematurity of cardiovascular disease in adults³. In this sense, Bibbins-Domingo et al⁴ showed an association between lipid levels in childhood and adolescence and atherosclerosis in adulthood.

Studies have shown a high prevalence of dyslipidemia among adolescents^{5,6}. Data from the Study of Cardiovascular Risks in Adolescents (ERICA), conducted in 2016 in Brazil, indicated that 46.8%, 20.1% and 7.8% of adolescents had low levels of HDL-c, hypercholesterolemia and hypertriglyceridemia, respectively⁷.

Some micronutrients have been related to cardiovascular defense, among them magnesium, selenium and zinc, antioxidant minerals that can act in the regulation of lipid profile^{8,9}. However, studies show that Brazilian adolescents consume high levels of ultra-processed foods, simple sugars, saturated fats, and low levels of fruits, which may impair the intake of these minerals^{10,11}.

Considering the high prevalence of dyslipidemia among adolescents, and the inadequate consumption of antioxidant micronutrients, as well as a lack of studies on the association between these variables, this study aimed to evaluate the average intake of magnesium, selenium and zinc and the lipid profile of adolescents in Brazil, as well as the association between these parameters.

MATERIALS AND METHODS

Study design and participants

The Study of Cardiovascular Risks in Adolescents was a cross-sectional, descriptive, multicenter, school-based and nationwide study that evaluated Brazilian adolescents aged 12 to 17 years, from public and private schools, from February 2013 to November 2014.

The sample size calculation was based on 32 geographic strata and conglomerates of schools and classes, with national, macroregional and capital representativeness. In the sampling process, 1251 schools in 124 municipalities out of a total of 273 municipalities with more than 100,000 inhabitants were selected¹².

The sample consisted of 37,023 adolescents, students of the morning shift in the last three grades of elementary school (seventh, eighth and ninth grade) or in the first, second or third grade (high school) of public and private schools in the different regions of Brazil that presented complete data on Personal Digital Assistant (PDA), blood analysis, and 24-hour dietary recall (R24hs). Pregnant adolescents and those with temporary or permanent physical disabilities that impaired anthropometric measurements were not included in the study.

Details about the protocol, design and sampling of the work have been described in detail in previous publications^{12,13,14}.

Data collect

Data collection was performed by previously trained evaluators using standardized techniques. Anthropometric evaluation was performed and R24h was applied to analyze

food consumption. In addition, blood was collected for lipid profile analysis¹³.

The dietary investigation consisted of an interview with the adolescents about their food intake in the previous 24 hours through the R24h. Two R24h were performed: the first with all adolescents, and the second in a subsample of two students per class^{14,15}. For this study, we chose to use only data from the 1st R24h.

Information pertaining to food intake was obtained using specific software and was recorded directly on netbooks. An interview technique based on the multiple-pass method was performed. The software contained a food list from the 2002-2003 Household Budget Survey, conducted by the Brazilian Institute of Geography and Statistics (IBGE). Regional foods that were not included in the list were added to our database^{11,13,15}.

Selenium, magnesium and zinc intake was estimated based on the Table of Nutritional Composition of Foods Eaten in Brazil and the Table of Reference Measures of Foods Eaten in Brazil¹⁰. The use of supplements or medications was not considered. After converting the food intake into grams, the dataset was linked to the nutritional composition table to obtain micronutrient consumption^{11,13,15}.

Mineral intake was categorized as adequate and inadequate (below recommendation) according to the Estimated Average Requirement (EAR) contained in the Dietary Reference Intake (DRI): magnesium: EAR= 200 mg/day (9 to 13 years – male and female); 340 mg/day (14 to 18 years – male) and 300 mg/day (14 to 18 years – female); selenium: EAR= 35 µg/day (9 to 13 years – male and female), and 45 µg/day (14 to 18 years – male and female); zinc: 7 mg/day (9 to 13 years – male and female), 8.5 mg/day (male) and 7.3 (female)^{16,17,18}.

For the collection of blood samples for analyses of lipid profile (total cholesterol, HDL cholesterol, LDL cholesterol and triglycerides), participants were instructed not to eat food for at least 10-12 hours. Blood was collected in the morning in a serum separator tube. Blood samples were processed and plasma and serum separated within two hours after collection and kept between 4° and 10 °C while moved to the study's single laboratory¹³.

Cholesterol and its fractions were analyzed by the following techniques: Total Cholesterol (TC) and Triglycerides (TGL) by Enzyme Kinetics; High Density Lipoproteins (HDL-c) by an Enzymatic Colorimetric Assay; and Low Density Lipoproteins (LDL-c) by the Friedewald Equation¹⁹.

Changes in plasma lipids were determined according to the Brazilian Guidelines for Dyslipidemias and Prevention of Atherosclerosis (2017), which establishes values considered undesirable for adolescents: TC ≥ 170 mg/dL; LDL-c ≥ 130 mg/dL; HDL-c < 45 mg/dL; and TGL ≥ 130 mg/dL¹.

To categorize weight status, used for statistical adjustment, weight and height data were collected and Body Mass Index (BMI) was calculated. Weight was measured using a digital scale (Líder® model P150m, 200 kg capacity and 50 g accuracy), and height was measured using a portable and detachable stadiometer (Altuxata®, maximum height recordable, 213 cm; resolution, 1 mm)¹⁴.

Body Mass Index was calculated as BMI= weight/height² and classified by age and sex-specific BMI curves proposed by the World Health Organization (WHO)²⁰. This classification indicates the following categories: very low weight (<z-score -3); low weight ($\geq$ z-score -3 <z-score -2); eutrophy ($\geq$ z-score -2 and $\leq$ z-score +1); overweight (>z-score +1 and $\leq$ z-score +2); and obesity (>z-score +2).

For statistical adjustment, weight status was categorized as: 0 indicating non-overweight (underweight and eutrophic) individuals; and 1 indicating overweight (overweight or obese) individuals.

Statistical analysis

Data analyses were performed in the Stata® software (Statacorp, College Station, Texas, USA) version 14.0, using the survey module to analyze complex sample data. Shapiro-Wilk normality test was used to check the normality of distribution and equality of variances.

Student's t-test was used to compare means between the variables of lipid profile and dietary intake of magnesium, selenium and zinc, according to sex, age group and type of school.

A logistic regression model was used to verify the associations between the independent variables and lipid

profile, using odds ratio (OR) with respective 95% confidence intervals (95% CI). Crude and adjusted OR values were estimated by sex, age group, type of school and weight status. The adopted significance level was 5%.

Ethical aspects

The study was approved by the Research Ethics Committees of the Institute of Collective Health Studies of the Federal University of Rio de Janeiro (Opinion n° 01/2009, Process 45/2008) and by the committees of the institutions responsible for conducting the study in each Brazilian state and the Federal District.

All participants interviewed and examined signed an Assent Form and provided an Informed Consent Form signed by their guardians.

RESULTS

A total of 37,023 Brazilian adolescents participated in the study, the majority (60%) being female. Table 1 shows the average dietary intake of magnesium, selenium and zinc in Brazilian adolescents, stratified by sex, age group and type of school.

Mineral intake was significantly higher among male adolescents. No significant differences were observed in the average consumption of minerals by school types (Table 1).

Table 1. Average dietary intake of antioxidant minerals in Brazilian adolescents stratified by sex, age group and type of school. ERICA, 2013-2014.

Parameters	Magnesium (mg)		Selenium (µg)		Zinc (mg)	
	Mean	95% CI	Mean	95% CI	Mean	95% CI
Sex						
Male (n = 14.811)	281	265-297	111	104-118	14.5	13.9-15.0
Female (n = 22.212)	228	221-234	91.0	87.9-94.1	11.5	11.2-11.8
p value	<0.001		<0.001		<0.001	
Age group						
12 to 13	245	227-263	97.1	89.3-105	12.4	11.8-13.0
14 to 17	262	255-269	104	100-108	13.4	13.0-13.8
p value	0.067		0.066		0.004	
Type of school						
Public (n = 27.268)	257	245-269	100	95.9-105	13.0	12.6-13.4
Private (n = 9.755)	245	233-257	103	94.7-111	12.8	12.0-13.7
p value	0.158		0.598		0.791	
Total population (n = 37.023)	254	244-264	101	96.8-105	12.9	12.6-13.3

Student's t-test. CI = confidence interval.

The average consumption of zinc and selenium by adolescents of all sexes and age groups was above the recommendation. In turn, the average intake of magnesium of adolescents of both sexes aged 14 to 17 years was below recommended levels.

Table 2 shows the relative frequency of the magnesium, selenium and zinc consumption profile of Brazilian adolescents according to sex. Most adolescents of both sexes consumed adequate levels of selenium and zinc, and inadequate levels of magnesium.

Table 3 shows the association between inadequate intake of the studied minerals and plasma lipid concentrations. Inadequate zinc consumption was associated with a higher chance of low HDL-c levels in males, even after adjusting for weight status, sex, age group, and school type.

There was also an association between inadequate consumption of this mineral and lower chance of hypertriglyceridemia among adolescents aged 14 to 17 years and among boys, an association that was also significant after adjustments. An association of inadequate zinc consumption was found with lower chances of high LDL-c levels among adolescents attending private school.

Inadequate selenium intake was found to be associated with a lower chance of high TC among 12- to 13-year-old female adolescents and a higher chance of low HDL-c levels in girls. Inadequate selenium intake, i.e. consumption below the recommendation, was associated with a higher chance of low HDL-c concentrations among adolescents attending

private schools. Inadequate selenium intake also decreased the chances of high triglyceride concentrations in the total sample and in males.

Inadequate magnesium consumption was associated with a higher chance of hypercholesterolemia and hypertriglyceridemia and a lower chance of high LDL-c levels in females. Among boys, inadequate magnesium consumption was associated with a higher chance of low HDL-c and high LDL-c concentrations.

DISCUSSION

This study evaluated the intake of magnesium, selenium and zinc and its association with the lipid profile of adolescents of both sexes attending private or public schools.

Adolescents are in an age group characterized by inadequate eating habits, with high consumption of ultra-processed foods rich in sodium, sugar and fat^{10,21}. These habits are linked to the development of chronic diseases such as dyslipidemia, whose prevalence is high in increasingly early age groups. Some antioxidant minerals like magnesium, selenium and zinc have been suggested to prevent changes in lipid concentrations^{9,22}.

In this study, it was observed that adolescents of both sexes and types of school consumed adequate amounts of selenium and zinc. Similar results were found in the Individual Food Consumption Survey conducted at the V Family Budget Survey¹⁰ with adolescents aged between 10 and 18 years, of both sexes, and in studies carried out in Brazil²³ and in the in the United States²⁴.

Table 2. Relative frequency of magnesium, selenium and zinc consumption profile in Brazilian adolescents by sex (n = 37.023). ERICA, 2013-2014.

Intake	Male (n= 14.811) %	Female (n= 22.212) %	Total population (n= 37.023) %	p value
Magnesium				
Adequate	38.9	30.0	34.4	<0.001
Inadequate	61.1	70.0	65.5	
Selenium				
Adequate	87.4	81.1	84.3	<0.001
Inadequate	12.6	18.9	15.7	
Zinc				
Adequate	77.4	70.0	73.7	<0.001
Inadequate	22.6	30.0	26.3	

Chi-square test.

Table 3. Association between inadequate antioxidant mineral intake and lipid profile - crude and adjusted odds ratio (OR) for sex, age group, type of school, and weight status. ERICA, 2013-2014.

INADEQUATE CONSUMPTION	LIPID PROFILE							
	Hypercholesterolemia		Low HDL-c		High LDL-c		Hypertriglyceridemia	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Zinc								
Total sample	1.06	0.92-1.24	1.07	0.97-1.19	0.90	0.75-1.06	0.92	0.82-1.02
Female	1.01	0.85-1.20	1.06	0.94-1.20	0.91	0.74-1.13	1.07	0.94-1.23
Male	1.01	0.78-1.30	1.28*	1.06-1.55	0.95	0.73-1.23	0.72*	0.57-0.90
12 to 13 years	0.93	0.72-1.21	1.22	0.96-1.54	0.89	0.71-1.12	1.09	0.92-1.30
14 to 17 years	1.13	0.96-1.34	1.01	0.88-1.16	0.90	0.73-1.10	0.85*	0.74-0.98
Public school	1.08	0.91-1.28	1.11	0.99-1.26	0.95	0.77-1.17	0.91	0.80-1.05
Private school	1.02	0.76-1.38	0.95	0.80-1.12	0.78*	0.61-0.99	0.91	0.78-1.07
Adjusted OR	0.98	0.84-1.13	1.11*	1.01-1.23	0.97	0.82-1.14	0.87*	0.78-0.97
Selenium								
Total sample	0.89	0.80-1.00	1.08	0.95-1.24	0.99	0.82-1.18	0.78*	0.77-0.97
Female	0.85*	0.74-0.97	1.20*	1.04-1.37	1.12	0.90-1.40	0.94	0.80-1.11
Male	0.80	0.60-1.02	1.19	0.89-1.60	0.90	0.64-1.24	0.74*	0.57-0.95
12 to 13 years	0.58*	0.41-0.82	1.27	0.99-1.62	1.20	0.89-1.60	0.97	0.70-1.36
14 to 17 years	1.01	0.87-1.18	1.00	0.86-1.17	0.95	0.75-1.20	0.86	0.74-1.01
Public school	0.92	0.80-1.06	1.01	0.87-1.18	1.04	0.83-1.28	0.89	0.77-1.01
Private school	0.88	0.72-1.07	1.33*	1.01-1.75	0.81	0.60-1.09	0.85	0.70-1.06
Adjusted OR	0.82*	0.73-0.92	1.10	0.96-1.26	1.10	0.91-1.31	0.83*	0.73-0.93
Magnesium								
Total sample	1.08	0.94-1.25	1.09	0.98-1.21	0.93	0.80-1.09	1.05	0.95-1.17
Female	1.21*	1.02-1.45	1.06	0.92-1.23	0.77*	0.66-0.90	1.25*	1.08-1.43
Male	0.83	0.68-1.02	1.30*	1.10-1.51	1.27*	1.02-1.58	0.89	0.74-1.06
12 to 13 years	1.00	0.86-1.18	1.05	0.90-1.23	0.93	0.73-1.20	1.10	0.94-1.30
14 to 17 years	1.21	0.98-1.50	1.00	0.85-1.16	0.95	0.76-1.18	1.13	0.95-1.36
Public school	1.12	0.93-1.35	1.11	0.98-1.26	0.90	0.73-1.10	1.05	0.93-1.18
Private school	1.08	0.94-1.25	0.95	0.81-1.12	0.99	0.81-1.20	1.13	0.87-1.46
Adjusted OR	1.01	0.88-1.16	1.02	0.91-1.15	1.05	0.91-1.22	1.02	0.92-1.15

Logistic regression. *p value<0,05. HDL-c: High-Density Lipoprotein cholesterol; LDL-c: Low-Density Lipoprotein cholesterol; OR: Odds Ratio.

Previous research conducted with data from ERICA showed that rice, beans, breads, juices, soft drinks and beef were the foods most consumed by adolescents, regardless of sex and age group¹⁵. Beans and meat are sources of zinc, what may explain the proper consumption of this mineral

by adolescents²⁵. In a study by Retondário et al²⁶, also with data from ERICA, meat, pasta, poultry and fish were the foods that contributed the most to the amount of selenium consumed by this group.

However, it was observed that male and female

adolescents aged 14 to 17 years had magnesium consumption below recommended levels, similar to the results found by Brazilian authors^{27,28} and in the National Health and Nutrition Examination Survey conducted in the United States²⁹. The NHANES results showed that almost half of the individuals evaluated had inadequate magnesium intake, which was higher in the 14 to 18 years old group, as in the present study.

Magnesium is the fourth most abundant mineral in the body and plays an important role as a cofactor in protein synthesis, cell energy production and storage, DNA and RNA synthesis, and mitochondrial membrane stabilization³⁰. Inadequate consumption of this mineral may be related to the low intake of its dietary sources, such as whole grains, green leafy vegetables, fruits, vegetables and tubers. Studies show that fruits and vegetables are among the least consumed foods by Brazilian teenagers^{10,31}.

Magnesium acts as a cofactor for several important enzymes of lipid metabolism. This mineral has been reported to increase HDL-c and reduce LDL-c and TGL by restricting the action of lecithin-cholesterol acyltransferase (LCAT) and HMG-CoA reductase, and increasing lipoprotein lipase (LPL) activity^{32,33}. In addition, it is assumed that magnesium may decrease its absorption by forming a non-absorbable soap with fatty acids and cholesterol in the intestine^{34,35}. As demonstrated in previous study that used ERICA data, the consumption of saturated fatty acids by the adolescents exceeded the recommended maximum limits of total energy intake¹¹.

Zinc is one of the most common trace elements in the human body and plays a role in growth and development, acting as a signaling factor³⁶. Regarding the association of inadequate zinc consumption with the lipid profile of the participants, this finding can be explained by the antioxidant role of this mineral. Decreasing zinc concentrations may lead to increased lipid peroxidation and increased TC, TGL and LDL-c levels by the releasing of cholesterol stored in lipid droplets of adipose tissue cells during stress^{8,37}. Zinc supplementation studies have reported reduced TC, TGL and LDL-c levels and increased HDL-c levels in the plasma^{8,38,39}.

The association between inadequate consumption of this mineral and lower chance of hypertriglyceridemia and high LDL-c levels may be related to the fact that some of the main sources of zinc, such as beef, consumed in large quantities by the adolescents evaluated, as reported by researchers who have previously published this data from the ERICA study¹¹, are also sources of saturated fats that may increase concentrations of lipid fractions⁴⁰.

Selenium is a trace element that acts in antioxidant defense, regulation of intracellular redox signaling and apoptosis, DNA and protein synthesis, immunomodulation, and metabolism of thyroid hormones. The potential cardiovascular benefits of this mineral are supported by the ability of selenoproteins, such as glutathione peroxidase and selenoprotein S, to combat oxidative lipid modification, inhibit platelet aggregation and reduce inflammation⁴¹.

In addition, selenium is related to the reduced expression

of fatty acid synthase, a catalyst protein in fatty acid synthesis. In addition, some studies indicate the role of this mineral in the metabolism of the thyroid hormones triiodothyronine (T3) and thyroxine (T4), which in turn have significant effects on plasma lipoprotein synthesis, mobilization and metabolism^{42,43,44}.

It is noteworthy that, in addition to minerals, non-modifiable factors such as genetics, age and sex, as well as modifiable factors such as overall diet and physical activity exert important influences on blood lipid concentrations. The present study included sex, age, type of school and weight as control variables.

Because this is a cross-sectional study, it is impossible to determine cause and effect relationships. Besides, the fact that the use of supplements or medications was not considered may have been a bias in the study. Considering the problem involving the relationship between inadequate consumption of antioxidant minerals and changes in lipid metabolism in Brazilian adolescents, it is suggested that interventions focus on behavioral changes and lifestyle in this group. Food and nutrition education in the school and family contexts can be a useful tool in improving the diet quality of this population.

CONCLUSIONS

The present study demonstrated a low consumption of magnesium by Brazilian adolescents of both sexes and an association between inadequate consumption of magnesium, zinc and selenium with their lipid profile. Considering that the ERICA study was the first with a representative sample involving adolescents in Brazil, including all capitals in the country and interior cities with more than 100 thousand inhabitants, the importance of its results is evident.

In this perspective, further research needs to be conducted with this population, in particular intervention studies with food and nutrition education and supplementation, in order to highlight effective ways to prevent cardiovascular diseases early.

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Conflicts of interests. The authors declare having no conflicts of interest.

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