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Magnesium intake in a Longitudinal Study of Adult Health: associated factors and the main food sources

Ingestão de magnésio no Estudo Longitudinal de Saúde do Adulto: fatores associados e os principais alimentos contribuintes

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Abstract *This study aimed to identify the sociodemographic and lifestyle factors associated with magnesium intake and describe the main food sources in the Brazilian Longitudinal Study of Adult Health (ELSA-Brazil). This observational, cross-sectional study was conducted using the baseline data from the ELSA-Brazil (2008–2010). Associations between usual magnesium intake and sociodemographic and lifestyle factors were analyzed using multiple linear regression. Food sources were identified by calculating the percentage contribution of each FFQ item to the amount of magnesium provided by all foods. The analysis was performed using Stata® software (version 12), assuming a statistical significance level of 5%. The top food sources to magnesium intake were as follows: beans, oats, nuts, white rice, orange, French bread, cooked fish, boneless meat, whole milk, and whole wheat bread. There were positive associations between magnesium intake and female sex; age ≥60 years; self-reported black, indigenous, or brown skin colors; per capita income ≥3 minimum wages, and moderate or vigorous physical activity levels. Sociodemographic and lifestyle factors were associated with magnesium intake among the evaluated individuals.*

Key words *Magnesium, Sociodemographic factors, Lifestyle, Food sources*

Resumo *O estudo tem por objetivo identificar fatores sociodemográficos e de estilo de vida associados à ingestão de magnésio e descrever seus principais alimentos contribuintes no Estudo Longitudinal de Saúde do Adulto (ELSA-Brasil). Trata-se de um estudo observacional, transversal, desenvolvido com dados da linha de base do ELSA -Brasil (2008-2010). Associações entre a ingestão habitual de magnésio e fatores sociodemográficos e de estilo de vida foram testadas por regressão linear múltipla. Contribuintes alimentares foram identificados a partir do cálculo do porcentual de magnésio fornecido por cada item do QFA em relação quantidade total proveniente de todos os alimentos. Os principais alimentos contribuintes para a ingestão de magnésio foram: feijão, aveia, nozes, arroz branco, laranja, pão francês, peixe cozido, carne sem osso, leite integral e pão integral. Foram encontradas associações positivas entre consumo de magnésio e sexo feminino, faixa etária ≥ 60 anos, cor de pele autodeclarada como negra, indígena ou parda, renda "per capita" ≥ 3 salários mínimos e níveis de atividade física moderado ou vigoroso. Alimentos da dieta tradicional do brasileiro foram os maiores contribuintes para a ingestão de magnésio, que também foi influenciada por fatores sociodemográficos e de estilo de vida.*

Palavras-chave *Magnésio, Fatores sociodemográficos, Estilo de vida, Alimentos contribuintes*

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Introduction

Magnesium is the second most abundant intracellular ion and is involved in many metabolic functions, being vital for the activity of more 300 enzymes[1]. It plays an important role in ATP synthesis and activates almost all glycolytic enzymes and those of citric acid cycle. It is related to cell membrane permeability and electrical activity, besides being important for bone mineralization, muscle relaxation, and neurotransmission[2-4]. Deficiency of this ion can favor the development of various chronic noncommunicable diseases (NCDs), such as metabolic syndrome[5-7], type 2 diabetes mellitus[8,9], fibromyalgia[10], hypertension[8,11,12], osteoporosis[13], and cardiovascular diseases[14].

The Estimated Average Requirement (EAR)[15] of magnesium is between 255 mg and 265 mg for women and between 330 mg/day and 350 mg/day for adult and elderly men. Magnesium is present in dark green vegetables, legumes, oilseeds, milk and dairy products, and whole grains. Fish, meat, and some fruits are the poorest sources of this mineral[2]. In the United States, 60% of the adult population have insufficient magnesium intake to attend the EAR[16]. This scenario was observed in more than 70% of the Brazilian adult population, according to the 2008-2010 National Food Survey (INA)[17].

Food consumption of an individual or a population is strongly influenced by age, sex, income, and schooling[18-20]. In Brazil, family income is positively associated with the consumption of milk, meat, fruits, vegetables, and legumes; however, the consumption of vegetables and legumes is moderate even in the richest stratum of the population[17]. Furthermore, some studies reported that families in less favored socioeconomic strata and mothers with lower educational level consume more sweets and products rich in fat[20].

Knowledge about food components of a population diet and the identification of the determinants of nutrient consumption can serve as subsidies for the formulation of public policies for the promotion of healthy eating and of combating NCDs. This study aimed to identify the sociodemographic and lifestyle factors associated with magnesium intake and describe the main foods that contribute to this nutrient among participants of the Longitudinal Study of Adult Health (ELSA-Brazil), the largest multicenter cohort ever recruited for research incidence and risk factors of NCD in the Brazilian population[21].

Methods

Study population

This observational, cross-sectional study was developed using the baseline data from the ELSA-Brazil. ELSA-Brazil participants were recruited between August 2008 and December 2010. ELSA-Brazil is a cohort of 15,105 participants of both genders, aged 35–74 years, and are active and retired workers from six different states of Brazil: Espírito Santo, Minas Gerais, Bahia, São Paulo, Rio de Janeiro, and Rio Grande do Sul. Data were collected by trained and certified personnel under strict quality control[21-23]. Those without food consumption information (n = 24) were excluded from this study, totaling 15,081 participants. Individuals below the 1st percentile and above the 99th percentile of the total energy intake estimates (n = 362) were also disregarded in order to exclude possibly invalid food intake data. Thus, the final study sample consisted of 14,719 individuals.

The ELSA-Brazil was approved by the research ethics committees of all its research centers. All individuals voluntarily participated in this study and signed an informed consent form.

Food consumption assessment

The food frequency questionnaire (FFQ) developed and validated for ELSA-Brazil was used to evaluate the habitual food consumption of participants in the last 12 months[24]. This semiquantitative FFQ has 114 food items and is answered by interview. The questions are structured into 3 sections: (1) food/preparations, (2) consumption portion measures, and (3) consumption frequencies, with 8 response options: “more than 3 times/day,” “2–3 times/day, “”once a day,””5–6 times a week,””2–4 times a week, “”once a week,”” 1–3 times a month,” and “never/almost never.” At the end of the FFQ, participants were asked if they changed their dietary intake or if they did a restrictive diet over the past six months, being the participants able to answer yes or no to this question.

To evaluate energy and nutrient intakes, we used the United States Department of Agriculture (USDA) Food Composition Database, except when its values were outside of the range of 80% to 120% from those described in the Brazilian Table of Food Composition, which cases the latter database was used[24]. To reduce the errors

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associated with dietary measurement, magnesium intake was adjusted by total energy intake using the residue method[25]. Energy-adjusted values were employed both in the stratification of quantiles and linear regression analysis.

Sociodemographic and lifestyle factors

The choice of sociodemographic and lifestyle factors that could influence the dietary pattern was based on previous studies that addressed the determinants of food intake in the Brazilian adult population[18,19]. Therefore, sex, age, schooling, income, self-reported skin color, smoking and alcohol habits, nutritional status, and physical activity level were selected for this study.

Participants were classified according to sex as male and female) and according to age as adults (34–59 years) and elderly (≥ 60 years). Schooling was categorized as "complete elementary school," "complete high school," and "higher education or postgraduate." The family income *per capita* was initially calculated as equivalent to the average minimum wage in the period between 2008 and 2010 (R$ 463.33) and then stratified into < 3 or ≥ 3 minimum wages. The following categories of self-reported skin color proposed by the Brazilian Institute of Geography and Statistics in the demographic census were questioned: "white," "black," "brown or mixed," "yellow," and "indigenous"[26]. Due the low frequency of yellow and indigenous reporters, these two categories were collapsed for analysis.

Smoking was evaluated using a semi-structured questionnaire about smoking habits at the time of the interview and in the past. Based on this questions, participants were categorized as "non-smokers," "former smokers," or "smokers." Alcohol consumption data (grams of ethanol/day) were obtained from the FFQ. Participants were classified as alcohol "non-consumers" or "consumer" based on the reporting of consumption of any alcoholic beverages in the previous 12 months, irrespective of its frequency or amount.

To assess nutritional status, body mass index (BMI) was calculated and classified according to the World Health Organization criteria: low weight (< 18.5 kg/m^2), eutrophia (18.5–24.9 kg/m^2), overweight (25–29.9 kg/m^2), and obesity (≥ 30 kg/m^2)[27]. For the evaluation of physical activity level, we used the International Physical Activity Questionnaire (IPAQ)[28], which consist in predetermined questions on frequency and duration of walking as well as moderate and vigorous physical activities at work, commuting, home and leisure times[29]. For the purposes of this study, we used only the domain of physical activity during leisure time, considering that these types of activities has been more consistently associated with socio-demographic factors, such as income, age, schooling and sex[30]. Moreover, physical activity in leisure is most frequently studied in epidemiological surveys[31,32].

Statistical analysis

The consumption of energy-adjusted magnesium was stratified in quintiles in order to better represent the ranking of dietary magnesium, and sociodemographic and lifestyle factors were described according to the lowest (1st quintile) and highest (5th quintile) levels of its intake. Sociodemographic and lifestyle factors were presented as frequencies and percentages according to the sex of the participants. Pearson's chi-squared test was used to evaluate the significant associations between variables.

The contribution of food to magnesium intake was calculated according to the methodology proposed by Block et al.[33]. Magnesium provided by each food item was divided by the total population magnesium intake to obtain the contribution of each food item. Then, the foods were listed according to the contribution ranking[34].

The associations between energy-adjusted magnesium intake (mg/day, dependent variable) and sociodemographic and lifestyle factors (predictors) were tested by multiple linear regression analysis using the *stepwise backward* method. The energy-adjusted magnesium consumption variable approaches normality, according to the Shapiro-Wilk test and the use of histogram and Q-Q plot graphs, thus meeting this assumption for multiple linear regression.The sociodemographic and lifestyle factors included in the model were sex (reference: male), age (reference: adults), income (reference: < 3 minimum salaries), skin color (reference: white), schooling (reference: complete primary school), smoking (reference: non-smoker), alcohol consumption (reference: non-consumer), assess nutritional status (reference: eutrophy) and physical activity (reference: light).

The multiple model was further adjusted by self-reported change in dietary habits over the past 6 months. All analyses were performed using the Stata® (version 12) software, assuming a level of statistical significance of 5%.

Results

The sample consisted of 14,719 participants, predominantly adults (78.5%), female sex (54.6%), non-smokers (57.1%), self-reported as white (52.6%), and with a higher education level or a post-graduate level (53.2%). As regards nutritional status, 40.3% of the population was classified as overweight and 22.8% were obese.

The distribution of sociodemographic and lifestyle characteristics according to the magnesium intake of men and women is presented in Table 1. Higher proportions of the elderly and individuals with a higher education or who achieved a postgraduate level, with income ≥ 3 minimum wages, who are former or non-smoker, with eutrophia, and with moderate or vigorous physical activity level had magnesium intake in the last quintile, compared with the first (Table 1).

The top ten contributors to magnesium intake are described in Table 2. The highest contributors were beans (24.0%), oats (4.5%), nuts (3.6%), white rice (3.3%), orange (3.3%), French bread (3.2%), cooked fish (3.0%), boneless meat (2.6%), whole milk (2.3%), and whole-grain bread (2.1%) (Table 2).

Except for schooling, all other sociodemographic and lifestyle variables investigated were independently associated with magnesium intake. As shown in Table 3, positive and significant correlations were found between intake of magnesium and female gender; age ≥60 years; skin color self-declared as black, brown, or indigenous; income ≥3 minimum wages; and moderate or vigorous physical activity levels. By contrast, smoking, alcohol consumption, and overweight or obesity were negatively associated with magnesium intake (Table 3).

Discussion

In this study, variations in magnesium intake among ELSA-Brazil participants (2008–2010) were explained by sociodemographic characteristics that influence food sources, such as sex, age, race/ethnicity, and family income. In addition, smoking and consume alcohol were lifestyle habits that were negatively associated with mineral intake, as did obesity and overweight, while the opposite was evidenced in relation to the level of leisure physical activity, independently of other factors evaluated. Food sources that contributed to more than a half of total magnesium consumption included beans, cereals (oats, rice, and French bread), nuts, oranges, meats (fish and cattle), and milk, although dark green vegetables, almonds, nuts, and legumes had little expressive participation, suggesting a possible dietary inadequacy[17,35,36].

Consistent with our observations, in a population-based study, Sales et al.[35] reported that more than a quarter of the magnesium in the diet of São Paulo inhabitants came from beans, rice, and French bread, confirming the important contribution of typical Brazilian food standards. Moreover, age had a positive effect on the intake of magnesium and other minerals, such as calcium, phosphorus, and potassium, signaling better quality of diet among the elderly, in relation to adults and adolescents[35]. In our study, female gender, as well as age, was also associated with higher magnesium intake. In a previous analysis performed with the same ELSA-Brazil sample, Cardoso et al.[37] revealed that women and elderly had higher adherence to a "healthy" diet characterized by vegetables and fruits[38], which could be related to the higher intake of magnesium among these individuals.

According to the data from POF 2008–2009, in the Brazilian population, schooling and income are indicators of socioeconomic status independently associated with the higher consumption of saturated fat, sodium, and lower consumption of fiber, indicating that purchasing power and educational level do not necessarily determine better food choices in our social context[33]. Furthermore, analyses showed that income, not schooling, was associated with higher magnesium intake, after adjusting for demographic and lifestyle characteristics. These findings may be due to factors related to access, availability, and prices of magnesium food sources (dairy products, fresh meats, and vegetables)[18,38]. Notably, ELSA-Brazil participants, linked to teaching and research institutions, present a higher level of education than the general Brazilian population, which could make income a stronger determinant of food consumption. In fact, we notice a relatively higher contribution of oats, walnuts, cooked fish and whole grain bread, but lower of beans to the total magnesium intake among participants with an income per capita ≥ 3 minimum wages, suggesting a different pattern of this mineral food sources consumption among the richer participants (Supplementary Table 1), corroborating with literature[39,40].

By contrast, individuals with self-declared skin color such as brown, black, or indigenous

Table 1. Socio-demographic and lifestyle data according to magnesium intake in ELSA-Brasil. Brazil, 2008-2010.

Characteristics	Magnesium Intake (Quintiles)												
	Total			Male					Female				
			P	1º Q		5º Q		P	1º Q		5º Q		P
Magnesium Quintis (mg / day, min-max)	11,6 -1290,5			58,9 -388,7		532,4 -1290,5			11,6-388,6		532,3 -1252,5		
Age Group (n,%)													
Adults	11547	78,5	< 0,001	1320	82,3	1020	72,5	< 0,001	1142	85,2	1095	71,3	< 0,001
Elderly	3172	21,6		284	17,7	387	22,3		198	14,8	441	28,7	
Self-reported skin color (n,%)													
White	7653	52,6	< 0,001	836	52,9	711	51,3	0,384	583	44,1	796	52,4	< 0,001
Brown	4082	28,1		471	29,8	420	30,3		389	29,4	398	26,2	
Black	2304	15,8		221	14,0	206	14,9		308	23,3	268	17,6	
Others	514	3,5		53	3,3	48	3,5		42	3,2	58	3,8	
Schooling (n,%)													
Complete primary education	1813	12,3	< 0,001	256	16,0	229	16,3	< 0,001	161	12,0	121	7,9	< 0,001
Complete high school	5078	34,5		587	36,6	470	33,4		626	46,7	464	30,2	
Higher or Postgraduate	7828	53,2		761	47,4	708	50,3		553	41,3	951	61,9	
Income per capita (n,%)													
< 3 minimum wages	7312	49,7	< 0,001	886	55,2	709	50,4	< 0,001	842	62,8	618	40,2	< 0,001
≥3 minimum wages	7407	50,3		718	44,8	698	49,6		498	37,2	918	59,8	
Smoking (n,%)													
Non-smoking	8405	57,1	< 0,001	763	47,6	749	53,2	< 0,001	801	59,8	1009	65,7	< 0,001
Former smoker	4419	30,0		542	33,8	517	36,7		318	23,7	413	26,9	
Smoker	1894	12,9		299	18,6	141	10,0		221	16,5	114	7,4	
Alcohol consumption (n,%)													
Non-consumer	2959	22,5	0,060	297	19,4	320	24,1	0,006	308	27,1	310	24,5	0,06
Consumer	10189	77,5		1235	80,6	1010	75,9		830	72,9	956	75,5	
Nutritional status (n,%)													
Low weight	135	0,9	< 0,001	14	0,9	13	0,9	0,007	15	1,1	17	1,1	< 0,001
Eutrophy	5291	36,0		499	31,1	534	38,0		465	34,7	639	41,6	
Overweight	5929	40,3		729	45,5	596	42,4		462	34,5	545	35,5	
Obesity	3358	22,8		362	22,6	263	18,7		397	29,7	335	21,8	
Leisure time physical activity (n,%)													
Light	11155	76,9	< 0,001	1260	79,9	917	66,1	< 0,001	1186	90,1	1041	68,9	< 0,001
Moderate	2037	14,1		182	11,5	262	18,9		87	6,6	296	19,6	
Vigorous	1309	9,0		136	8,6	208	15,0		43	3,3	175	11,6	

The values presented are minimum and maximum for the continuous variable and frequencies and percentages for the categorical variables. Associations between categories were analyzed with the Pearson Chi-square test. A value of $P < 0.05$ was considered statistically significant.

Table 2. Main food sources of magnesium intake at ELSA-Brasil. Brazil, 2008-2010.

Rank	Food	Percentage contribution	95% confidence interval
1º	Bean	24,2	(23,8; 24,6)
2º	Oats	4,5	(4,3; 4,6)
3º	Walnuts	3,6	(3,4; 3,8)
4º	White rice	3,3	(3,2; 3,3)
5º	Orange	3,3	(3,2; 3,3)
6º	Bread	3,2	(3,1; 3,2)
7º	Cooked fish	3,0	(2,9; 3,0)
8º	Boneless meat	2,6	(2,5; 2,6)
9º	Whole Milk	2,3	(2,3; 2,4)
10º	Whole grain bread	2,1	(2,0; 2,2)

presented higher values of dietary magnesium. Due to ethnic miscegenation in Brazil, it is a fundamental element to understand the association of race/ethnicity with food consumption, given the recognized role of cultural heritage and historical value of food in the construction of traditional and healthy eating habits. In the National Health Survey (PNS, 2013), for example, black and brown skin colors were associated with a significantly higher frequency of regular bean consumption (≥ 5 times/week)[18]. As already commented, almost a quarter of the total intake of magnesium in ELSA-Brazil was attributed to this legume. Together with rice, beans make up the basis of traditional Brazilian lunch and dinner, and this combination has been shown to be a protective factor for obesity and other NCDs[41-43].

Changes in the gustatory ability of foods due to smoking and the recognized negative effect of

Table 3. Multiple linear regression model between magnesium intake and socio-demographic and lifestyle factors in ELSA-Brasil, 2008-2010.

Predictors	β	95% confidence interval	P
Sex (reference: Male)			
Female	7,8	(4,2; 11,3)	< 0,001
Age group (reference: Adults)			
Elderly	20,2	(15,9; 24,6)	< 0,001
Self-Decawn Skin Color (Reference: White)			
Brown	5,3	(1,1; 9,5)	0,013
Black	8,5	(3,3; 13,8)	0,001
Others	3,7	(-6,1; 13,4)	0,460
Education (reference: Complete primary school)			
Complete high school	-5,4	(-11,4; 0,6)	0,080
Higher or postgraduate	0,6	(-6,4; 6,5)	0,985
Income per capita (reference: < 3 minimum salaries)			
≥ 3 minimum wages	11,6	(7,4; 15,8)	< 0,001
Smoking (reference: Non-smoker)			
Former smoker	1,8	(-2,1; 5,7)	0,376
Smoker	-18,0	(-23,3; -12,7)	< 0,001
Ethic (reference: Non-consumer)			
Consumer	-7,0	(-11,2; -2,8)	< 0,001
Nutritional status (reference: Eutrophy)			
Low weight	14,0	(-4,4; 32,5)	0,1037
Overweight	-6,7	(-10,7; -2,8)	< 0,001
Obesity	-13,3	(-17,9; -8,6)	< 0,001
Physical activity level (reference: Light)			
Moderate	27,8	(22,8; 32,9)	< 0,001
Vigorous	31,5	(25,5; 37,5)	< 0,001

A value of P < 0.05 was considered statistically significant. The model was further adjusted by self-reported change in dietary habits over the past 6 months.

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Supplement Table 1. Main food sources of magnesium intake second income at ELSA-Brasil. Brazil, 2008-2010.

Income per capita							
< 3 minimum wages				≥3 minimum wages			
Rank	Food	Percentage contribution	95% confidence interval	Rank	Food	Percentage contribution	95% confidence interval
1º	Bean	28,6	(28,1;29,2)	1º	Bean	18.9	(18,5;19,4)
2º	White rice	3,8	(3,7;3,8)	2º	Oats	5.8	(5,6;6,0)
3º	French bread	3,6	(3,5;3,7)	3º	Walnuts	5.3	(5,1;5,5)
4º	Orange	3,5	(3,3;3,6)	4º	Cooked Fish	3.2	(3,1;3,3)
5º	Oats	3,3	(3,1;3,4)	5º	Orange	3.0	(2,9;3,1)
6º	Whole Milk	2,9	(2,8;3,0)	6º	Whole grain bread	2.7	(2,6;2,8)
7º	Cooked fish	2,7	(2,6;2,8)	7º	French bread	2.7	(2,6;2,8)
8º	Boneless meat	2,6	(2,5;2,6)	8º	White rice	2.7	(2,6;2,7)
9º	Banana	2,2	(2,1;2,3)	9º	Boneless meat	2.6	(2,5;2,7)
10º	Walnuts	2,2	(1,8;2,5)	10º	Skimmed milk	2.6	(2,5;2,6)

excessive alcohol consumption on appetite and food consumption could explain the inverse correlation between these two lifestyle habits and the intake of magnesium. On the other hand, as already evidenced by another study[35], higher values of dietary magnesium were estimated among the participants classified in the levels of moderate and vigorous physical activity. As characteristics of the nutritional transition faced by the country, urbanization and the adoption of unhealthy lifestyle habits have accompanied the increase in the consumption of ultra-processed foods and of low nutritional value[18,22]. The findings indicate the importance of promoting diet quality, with a stimulus to the consumption of magnesium sources, especially among subgroups at risk for NCDs.

That way, there is an inverse association between magnesium intake and excessive body weight, that is, the worse the nutritional status the lower the consumption of magnesium, even after adjustment for energy consumption, physical activity level, and other sociodemographic and lifestyle characteristics evaluated. Some authors, based on evidence of a deleterious role of magnesium deficiency on insulin resistance, inflammation, and oxidative stress, support the hypothesis of a causal relationship between the inadequacy of the mineral and the aggravation of weight gain and expansion of body adiposity, a characteristic of obesity[44-46]. Although other population studies, such as ours, reported a lower intake of magnesium among obese individuals[16,44], it is still uncertain whether these findings reflect a poor overall quality of the diet or if the inadequacy of its consumption would be a risk factor for the disease[45,46]. Due to the transversal design of the study, inferences of causality are not possible; however, they can be explored with a longitudinal follow up of these individuals.

Furthermore, we estimated magnesium intakes with a FFQ, which is a method widely used in large epidemiological studies to rank individual according to their levels of dietary intakes in the previous twelve months[45]. However, its use can be considered another study limitation since this method is not consider the most appropriate for the quantitative analysis of micronutrients, given its inherent inaccuracy, that preclude the evaluation of individual or population nutrients intake adequacy. However, ELSA-Brazil FFQ was previously validated and performed well in classifying individuals according to magnesium intake levels, allowing their use in our comparative analysis between groups[24,47].

To evaluate the energy and nutrient intake, the Food Composition Database of the United States Department of Agriculture (USDA) or the Brazilian Food Composition Table were used. In the Brazilian Table of Food Composition many foods are still presented only in their raw form; in addition, the table does not present many essential nutrients for analysis in studies on chronic diseases. The table used in the NDSR is representative for North American countries, therefore, the amounts of nutrients may vary in relation to food in Brazil. To overcome this issue, we used a systematic routine to correct contrasting nutrient values between databases, similarly to an approach employed by an American Latin multicentric study[48] .

Conclusion

Foods from the traditional Brazilian diet were the largest contributors of dietary magnesium among the evaluated participants. In addition, not only sociodemographic but also lifestyle factors were associated with the ingestion of this mineral.

Collaborations

The first author of the article, J Levy, done design and design of the study, analysis, interpretation of data and review of the article; AAM Miranda, JA Teixeira and E De Carli contributed analysis, interpretation of data and revision of the article; IJM Benseñor and PA Lotufo contribuited article revision and DML Marchioni contribuited review of the article and approval of the final version.

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References

1. Pickering G, Morel V, Simen E, Cardot JM, Moustafa F, Delage N, Picard P, Eschalier S, Boulliau S, Dubray C. Oral magnesium treatment in patients with neuropathic pain: A randomized clinical trial. *Magnes Res* 2011; 24(2):28-35.
2. Helena Monteiro T, Vannucchi H. Magnésio. In: *Funções Plenamente Reconhecidas de Nutrientes*. São Paulo: ILSI Brasil; 2010. [cited 2019 Jul 2]. Available from: http://ilsi.org/brasil/wp-content/uploads/sites/9/2016/05/16-Magnésio.pdf
3. Bagis S, Karabiber M, AS I, Tamer L, Erdogan C, Atalay A. Is magnesium citrate treatment effective on pain, clinical parameters and functional status in patients with fibromyalgia? *Rheumatol Int* 2013; 33(1):167-172.
4. Crosby V, Elin RJ, Twycross R, Mihalyo M, Wilcock A. Magnesium. *J Pain Symptom Manage* 2013; 45(1):137-144.
5. Ford ES, Li C, McGuire LC, Mokdad AH, Liu S. Intake of dietary magnesium and the prevalence of the metabolic syndrome among U.S. adults. *Obesity (Silver Spring)* 2007; 15(5):1139-1146.
6. He K, Liu K, Daviglus ML, Morris SJ, Loria CM, Van Horn L, Jacobs Junior DR, Savage PJ. Magnesium intake and incidence of metabolic syndrome among young adults. *Circulation* 2006; 113(13):1675-1682.
7. McKeown NM, Jacques PF, Zhang XL, Juan W, Sahyoun NR. Dietary magnesium intake is related to metabolic syndrome in older Americans. *Eur J Nutr* 2008; 47(4):210-216.
8. Song Y, Manson JE, Buring JE, Liu S. Dietary Magnesium Intake in Relation to Plasma Insulin Levels and Risk of Type 2 Diabetes in Women. *Diabetes Care*. 2004; 27(1):59-65.
9. Lopez-Ridaura R, Willett WC, Rimm EB, Liu S, Stampfer MJ, Manson JE, Hu FB. Magnesium Intake and Risk of Type 2 Diabetes in Men and Women. *Diabetes Care* 2004; 27(1):134-140.
10. King JL, Miller RJ, Blue JP, O'Brien WD, Erdman JW. Inadequate dietary magnesium intake increases atherosclerotic plaque development in rabbits. *Nutr Res* 2009; 29(5):343-349.
11. Touyz RM. Transient receptor potential melastatin 6 and 7 channels, magnesium transport, and vascular biology: implications in hypertension. *AJP Hear Circ Physiol* 2007; 294(3):H1103-H1118.
12. Sontia B, Touyz RM. Role of magnesium in hypertension. *Arch Biochem Biophys* 2007; 458(1):33-39.
13. Rude RK, Singer FR, Gruber HE. Skeletal and hormonal effects of magnesium deficiency. *J Am Coll Nutr* 2009; 28(2):131-141.
14. Rosanoff A, Weaver CM, Rude RK. Suboptimal magnesium status in the United States: Are the health consequences underestimated? *Nutr Rev* 2012; 70(3):153-164.
15. Food and Nutriton Board, IOM. Dietary Reference Intakes (DRIs): Estimated Average Requirements. *Nutrition Reviews* 2004; 62(10):400-401.
16. Agarwal S, Reider C, Brooks JR, Fulgoni VL. Comparison of Prevalence of Inadequate Nutrient Intake Based on Body Weight Status of Adults in the United States: An Analysis of NHANES 2001–2008. *J Am Coll Nutr* 2015; 34(2):126-134.
17. Instituto Brasileiro de Geografia e Estatística (IBGE). *Pesquisa de Orçamentos Familiares: 2008-2009. Análise Do Consumo Alimentar Pessoal No Brasil*. Rio de Janeiro: IBGE; 2011.
18. Jaime PC, Stopa SR, Oliveira TP, Vieira ML, Szwarcwald CLMD. Prevalence and sociodemographic distribution of healthy eating markers, National Health Survey, Brazil 2013. *Epidemiol e Serviços Saúde* 2015; 24(2):267-276.
19. Olinto MT, Willett WC, Gigante DP, Victora CG. Sociodemographic and lifestyle characteristics in relation to dietary patterns among young Brazilian adults. *Public Health Nutr* 2011; 14(1):150-159.
20. Estima CCP, Philipp ST, Alvarenga MS. Fatores determinantes de consumo alimentar: por que os indivíduos comem o que comem? *Rev Bras Nutr Clin* 2009; 24(4):263-268.
21. Aquino EML, Barreto SM, Bensenor IM, Carvalho MS, Chor D, Duncan BB, Lotufo PA, Mill JG, Molina Mdel C, Mota EL, Passos VM, Schmidt MI, Szklo M. Brazilian Longitudinal Study of Adult Health (ELSA -Brasil): Objectives and Design. *Am J Epidemiol* 2012; 175(4):315-324.
22. Schmidt MI, Duncan BB, Mill JG, Lotufo PA, Chor D, Barreto SM, Aquino EM, Passos VM, Matos SM, Molina Mdel C, Carvalho MS, Bensenor IM. Cohort Profile: Longitudinal Study of Adult Health (ELSA-Brasil). *Int J Epidemiol* 2015; 44(1):68-75.
23. Bensenor IM, Griep RH, Pinto KA, Faria CP, Felisbino-Mendes M, Caetano EI, Albuquerque LS, Schmidt MI. Routines of organization of clinical tests and interviews in the ELSA-Brasil investigation center. *Rev Saude Publica* 2013; 47(Supl. 2):37-47.
24. Molina MDCB, Benseñor IM, Cardoso LO, Velasquez-Melendez G, Drehmer M, Pereira TS, Faria CP, Melere C, Manato L, Gomes AL, Fonseca MJ, Sichieri R. Reproducibility and relative validity of the Food Frequency Questionnaire used in the ELSA-Brasil. *Cad Saude Publica* 2013; 29(2):379-389.
25. Willett W. Nutritional epidemiology. *Oxford Univ Press* 1998; (January):768-772.
26. Petruccelli JL, Saboia AL, organizadores. *Pesquisa sobre as Características Étnico-raciais da População*. Rio de Janeiro: IBGE; 2013.
27. World Health Organization (WHO). *Global status report on noncommunicable diseases 2014*. Geneva: WHO; 2014.
28. International Physical Activity Questionniare Group. International physical activity questionnaire short last 7 days self-administered format for use with young and middle aged adults. *Res Q Exerc Sport* 2002; 71:3.
29. Matsudo S, Araújo T, Matsudo V, Andrade D, Andrade E, Oliveira LC, Braggion G. Questionário internacional de atividade física (IPAQ): estudo de validade e reprodutibilidade no Brasil. *Rev Bras Atividade Física Saúde* 2001; 6(2):5-18.
30. Lindström M, Hanson BS, Ostergren PO. Socioeconomic differences in leisure-time physical activity: the role of social participation and social capital in shaping health related behaviour. *Soc Sci Med* 2001; 52(3):441-451.

31. Dias-da-Costa JS, Hallal PC, Wells JCK, Daltoé T, Fuchs SC, Menezes AM, Olinto MT. Epidemiology of leisure-time physical activity: a population-based study in southern Brazil. *Cad Saude Publica* 2005; 21(1):275-282.
32. Monteiro CA, Conde WL, Matsudo SM, Matsudo VR, Bonseñor IM, Lotufo PA. A descriptive epidemiology of leisure-time physical activity in Brazil, 1996-1997. *Rev Panam Salud Publica* 2003; 14(4):246-254.
33. Block G, Dresser CM, Hartman AM, Carroll MD. Nutrient sources in the American diet: Quantitative data from the nhanes II survey: II. Macronutrients and fats. *Am J Epidemiol* 1985; 122(1):27-40.
34. Marchioni DML, Verly E, Steluti J, Cesar CLG, Fisberg RM. Folic acid intake before and after mandatory fortification: a population-based study in São Paulo, Brazil. *Cad Saude Publica* 2013; 29(10):2083-2092.
35. Sales CH, Fontanelli MDM, Vieira DiAS, Marchioni DiM, Fisberg RM. Inadequate dietary intake of minerals: Prevalence and association with socio-demographic and lifestyle factors. *Br J Nutr* 2017; 117(2):267-277.
36. Sales CH, Nascimento DA, Medeiros ACQ, Lima KC, Pedrosa LFC, Colli C. There Is Chronic Latent Magnesium Deficiency in Apparently Healthy University Students. *Nutr Hosp* 2014; 30(1):200-204.
37. Cardoso LO, Carvalho MS, Cruz OG, Melere C, Luft VC, Molina MC, Faria CP, Benseñor IM, Matos SM, Fonseca MJ, Griep RH, Chor D. Eating patterns in the Brazilian Longitudinal Study of Adult Health (ELSA -Brasil): an exploratory analysis. *Cad Saude Publica* 2016; 32(5):e00066215.
38. Kaidar-Person O, Person B, Szomstein S, Rosenthal RJ. Nutritional deficiencies in morbidly obese patients: A new form of malnutrition? Part B: Minerals. *Obes Surg* 2008; 18(8):1028-1034.
39. Bezerra IN, Souza AM, Pereira RA, Sichieri R. Contribution of foods consumed away from home to energy intake in Brazilian urban areas: The 2008-9 Nationwide Dietary Survey. *Br J Nutr* 2013; 109(7):1276-1283.
40. Souza ADM, Pereira RA, Yokoo EM, Levy RB, Sichieri R. Alimentos mais consumidos no Brasil: Inquérito Nacional de Alimentação 2008-2009. *Rev Saude Publica* 2013; 47(Supl. 1):190-199.
41. Araujo MC, Verly Junior E, Junger WL, Sichieri R. Independent associations of income and education with nutrient intakes in Brazilian adults: 2008-2009 National Dietary Survey. *Public Health Nutr*. 2013; 17(12):2740-2752.
42. Sichieri R. Dietary patterns and their associations with obesity in the Brazilian City of Rio de Janeiro. *Obes Res* 2002; 10(1):42-48.
43. Belin RJ, He K. Magnesium physiology and pathogenic mechanisms that contribute to the development of the metabolic syndrome. *Magnes Res* 2007; 20(2):107-129.
44. Santos RO, Vieira DADS, Miranda AAM, Fisberg RM, Marchioni DM, Baltar VT. The traditional lunch pattern is inversely correlated with body mass index in a population-based study in Brazil. *BMC Public Health* 2017; 18(1):33.
45. Nielsen FH. Magnesium, inflammation, and obesity in chronic disease. *Nutr Rev* 2010; 68(6):333-340.
46. Rayssiguier Y, Libako P, Nowacki W, Rock E. Magnesium deficiency and metabolic syndrome: Stress and inflammation may reflect calcium activation. *Magnes Res* 2010; 23(2):73-80.
47. Willett W. *Nutritional Epidemiology*. 3rd ed. New York: Oxford University Press; 2013.
48. Kovalskys I, Fisberg M, Gómez G, Rigotti A, Cortés LY, Yépez MC, Pareja RG, Herrera-Cuenca M, Zimberg IZ, Tucker KL, Koletzko B, Pratt M; ELANS Study Group. Standardization of the food composition database used in the latin american nutrition and health study (Elans). *Nutrients* 2015; 7(9):7914-7924.

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