

Factors associated with urinary sodium/ potassium ratio in participants in the ELSA-Brazil study

Fatores associados à relação sódio/potássio
urinária em participantes do ELSA-Brasil

Factores asociados a la excreción urinaria sodio/
potasio en participantes del ELSA-Brasil

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Abstract

This study aimed to identify sociodemographic factors associated with high estimated sodium/potassium ratio. A total of 15,105 participants were assessed, from 35 to 74 years of age, from a cohort of public employees (ELSA-Brazil). Socioeconomic data were collected with a questionnaire, and 12-hour nighttime urine samples were collected to estimate sodium and potassium intake. Sodium/potassium ratio was calculated in mmol/L and divided into tertiles: 1st tertile, corresponding to “low”; 2nd tertile for “medium”; and 3rd tertile for “high” sodium/potassium ratio. The proportions and means were compared according to the classification of tertiles in the sodium/potassium ratio, using chi-square test and analysis of variance (ANOVA). Crude and adjusted multinomial logistic regression models were tested, with the 1st tertile as the reference. Factors associated with sodium/potassium ratio were: male sex (OR = 1.78; 95%CI: 1.60-1.98); age 35 to 44 years (OR = 1.71; 95%CI: 1.33-2.19); incomplete elementary schooling (OR = 2.38; 95%CI: 1.78-3.18); and lower income (OR = 1.47; 95%CI: 1.26-1.73). Men, younger individuals, and those with less schooling and income showed higher mean sodium/potassium ratio.

Sodium; Potassium; Urine

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Introduction

Sodium and potassium intake is an important predictor of morbidity and mortality, and the ratio between them has proven an even better predictor of risk of hypertension and cardiovascular diseases; the ratio is considered more important than the single estimates of these two nutrients^{1,2,3}. The single estimates allow assessing excessive salt intake and inadequate consumption of fruits and vegetables, which are high in potassium. The World Health Organization (WHO)⁴ recommends a sodium-to-potassium ratio of 1. An increase in this ratio can be due to either elevated sodium from industrialized foods and added table salt and/or decreased potassium intake, as in a diet with low nutritional quality^{5,6}.

Studying the relationship between food consumption and health outcomes is fundamentally important for a better understanding of their determinants, as well as for planning preventive and health promotion measures. Meanwhile, the assessment of food consumption in population-based studies can be done with different methods, including dietary methods, which are feasible and less expensive, but which are less precise and prone to recall bias and error in estimating the size of portions⁷. On the other hand, biomarkers are independent of random errors in relation to the inherent errors of dietary surveys, besides presenting higher precision⁸. In the case of sodium and potassium intake, urinary excretion provides a more precise estimate than dietary methods⁹, and the ratio between them is also more precise for identifying diet with lower sodium and higher potassium intake¹⁰.

Diet is influenced by various factors (economic, social, and cultural) and even some health conditions¹¹. These factors intervene directly in access to foods and the diet's nutritional quality. Evidence has shown that higher income, more schooling, and a favorable environment increase access to healthy foods^{12,13}. Meanwhile, the presence of certain diseases interferes in food intake, whether related to inherent difficulties in the disease process or due to dietary restrictions as part of a food plan or specific diet therapy¹⁴. Considering that sodium/potassium ratio can be used as a good marker of intake of these electrolytes, the current study aims to identify sociodemographic factors associated with high sodium/potassium ratio in adults.

Methods

Study design and population

This cross-sectional study used baseline data from the *Brazilian Longitudinal Study of Adult Health* (ELSA-Brazil), a multicenter study of active and retired public employees 35 to 74 years of age, whose central focus is the incidence of chronic diseases and their risk factors, particularly cardiovascular diseases and diabetes¹⁵. ELSA-Brazil is being conducted in six state capitals in three of Brazil's five major geographic regions (South, Southeast, and Northeast), with six research centers, five in public universities [Federal University of São Paulo (USP), São Paulo State; Federal University of Minas Gerais (UFMG), Minas Gerais State; Federal University of Bahia (UFBA), Bahia State; Federal University of Rio Grande do Sul (UFRGS), Rio Grande do Sul State; and Federal University of Espírito Santo (UFES), Espírito Santo State] and one research institution under the Brazilian Ministry of Health (Oswaldo Cruz Foundation – Fiocruz, Rio de Janeiro State). ELSA-Brazil was approved by the institutional review boards of the six institutions, and all the participants signed the Informed Consent Form.

Exclusion criteria

The study excluded individuals that did not provide validated urine samples and those in use of any class of antihypertensive medication, since diuretics have reported natriuretic effects with the decreased extracellular volume, thus presenting altered potassium excretion (hypopotassemia)¹⁶.

Data collection

The tests and questionnaires were performed from 2008 to 2010 in standardized fashion in the six study centers, as published previously in full detail ^{15,17}.

12-hour sodium and potassium excretion

ELSA-Brazil adopted 12-hour nighttime urine collection to estimate sodium and potassium excretion and assess creatinine clearance ¹⁵. Participants received verbal and written instructions from trained and certified personnel on the samples' collection, storage, and transportation. Urinary volume was measured with a graduated cylinder with a capacity of 1,000mL and precision to 10mL. Sodium and potassium titrations were performed with selective electrodes. Urinary samples were defined as collection period from 10 to 14 hours, diuresis greater than 250mL, and no report of complete losses of micturition. Urine samples were considered valid when total weight-corrected creatinine excretion adjusted for 12 hours was between 7.2 and 16.8mg/kg in men and 5.4 and 12.6mg/kg in women ¹⁸.

The study used 12-hour nighttime urinary sodium and potassium excretion and estimated 24-hour sodium and potassium intake in milligrams. 12-hour urinary excretion can be used in epidemiological studies because it estimates 24-hour consumption/excretion with reliable precision ¹⁹. Sodium/potassium ratio was calculated in mmol/mmol and later divided into tertiles, classified as 1st tertile = low, 2nd tertile = medium, and 3rd tertile = high.

Exploratory variables

Individuals of both sexes were evaluated. Age was classified in four brackets, namely 35 to 44, 45 to 54, 55 to 64, and 65 to 74 years. Schooling was grouped in incomplete and complete elementary, complete secondary, and complete university. Per capita income was based on information on approximate net family income in the month prior to the interview and the number of persons that depended on it. This variable was divided into tertiles, where the first tertile indicates the lowest income and the last tertile the highest income. Race/color was self-reported and grouped into white and non-white (black, brown, Asian-descendant, and indigenous).

Statistical analysis

Descriptive analysis of the sociodemographic variables was performed according to tertiles of sodium/potassium ratio using the chi-square test. Mean values for sodium, potassium, and sodium/potassium ratio were compared using analysis of variance (ANOVA) followed by Tukey post hoc and Student's t-test. Crude and adjusted multinomial logistic regression model was tested, where the dependent variable was sodium/potassium ratio in tertiles and the reference was low ratio (1st tertile). The independent variables used in the model were sex, age bracket, schooling, race/color, and income. The data were analyzed with the SPSS version 18.0 (<https://www.ibm.com/>).

Results

Of the 15,105 participants, 2,292 individuals were excluded because they failed to provide validated urine collection and 3,734 were excluded because they reported use of antihypertensive medication, thus constituting a final sample of 9,079 individuals.

Individuals with high sodium/potassium ratio presented the highest mean sodium and lowest potassium (Table 1). High mean sodium/potassium ratio was associated with male sex, younger age (35 to 44 years), lower schooling, non-white ethnicity, and lower income (Table 2).

Estimated sodium and potassium intake showed a significant difference between sex and schooling (Table 3). Higher mean sodium/potassium ratios were observed in men, younger individuals, and individuals with lower schooling and income (Table 3). Table 4 shows the crude and adjusted multinomial logistic regression models. In the adjusted model, men showed 78% higher odds of high

Table 1

Means and standard deviations (SD) for variables in the sodium/potassium ratio, ELSA-Brazil (2008-2010).

Variables	Sodium/potassium ratio		
	Low (1 st tertile)	Medium (2 nd tertile)	High (3 rd tertile)
	Mean ± SD	Mean ± SD	Mean ± SD
Urinary sodium (mg)	1,357 ± 583	1,952 ± 725	2,645 ± 1,029
Urinary potassium (mg)	1,100 ± 447	937 ± 342	784 ± 292
Sodium/potassium (mmol/mmol)	2.1 ± 0.5	3.5 ± 0.4	5.9 ± 1.6

Table 2

Sociodemographic characteristics according to tertiles of sodium/potassium ratio. ELSA-Brazil (2008-2010).

	Sodium/potassium ratio			p-value
	Low (1 st tertile)	Medium (2 nd tertile)	High (3 rd tertile)	
	n (%)	n (%)	n (%)	
Sex				
Male	1,167 (27.6)	1,403 (33.2)	1,654 (39.2)	< 0.001
Female	1847 (38.1)	164 (33.8)	1,365 (28.1)	
Age bracket (years)				< 0.001
35 to 44	783 (31.1)	838 (33.3)	897 (35.6)	
45 to 54	1,184 (31.0)	1,289 (33.8)	1,345 (35.2)	
55 to 64	843 (38.2)	723 (32.8)	638 (28.9)	
65 to 74	204 (37.9)	195 (36.2)	139 (25.8)	
Schooling				< 0.001
Incomplete Elementary	89 (20.7)	151 (35.1)	190 (44.2)	
Complete Elementary	118 (22.4)	171 (32.4)	238 (45.2)	
Complete Secondary	833 (27.3)	1,009 (33.1)	1,206 (39.6)	
Complete University	1,974 (38.9)	1,714 (33.8)	1,385 (27.3)	
Race/Color				< 0.001
White	1,721 (35.0)	1,660 (33.7)	1,538 (31.3)	
Non-white	1,251 (30.8)	1355 (33.4)	1,453 (35.8)	
Per capita income (BRL)				< 0.001
< 968.00	744 (25.3)	983 (33.4)	1,212 (41.2)	
968.00-1,868.00	976 (33.5)	986 (33.8)	953 (32.7)	
> 1,868.00	1,274 (40.0)	1,068 (33.6)	840 (26.4)	

sodium/potassium ratio when compared to women. Younger individuals (35 to 44 years: OR = 1.71; 95%CI: 1.33-2.19) and those with lower schooling (OR = 2.38; 95%CI: 1.78-3.18) and income (OR = 1.47; 95%CI: 1.26-1.73) showed higher odds of high sodium/potassium ratio.

Discussion

Factors associated with high sodium/potassium ratio were male sex, younger age, and lower schooling and income. These characteristics were associated with higher odds of consuming a high-sodium and low-potassium diet. Elevated sodium/potassium ratio is due to consumption of high-sodium foods such as processed and ultra-processed products and the addition of table salt and industrialized

Table 3

Means and standard deviations of sodium, potassium, and sodium/potassium ratio according to associated factors. ELSA-Brazil (2008-2010).

	Sodium (mg)	Potassium (mg)	Sodiu/potassium ratio (mmol/mmol)
Sex			
Male	4,963 ± 2,225	2,595 ± 1,043	4.1 ± 2.0
Female	3,580 ± 1,604	2,140 ± 847	3.6 ± 1.7
p-value	< 0.001	< 0.001	< 0.001
Age bracket (years)			
35 to 44	4,152 ± 2,085	2,238 ± 907	4.0 ± 1.9
45 to 54	4,247 ± 2,051	2,301 ± 949	3.9 ± 1.8
55 to 64	4,269 ± 2,026	2,509 ± 1,030	3.7 ± 1.8
65 to 74	4,223 ± 1,755	2,598 ± 1,033	3.5 ± 1.5
p-value	0.190	< 0.00	< 0.001
Schooling			
Incomplete Elementary	5,072 ± 2,292	2,442 ± 987	4.5 ± 2.1
Complete Elementary	4,969 ± 2,393	2,360 ± 992	4.5 ± 2.0
Complete Secondary	4,458 ± 2,124	2,303 ± 949	4.1 ± 1.9
Complete University	3,933 ± 1,858	2,372 ± 978	3.6 ± 1.6
p-value	< 0.00	0.004	< 0.001
Per capita income (BRL)			
< 968.00	4,572 ± 2,194	2,290 ± 912	4.2 ± 2.0
968.00-1,868.00	4,204 ± 2,024	2,350 ± 984	3.8 ± 1.8
> 1,868.00	3,918 ± 1,841	2,405 ± 1,003	3.5 ± 1.6
p-value	< 0.00	< 0.00	< 0.001

Table 4

Crude and adjusted multinomial logistic regression, with low sodium/potassium ratio as the reference, ELSA-Brazil.

	Sodium/potassium ratio			
	Medium (2 nd tertile)		High (3 rd tertile)	
	Adjusted OR (IC95%)	Crude OR (95%CI)	Adjusted OR (IC95%)	Ajustado OR (IC95%)
Sex				
Male	1,35 (1,22-1,50)	1,30 (1,17-1,45)	1,92 (1,73-2,12)	1,78 (1,60-1,98)
Female	Ref.	Ref.	Ref.	Ref.
Age bracket (years)				
35 to 44	1.12 (0.90-1.39)	1.13 (0.90-1.42)	1.68 (1.33-2.13)	1.71 (1.33-2.19)
45 to 54	1.14 (0.92-1.40)	1.11 (0.89-1.38)	1.67 (1.33-2.01)	1.58 (1.24-2.00)
55 to 64	0.90 (0.72-1.12)	0.89 (0.71-1.12)	1.11 (0.87-1.41)	1.13 (0.88-1.45)
65 to 74	Ref.	Ref.	Ref.	Ref.
Schooling				
Incomplete Elementary	1.95 (1.49-2.56)	1.78 (1.32-2.38)	3.04 (2.34-3.95)	2.38 (1.78-3.18)
Complete Elementary	1.67 (1.31-2.13)	1.51 (1.17-1.97)	2.87 (2.28-3.62)	2.32 (1.80-3.00)
Complete Secondary	1.39 (1.25-1.56)	1.25 (1.01-1.43)	2.06 (1.84-2.30)	1.69 (1.48-1.93)
Complete University	Ref.	Ref.	Ref.	Ref.
Race/Color				
White	Ref.	Ref.	Ref.	Ref.
Non-white	1.12 (1.01-1.24)	0.97 (0.87-1.08)	1.30 (1.17-1.44)	0.97 (0.87-1.08)
Per capita income (BRL)				
< 968.00	1.58 (1.39-1.77)	1.25 (1.07-1.46)	2.47 (2.18-2.80)	1.47 (1.26-1.73)
968.00-1,868.00	1.20 (1.07-1.36)	1.09 (0.96-1.24)	1.48 (1.31-1.67)	1.16 (1.02-1.33)
> 1,868.00	Ref.	Ref.	Ref.	Ref.

95%CI: 95% confidence interval; OR: odds ratio; Ref.: reference.

seasonings when preparing meals²⁰. Meanwhile, lower ratio indicates higher consumption of fruits and vegetables, considered important sources of potassium²¹.

In this study, women showed lower mean sodium/potassium ratio than men. This may mean that women were more concerned about their health²² and thus probably ate a better diet, including daily fruits and vegetables. Assumpção et al.²³ found that women eat more fruits and vegetables when compared to men. The same result appeared in the *Brazilian National Health Survey*²⁴.

Another issue is changes with aging, since older individuals may be more aware of their own health care, as demonstrated by Deeks et al.²². However, we noted that older participants presented lower sodium/potassium ratio, probably due to higher consumption of fruits and vegetables. Younger individuals tend to eat away from home more often, frequently replacing full meals with quick snacks like fast foods, contributing to worse diet²⁵.

Information on the benefits of healthy eating with lower amounts of sodium and processed foods is currently available to the entire population, but real access to this type of diet can be limited to individuals with more schooling. Better knowledge on the benefits of adequate or more nutritious diet assists eating choices. Data from the VIGITEL survey (*Risk and Protective Factors Surveillance System for Chronic Non-communicable Diseases through Telephone Interview*)²⁶ show that 44.3% of Brazilian adults with 12 or more years of schooling report consuming fruits and vegetables five or more days a week, while those with fewer than nine years of schooling consumed 29.9%.

Income is also a determinant factor for food choices. Faleiro et al.²⁷ demonstrated that lower socioeconomic status was associated with higher prevalence of low consumption of fruits and vegetables. Healthy foods tend to be costlier than industrialized foods²⁸, which is one factor favoring choice of the latter for people with less buying power¹². Although less costly and more practical, industrialized foods are high in calories, fat, salt, and sugar²⁰. A study by Simões et al.²⁹, with participants in ELSA-Brazil, showed that the highest share of energy density came from ultra-processed foods, among individuals with less schooling. The race/color variable did not remain in the final model. Although participants in ELSA-Brazil are public employees with higher income and schooling than the Brazilian national average, the sodium/potassium ratio was higher than in the U.S. population².

Urinary excretion is a gold standard for estimating sodium and potassium intake⁹. Thus, sodium/potassium ratio can be used as a marker of intake of these electrolytes, since it lacks the biases found in dietary methods. Still, this indicator is not able to identify the foods consumed by the population, which is considered a limitation. However, Oliveira et al.³⁰ found that frequent consumption of industrialized seasonings is associated with the highest urinary sodium excretion and sodium/potassium ratio. Higher consumption of ultra-processed foods has also been associated with higher sodium/potassium ratio³⁰. Thus, the higher the sodium/potassium ratio, the higher the sodium intake and the lower the potassium intake.

Although sodium is widely distributed in small amounts in whole foods, its principal source in contemporary diet is table salt. Foods with the highest amounts of sodium include cold cuts, cookies, and readymade meals and seasonings, among others. Since this nutrient is present in the foods that are part of current global food variety, one can predict that individuals will tend to consume much more sodium than recommended, potentially increasing the sodium/potassium ratio. The addition of salt to readymade meals is also more common in men than in women³¹.

Therefore, even though urinary sodium/potassium ratio does not allow identifying food sources or the precise sources increasing the ratio, one can state that higher ratios are associated with greater consumption of industrialized seasonings and processed foods³⁰. Thus, the study's results corroborate the fact that demographic and socioeconomic factors are important determinants of food choices^{23,32}, and that sodium/potassium ratio can be used as a summary indicator of diet quality, contributing to monitoring of policies to promote healthy eating.

Conclusion

High sodium/potassium ratio was found in males, young individuals, and those with lower schooling and lower income. In addition, individuals in the first tertile of the sodium/potassium ratio showed higher levels than recommended.

Contributors

T. S. S. Pereira participated in the study's conception and design, statistical analyses, and editing and revision of the manuscript. J. G. Mill collaborated in the study's conception and design and revision of the manuscript. N. V. Cade e R. Sichieri participated in the revision of the manuscript. R. H. Griep participated in the editing and revision of the manuscript. M. C. B. Molina participated in the study's conception and design and editing and revision of the manuscript.

Additional informations

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Resumo

Este estudo teve por objetivo identificar os fatores sociodemográficos associados à estimativa de alta relação de consumo de sódio/potássio. Foram avaliados 15.105 participantes, de 35 a 74 anos, de uma coorte de servidores públicos (ELSA-Brasil). Dados socioeconômicos foram coletados por meio de questionário e realizada coleta urinária de 12 horas noturnas para estimar o consumo de sódio e potássio. A relação sódio/potássio foi calculada em mmol/L e dividida em tercils: 1º tercil corresponde à “baixa” relação; 2º à “intermediária” e 3º tercil à “alta” relação sódio/potássio. Foram comparadas as proporções e médias segundo as classificações do tercil da relação sódio/potássio, utilizando-se os testes de qui-quadrado e análise de variância (ANOVA). Foram testados modelos brutos e ajustados de regressão logística multinomial, tendo como referência o 1º tercil. Os fatores associados à alta relação sódio/potássio foram: sexo masculino (OR = 1,78; IC95%: 1,60-1,98); indivíduos de 35 a 44 anos (OR = 1,71; IC95%: 1,33-2,19); Ensino Fundamental incompleto (OR = 2,38; IC95%: 1,78-3,18) e menor renda (OR = 1,47; IC95%: 1,26-1,73). Verificou-se que os homens, indivíduos mais jovens e de menor escolaridade e renda apresentaram médias mais elevadas da relação sódio/potássio.

Sódio; Potássio; Urina

Resumen

El objetivo de este estudio fue identificar los factores sociodemográficos asociados a la estimación respecto a la alta relación de consumo de sodio/potasio. Se evaluaron a 15.105 participantes, de 35 a 74 años, dentro de una cohorte de servidores públicos (ELSA-Brasil). Se recogieron datos socioeconómicos mediante un cuestionario y se realizó una toma nocturna de orina de 12 horas para estimar el consumo de sodio y potasio. La relación sodio/potasio se calculó en mmol/L y se dividió en terciles: 1er tercil corresponde a la “baja” relación; 2º tercil a la “intermedia” y 3er tercil a la “alta” relación sodio/potasio. Se compararon las proporciones y medias, según las clasificaciones del tercil de la relación sodio/potasio, utilizando los testes de chi-cuadrado y análisis de variancia (ANOVA). Se utilizaron modelos brutos y ajustados de regresión logística multinomial, teniendo como referencia el 1er tercil. Los factores asociados a la alta relación sodio/potasio fueron: sexo masculino (OR = 1,78; IC95%: 1,60-1,98); individuos de 35 a 44 años (OR = 1,71; IC95%: 1,33-2,19); enseñanza fundamental incompleta (OR = 2,38; IC95%: 1,78-3,18) y menor renta (OR = 1,47; IC95%: 1,26-1,73). Se verificó que los hombres, individuos más jóvenes y con menor escolaridad y renta presentaron medias más elevadas en la relación sodio/potasio.

Sodio; Potasio; Orina

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