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Consumption of non-nutritive sweeteners and prevalence of systemic arterial hypertension in adults and older adults from a capital city in northeast Brazil

Consumo de adoçantes não nutritivos e prevalência de hipertensão arterial sistêmica em adultos e idosos de uma capital do Nordeste brasileiro

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ABSTRACT

Objective

To characterize the consumption of Non-nutritive sweeteners and to verify the association between the intake of these additives and the prevalence of Systemic Arterial Hypertension in adults and the elderly in a Brazilian capital.

Methods

This was a cross-sectional household and population-based study carried out with 489 individuals aged 20 years and older residents of Teresina, Piauí, Brazil. Complex probabilistic cluster sampling was used. Sociodemographic, economic, lifestyle and diseases diagnosis, such as SAH diagnosis, data were obtained by self-report. Weight, height, waist circumference and blood pressure were measured. Data on food consumption and Non-nutritive sweeteners consumption were obtained using 24-hour dietary recall. The association between the consumption of Non-nutritive sweeteners and the prevalence of Systemic Arterial Hypertension was verified using Poisson regression.

Results

The most commonly consumed types of Non-nutritive sweeteners were cyclamate and saccharin and the main source of consumption was tabletop sweeteners. The consumption of Non-nutritive sweeteners was well below the Acceptable Daily Intake. Mean systolic blood pressure and diastolic blood pressure were higher in women and men who consumed Non-nutritive sweeteners (p=0.04), respectively. Individuals who consumed Non-nutritive sweeteners had a 36% higher prevalence of Systemic Arterial Hypertension compared to non-consumers (p=0.04), after adjustments. Female consumers of Non-nutritive sweeteners had a 31% higher prevalence of Systemic Arterial Hypertension (p=0.04).

Conclusion

The consumption of Non-nutritive sweeteners was positively associated with the prevalence of Systemic Arterial Hypertension. It is therefore important to continue studies investigating the possible health consequences of consuming these substances.

Keywords: Blood Pressure. Hypertension. Non-nutritive sweeteners. Saccharin. Stevia.

RESUMO

Objetivo

Caracterizar o consumo de adoçantes não nutritivos e verificar a associação entre a ingestão desses aditivos e a prevalência de Hipertensão Arterial Sistêmica em adultos e idosos de uma capital brasileira.

Métodos

Estudo transversal de base populacional e domiciliar realizado com 489 indivíduos com 20 anos ou mais residentes em Teresina, Piauí, Brasil. Foi utilizada amostragem probabilística complexa por conglomerados. Dados sociodemográficos, econômicos, de estilo de vida e de diagnóstico de doenças, como Hipertensão Arterial Sistêmica, foram autorrelatados. Foram aferidos o peso, a altura, a circunferência da cintura e a pressão arterial. O consumo alimentar e de adoçantes não nutritivos foram avaliados por meio de recordatório alimentar de 24 horas. A associação entre o consumo de adoçantes não nutritivos e a prevalência de Hipertensão Arterial Sistêmica foi verificada por meio da regressão de Poisson.

Resultados

Os tipos de adoçantes não nutritivos mais comumente consumidos foram o ciclamato e a sacarina, e a principal fonte de consumo foram os adoçantes de mesa. O consumo de adoçantes não nutritivos foi bem inferior à Ingestão Diária Aceitável. A pressão arterial sistólica e a pressão arterial diastólica foram mais elevadas em mulheres e homens que consumiam adoçantes não nutritivos (p=0,04), respectivamente. Os indivíduos que consumiam adoçantes não nutritivos apresentaram 36% maior prevalência de Hipertensão Arterial Sistêmica em comparação aos não consumidores (p=0,04), após ajustes. As mulheres consumidoras de adoçantes não nutritivos apresentaram uma prevalência 31% maior de Hipertensão Arterial Sistêmica (p=0,04).

Conclusão

O consumo de adoçantes não nutritivos foi positivamente associado à prevalência de Hipertensão Arterial Sistêmica. Portanto, é importante dar continuidade aos estudos que investigam as possíveis consequências do consumo dessas substâncias para a saúde.

Palavras-chave: *Pressão arterial. Hipertensão. Adoçantes não calóricos. Sacarina. Stevia.*

INTRODUCTION

Excessive consumption of added sugars is a recognized dietary risk factor for the global burden of disease and is associated with obesity, type 2 diabetes and cardiovascular diseases, among other health problems, especially when consumed in sugar-sweetened beverages [1,2]. In this context, artificial sweeteners have emerged as an alternative to added sugar, allowing the sweet taste to be reproduced without the use of sugar and therefore reducing the calorie content of free sugar [3].

Sweeteners are food additives known by various nomenclatures such as Low Calorie Sweeteners, Non-Calorie Sweeteners or Non-Nutritive Sweeteners and Sugar Substitutes [4]. Non-Nutritive Sweeteners (NNS) include a wide variety of synthetically derived chemical substances and natural extracts that may or may not be chemically modified. The most common NNS are acesulfame K, aspartame, advantame, cyclamates, neotame, saccharin, sucralose, stevia, certain D-amino acids and various plant proteins and other extracts that also impart a sweet taste [4].

These NNS mimic the taste of sugar, but are used in much smaller quantities because they have much greater sweetness than sucrose. They are substances that have been deemed safe for consumption and are approved for use by regulatory authorities around the world. However, it is essential to emphasize the importance of adhering to acceptable daily intake levels for safe consumption [5,6].

Nevertheless, in 2023, the World Health Organization (WHO) published a new guideline on the consumption of sweeteners, suggesting that these substances should not be used as a means of weight control or to reduce the risk of chronic non-communicable diseases, due to the fact that comprehensive randomized controlled trials and prospective cohort studies have contributed to highlighting the uncertainties regarding the safety of NNS use [4].

Thus, the use of NNS is controversial and health authorities in different countries have different opinions. Some are banned in the United States due to suspected cancer risks, but they are allowed in the European Union [7]. In addition, studies have shown that NNS consumption can contribute to the development of other chronic non-communicable diseases and metabolic disorders such as glucose intolerance [8], obesity, diabetes, kidney dysfunction [9], cardiovascular and cerebrovascular diseases [3] as well as arterial hypertension [10].

In this context, Systemic Arterial Hypertension (SAH) is the main risk factor for cardiovascular diseases and strokes, and is estimated to be the cause of 9.4 million deaths a year worldwide [11]. According to data from a nationally representative study carried out in Brazil, approximately 24% of Brazilians reported a diagnosis of SAH in 2019 [12]. In addition, data from the 2022 Surveillance System for Risk and Protective Factors for Chronic Diseases by Telephone Survey, showed that the frequency of medical diagnosis of SAH in Brazil was 27.9%, being higher among women (29.3%) than among men (26.4%) [13]. SAH is a disease with a complex pathogenesis, but lifestyle factors, such as diet, are important contributors to its development [11].

Thus, the use of NNS remains a controversial topic, so there are still many gaps about these substances that are currently undergoing a reevaluation by various health authorities, including the WHO, which reinforces the need for scientific studies on the subject [7,3]. The aim of this study was therefore to characterize the consumption of NNS and to verify the association between the consumption of these substances and the prevalence of SAH and blood pressure levels in individuals aged 20 years old and over in a capital city in northeast Brazil.

METHODS

Study design

A cross-sectional, population-based study of data from the "Household health survey in the cities of Teresina and Picos (PI)", which aimed to analyze the living conditions and health situation of the population by visiting households located in the urban area of the cities of Teresina and Picos, Piauí, Brazil. The present study considered only the population of the city of Teresina, Piauí, Brazil.

The study's sampling was of the complex probabilistic type, by conglomerates, in two stages: census tract and household. To calculate the size of the sample, the population of Teresina (767,557 inhabitants) was taken into account, based on the 2010 Instituto Brasileiro de Geografia e Estatística

(IBGE, Brazilian Institute of Geography and Statistics) census [14], as well as the stratification of the population, according to the age of the individuals for both sexes.

Based on this, the average number of individuals in each age group per household was calculated and the number of households needed for each group was calculated so that at least 30 individuals from each age group would take part in the sample. Subsequently, the expected number of individuals within the age group and sex was calculated, considering the one with the largest sample size in terms of number of households, represented by the 3-4 year old female group (n=578 households) in Teresina. Thus, the expected number of individuals for each age group and sex was calculated based on 578 households.

A simulation study was conducted to examine the behavior of the 95% confidence interval and the coefficient of variation of the standard error of the proportion for estimates of the proportion ranging from 10% to 70%, according to age groups, sex and respective sample sizes (values for 50% estimates).

However, considering that losses could occur during the data collection for various reasons, the final sample size for this study was adjusted using n=n0/0.90, assuming a response rate of 90%, resulting in an approximate n of 642 households in Teresina.

In this study were included adults (20 to 59 years old) and older adults (aged 60 or over) of both sexes, who had complete data on food consumption, anthropometry, blood pressure, medical diagnosis of SAH and also sociodemographic, economic and lifestyle data, comprising 489 individuals. More information on the sampling process is described in Rodrigues et al. [15].

Data collection

Sociodemographic data (age, sex, skin color, education), economic data (family income), lifestyle data (alcohol consumption, smoking and physical activity) and self-reported chronic disease diagnoses were obtained by applying questionnaires previously used in other Brazilian population-based studies [16,17], using the Epicollect 5® app (Imperial College London, 2018) on mobile devices.

Diagnosis of Systemic Arterial Hypertension and blood pressure measurement

The diagnosis of SAH was obtained through self-reported answers to the question "Has a doctor ever diagnosed you with SAH?".

Moreover, blood pressure was measured and individuals with Systolic Blood Pressure (SBP) values greater than or equal to 140 mmHg and/or Diastolic Blood Pressure (DBP) greater than or equal to 90 mmHg were classified as with hypertension [18].

Blood pressure was measured in duplicate using a manual sphygmomanometer, with cuffs of the appropriate size for the brachial circumference, with the patient seated and at rest for at least 5 minutes and an interval of 1 minute between each measurement. The average of the two measurements was taken to classify blood pressure [18].

In order to avoid possible cases of underreporting of the disease and to reduce possible bias from the use of antihypertensive medication, both the self-reported diagnosis of SAH and the measured blood pressure were taken into account to define the prevalence of SAH.

Food consumption

Food intake was obtained through a 24-hour food recall (24HR), applied in one single day, using the Multiple-Pass Method [19]. Subsequently, a second 24HR was carried out on 40% of the population, after an interval of two months, using the same procedures as the first interview, in order to correct for intrapersonal variability, in line with the research by Verly-Jr et al. [20], which showed that there was no expressively loss of accuracy in estimating food consumption, regardless of sample size. The individuals were interviewed and with the aim of helping to identify and report the quantities of food eaten, photos of utensils and portions were used [21]. The home measures reported by the interviewees were transformed into grams (g) or milliliters (mL) using the Table for Evaluating Food Consumption in Home Measures [22]. The data from both 24-hour food recall were used to correct the intrapersonal variability in intake (in grams) using the Multiple Source Method statistical technique [23].

The foods reported were categorized according to the NOVA food classification based on the extent and purpose of processing into four groups: in natura or minimally processed foods, processed culinary ingredients, processed foods and ultra-processed foods [24]. Subsequently, the calorie and sodium intake in each group was estimated based on the Brazilian Table of Food Composition [25], Table of Nutritional Composition of Foods Consumed in Brazil [26] and Table of Food Composition: Support for Nutritional Decisions [27]. Finally, the percentage contribution of each group in the NOVA classification to the Total Energy Value of the Diet (TEV) was calculated.

Non-Nutritive Sweeteners consumption

The consumption of NNS was estimated considering the use of tabletop sweeteners as well as the consumption of foods containing sweeteners in their composition, by analyzing the food label or contacting the manufacturer when the information on the label was insufficient. Some foods containing sweeteners, such as dairy beverages, were not included in the analysis because it was not possible to estimate the amounts of sweeteners in the products, since there was no information about this on the labels and the manufacturer reported formulation secrecy. However, only two participants reported consuming these beverages. The sweeteners consumed were then grouped by type (cyclamate, saccharin, acesulfame K, aspartame, sucralose and stevia), quantity and food source.

In order to check that the amount of sweeteners ingested was in line with the Acceptable Daily Intake (ADI) established by the Joint FAO/WHO Expert Committee on Food Additives - JECFA [6], the maximum intake limit was calculated by multiplying the ADI value in milligrams by the average weight of the participants. To obtain the percentage of adequacy of sweetener intake, the amount ingested was divided by the intake limit obtained and multiplied by 100.

Covariates

Data on sex were analyzed in a dichotomous qualitative way, classifying participants as male and female. Age was expressed in years old. Education was classified into levels of education such as illiterate, elementary education, high school and higher education. Skin color was self-reported, with individuals grouped into white, black, brown and others. Total family income was categorized as less than 2 minimum wages and greater than or equal to two minimum wages, according to the current value in 2019 (R$998.00).

Alcohol consumption was estimated using the question "Do you currently drink alcohol?". Smoking was estimated using the question "Do you currently smoke or have you ever smoked (at least 100 cigarettes or 5 packs)?". And through the question "Do you currently smoke? If so, do you smoke daily?" [16,17].

The diagnosis of diabetes *mellitus* was obtained through yes-no question "Has a doctor ever diagnosed you with diabetes mellitus?" [16,17].

Physical activity was estimated using the International Physical Activity Questionnaire (IPAQ), long version for adults and short version for older adults [28]. Individuals were classified as insufficiently active or active according to the 2020 World Health Organization recommendations, which recommend as sufficient at least 150 minutes of light to moderate physical activity and/or 75 minutes of vigorous physical activity per week [29].

Weight and height were measured according to Jelliffe and Jelliffe [30] and Cameron [31]. Weight was measured using an electronic scale accurate to 100 grams. Height was measured using a portable stadiometer with an accuracy of 0.1 centimeters. Body Mass Index (BMI) was calculated according to the World Health Organization (BMI = weight (kg)/ height(m)^2) [32]. Waist Circumference (WC) was measured at the midpoint between the last rib and the iliac crest, according to the recommendations of the World Health Organization [33], using an inelastic tape measure with an accuracy of 0.1 centimeters.

Ethical aspects

This study was approved by the Human Research Ethics Committee of the Federal University of Piauí under opinion number 2.552.426 and all participants provided written consent.

Statistical Analysis

Continuous variables were expressed as means and standard errors and categorical variables were expressed as absolute and relative values. Data distribution and homoscedasticity were analyzed using the Shapiro Wilk and Levene tests, respectively. Continuous variables were compared using the Mann-Whitney U test and categorical variables were compared using Pearson's chi-square test or Fisher's exact test. The association between the consumption of NNS and the prevalence of SAH was verified using Poisson regression, expressed as Prevalence Ratio crude and adjusted for potential confounding factors. The adjustment variables were selected using the Acyclic Graph Diagram (AGD), through the dagitty program version 3.0, employing the back door method [34,35]. The minimum necessary adjustment was demonstrated for the variables of age, sex, education, skin color, family income, alcohol consumption, smoking, sodium consumption, physical activity, diagnosis of diabetes *mellitus*, BMI, WC, percentage calorie contribution of the NOVA groups and total calories in the diet.

All the analyses were carried out using the program Stata version 13.0 Survey mode was used in order to correct the analyses for the complex sampling of the research. A significance level of 5% and 95% confidence intervals were adopted.

RESULTS

The results of the characterization of the study sample are shown in Table 1. The average age was 46.5 years old, the majority of the population was female, reported brown skin color, had studied until high school, had a family income of less than 2 minimum wages, did not consume alcohol, did not smoke and was physically active. The prevalence of diabetes *mellitus* in the total sample was 9.6%, being higher in NNS consumers (38.0%) than in non-consumers (6.4%). In addition, the prevalence of SAH was 43.6% in the total sample, also being higher in NNS consumers (66.0%) compared to non-consumers (41.0%). In terms of food consumption, the average percentage contribution of NOVA food groups was greater for minimally processed foods/ culinary ingredients group. The prevalence of NNS consumption in this study was 10.2%.

In relation to consumers and non-consumers of NNS, it was found that individuals who consumed NNS were significantly older (p=0.004), had a higher prevalence of SAH (p=0.005), and diabetes *mellitus* (p=0.0001), as well as a higher mean BMI (p=0.03) in the total sample and higher mean WC (p=0.005) in the total sample and in women (p=0.002). In addition, consumers of NNS had a lower mean sodium intake (p=0.02).

Table 1 – Characterization of the study sample consisted of adults (20-59 years old) and older adults (≥60 years old) (n=489). Teresina (PI), Brazil, 2019.

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Variables	Total n (%)	Non-consumers of NNS n (%)	Consumers of NNS n (%)	*p*-value
Age (mean±sd)	46.5±17.2	45.8±17.1	52.8±16.9	0.004***
Sex				
Female	327 (66.9)	289 (65.8)	38 (76.0)	0.10*
Male	162 (33.1)	150 (34.2)	12 (24.0)	
Skin color				
White	56 (11.4)	52 (11.9)	4 (8.0)	0.32**
Black	83 (17.0)	73 (16.6)	10 (20.0)	
Brown	305 (62.4)	277 (63.1)	28 (56.0)	
Others[1]	45 (9.2)	37 (8.4)	8 (16.0)	
Education				
Illiterate	29 (5.9)	26 (5.9)	3 (6.0)	
Elementary School	149 (30.5)	133 (30.3)	16 (32.0)	0.95**
High School	200 (40.9)	181 (41.3)	19 (38.0)	
Higher Education	111 (22.7)	99 (22.5)	12 (24.0)	
Total Family Income				
Less than 2 MW	374 (76.5)	337 (76.8)	37 (74.0)	0.64*
Greater than or equal to 2 MW	115 (23.5)	102 (23.2)	13 (26.0)	
Alcohol consumption				
No	293 (59.9)	257 (58.5)	36 (72.0)	0.07*
Yes	196 (40.1)	182 (41.5)	14 (28.0)	
Smoking				
No	382 (78.1)	345 (78.6)	37 (74.0)	0.50**
Ex-smoker	71 (14.5)	61 (13.9)	10 (20.0)	
Smoker	36 (7.4)	33 (7.5)	3 (6.0)	
Physical activity				
Insufficiently active	96 (19.6)	82 (18.7)	14 (28.0)	0.13*
Active[2]	393 (80.4)	357 (81.3)	36 (72.0)	
Diabetes Mellitus diagnosis				
No	442 (90.4)	411 (93.6)	31 (62.0)	0.0001*
Yes	47 (9.6)	28 (6.4)	19 (38.0)	
Systemic Arterial Hypertension diagnosis				
No	276 (56.4)	259 (59.0)	17 (34.0)	0.005*
Yes	213 (43.6)	180 (41.0)	33 (66.0)	

Table 1 – Characterization of the study sample consisted of adults (20-59 years old) and older adults (≥60 years old) (n=489). Teresina (PI), Brazil, 2019.

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Variables	Total n (%)	Non-consumers of NNS n (%)	Consumers of NNS n (%)	*p*-value
Variables	Mean±Standard error	Mean±Standard error	Mean±Standard error	*p*-value
BMI† (kg/m²)	27.3±0.2	27.2±0.3	28.7±0.8	0.03***
WC†† (m)	89.3±0.6	88.8±0.6	95.7±1.7	0.005***
Women WC (cm)	87.0±0.7	86.3±0.7	92.4±1.8	0.002***
Men WC (cm)	94.0±1.0	93.7±1.0	98.2±3.9	0.27***
SBP# (mmHg)	125.3±0.9	124.9±1.0	128.8±2.6	0.08***
Women SBP (mmHg)	122.2±1.0	121.5±1.1	127.5±3.2	0.04***
Men SBP (mmHg)	132.0±1.7	131.9±1.8	133.1±4.6	0.53***
DBP## (mmHg)	80.4±0.6	80.4±0.6	80.4±2.2	0.81***
Women DBP (mmHg)	78.7±0.7	78.9±0.7	77.3±2.4	0.57***
Men DBP (mmHg)	83.8±1.1	83.3±1.1	90.3±3.9	0.04***
Variables	Mean±Standard error	Mean±Standard error	Mean±Standard error	*p*-value
% contribution to the TEV of ultra-processed foods	19.7±0.8	19.6±0.9	20.7±2.5	0.53***
% contribution of unprocessed or minimally processed foods and culinary ingredients to TEV	76.7±0.8	76.6±0.9	76.9±2.5	0.94***
% contribution to TEV of processed foods	3.6±0.4	3.8±0.4	2.4±0.8	0.46***
TEV### (kcal/day)	1797.8±40.1	1818.4±42.8	1617.1±111.2	0.12***
Dietary sodium (mg)	1425.9±64.3	1459.4±69.7	1132.1±141.4	0.02***

Note: * Pearson's Chi-square test; ** Fisher's exact test; *** Mann-Whitney U-test. [1] Yellow, indigenous and others; [2] At least 150 minutes of light to moderate physical activity and/or 75 minutes of vigorous physical activity per week. †BMI: Body Mass Index; ††WC: Waist circumference; #SBP: Systolic Blood Pressure; ##DBP: Diastolic Blood Pressure; ### TEV: Total Energy Value. MW: Minimum Wages.

Moreover, DBP levels were significantly higher in males NNS consumers compared to non-consumers (*p*=0.04). Among women, SBP levels were significantly higher in consumers of NNS (*p*=0.04).

Table 2 shows the prevalence of sweetener consumption according to type and food source. The majority of the population consumed saccharin/cyclamate, with aspartame/acesulfame K being the second most consumed, followed by sucralose and stevia. As for food sources, most sweetener consumption came from tabletop sweeteners added to beverages by the individuals themselves, followed by consumption through powdered fruit juices and, lastly, diet soft drinks.

Table 3 shows the results of the amount of sweetener consumption in milligrams and the adequacy of consumption according to the respective ADI values for each type. It was observed that the most consumed sweetener was the saccharin/cyclamate blend and that no individual exceeded the ADI for NNS.

Table 2 – Types and sources of Non-nutritive sweeteners consumed by adults (20-59 years old) and older adults (≥60 years old) (n=489). Teresina (PI), Brazil, 2019.

Types and sources of Non-nutritive sweeteners consumed	n	%
Non-nutritive sweeteners		
Non-consumers	440	89.8
Sacharin/cyclamate	34	6.9
Aspartame/acesulfame K	19	2.1
Sucralose	4	0.8
Stevia	2	0.4
Sources of Non-nutritive sweeteners		
Tabletop sweeteners added to beverages	40	80.0
Powdered fruit juices	8	16.0
Diet soda	2	4.0

Table 3 – Adequacy of the amount of Non-nutritive sweeteners ingested according to the Acceptable Daily Intake (n=489). Teresina (PI), Brazil, 2019.

Non-nutritive sweeteners	Mean milligrams ingested (standard error)	Mean body weight (kg)	ADI (mg/kg body weight)*	Mean consumption limit	Consumption adequacy percentage
Sacharin/cyclamate**	1.84 (0.47)		–	–	–
Sucralose	0.10 (0.06)		5.0	345.25	0.03
Stevia	0.04 (0.03)	69.05	4.0	276.20	0.01
Aspartame	1.50 (0.52)		40.0	2762.00	0.05
Acesulfame K	0.52 (0.20)		15.0	1,035.75	0.05
Total	4.00 (1.15)		–	–	–

Note: *JECFA/WHO [6]; **The sweeteners were used as a blend and it was not possible to establish the individual quantities in the product to calculate adequacy, as they have different ADI values.

The results of the association between NNS consumption and the prevalence of SAH in the study are shown in Table 4. It was found that individuals who consumed NNS had a 36% higher prevalence of SAH compared to non-consumers (*p*=0.04), after adjustments.

Table 4 – Association between Systemic Arterial Hypertension and Non-nutritive sweeteners consumption in adults and older adults (n=489). Teresina (PI), Brazil, 2019.

Groups	Systemic Arterial Hypertension				
	% (95% CI)	PR (95% CI)	*p*-value	PR adjusted (95% CI)*	*p*-value
Total population (n=489)					
Non-consumers of NNS	41.0 (36.8-45.3)	Ref.		Ref.	
Consumers of NNS	66.0 (48.8-79.8)	1.61 (1.25-2.07)	0.001	1.36 (1.01-1.83)	0.04
Women (n= 327)					
Non-consumers of NNS	37.7(33.3-42.3)	Ref.		Ref.	
Consumers of NNS	60.5 (44.0-74.0)	1.60 (1.20-2.14)	0.002	1.31 (1.02-1.69)**	0.04
Men (n=162)					
Non-consumers of NNS	47.3 (38.4-56.4)	Ref.		Ref.	
Consumers of NNS	83.3 (49.0-96.3)	1.76 (1.27-2.43)	0.001	1.46 (0.82-2.61)**	0.19

Note: * Adjusted for age, sex, education, family income, skin color, alcohol consumption, smoking, physical activity, diagnosis of diabetes mellitus, Body Mass Index, Waist Circumference, sodium intake, total calories in the diet and the percentage of caloric contribution of the NOVA groups in the Total Energy Value; ** Adjusted for all other variables except sex. CI: Confidence Interval; NNS: Non-Nutritive Sweeteners; PR: Prevalence Ratio.

Similarly, women who consumed NNS had a 31% higher prevalence of SAH compared to non-consumers, even after adjusting for potential confounding factors (*p*=0.04). However, no association was observed for males after adjustments.

DISCUSSION

The data from this study showed that individuals who consumed NNS were older, had a higher prevalence of hypertension and diabetes mellitus, and had a higher BMI and WC. On the other hand, they had lower sodium intake.

The use of NNS is generally part of the dietary recommendations for the treatment of diabetic individuals [36], explaining the higher consumption among people diagnosed with the disease. In addition, overweight individuals can use NNS as a strategy to reduce calorie intake and help with weight control [36]. However, the issue of compensatory energy intake related to NNS should also be highlighted, due to the possible belief that consumption of a low-calorie beverage or food would allow more calories to be ingested or due to changes in appetite control and increased motivation for sweet foods [37,38].

Furthermore, NNS consumers are more likely to adopt a healthier eating behavior, characterized by a lower calorie intake [39], as well as a greater likelihood of healthier lifestyle choices in general [40], which may explain the lower mean sodium intake observed for individuals consuming NNS in this study.

There was a higher prevalence of cyclamate and saccharin consumption and the main food sources of sweeteners, were tabletop sweeteners, powdered fruit juices and diet soft drinks. Similarly, according to data from the Brazilian Association of the Food Industry for Special Purposes and Congeners approximately 35% of the Brazilian population in general consumes some kind of diet product, with diet soda being the most consumed [41].

Moreover, cyclamate and saccharin are the cheapest sweeteners and comprise the majority of sweetener consumption worldwide [42]. Thus, the fact that most of the study population had a family income of less than two minimum wages may explain the preference for cyclamate and saccharin, as they are more affordable sweeteners.

The results of this study showed a prevalence of SAH of 43.6%. Prevalences of 23.9% and 27.4% were observed in other studies of Brazilian adults, one being nationally representative and the other carried out with adults from the backlands of Pernambuco, respectively [43,44]. The higher prevalence of SAH in this study may be related to the combination of self-reported diagnosis and measured blood pressure for the definition of SAH, revealing possible cases of underdiagnosis, as well as differences in the lifestyle of this specific population [45,46].

The prevalence of NNS consumption in this study was 10.2%. A population-based study carried out with adults in a city in southern Brazil revealed a prevalence of NNS consumption of 19%, being higher among the older adults than among younger individuals [47], comparable to that observed in the present study, in which the consumption of NNS was more prevalent in older individuals. Similarly, Monteiro et al. [39] reported a prevalence of NNS consumption of 7.6% in the Brazilian population, which was more prevalent in the older adults.

We found that consumption of NNS was well below the ADI in this study. Similarly, in a study carried out with data from the 2008-2009 Brazilian Household Budget Survey, which was nationally representative, the estimated consumption of sweeteners such as acesulfame K, aspartame, cyclamate, saccharin, stevia and sucralose did not exceed the ADI in the total population or in any of the population subgroups assessed [48]. The same was observed by Daher et al. [49], who assessed the consumption of sweeteners in Lebanese individuals and found that consumption was within the established ADI.

In the present study, it was observed that individuals who consumed NNS had a higher prevalence of SAH than those who did not, both for the total sample and for females, regardless of age, education, skin color, alcohol consumption, smoking, physical activity, diagnosis of diabetes mellitus, BMI, WC, diet TEV and the percentage of caloric contribution of the NOVA groups in the total TEV.

Similar results were observed in a meta-analysis of prospective studies, in which high intake of NNS was associated with an increased risk of hypertension during 5 to 38 years of follow-up in 232,630 participants (RR: 1.13; 95%CI: 1.06 to 1.20), considering data from 5 cohorts [10].

Similarly, the results of another meta-analysis study showed that higher consumption of artificially sweetened beverages and increased consumption of these beverages by at least one portion per day was also associated with a 14% and 10% higher risk of hypertension, respectively [50]. Furthermore, as assessed in another meta-analysis of prospective cohort studies, higher intake of beverages containing NNS was associated with a 13% increase in the risk of SAH [51]. However, as reported in the WHO guideline on the consumption of non-nutritive sweeteners, despite studies demonstrating an association between NNS consumption and the risk of SAH, the level of certainty of scientific evidence is considered low [4].

The possible mechanisms of the increase in blood pressure and consequent development of SAH due to NNS consumption are not yet fully understood. However, it has been suggested that the consumption of artificial sweeteners, may contribute to negative metabolic consequences, such as glucose intolerance, by inducing changes in the intestinal microbiota [8, 52]. Such alterations could lead to the development of SAH, since it is likely that the metabolic profile of SAH is associated with the composition of the intestinal microbiota and the systemic distribution of its products, since the human intestinal microbiota in patients with SAH would present a lower microbial diversity than the intestinal microbiota of a healthy individual, containing lower amounts of bacteria associated with the homeostasis of the intestinal microbiota as well as the production of short-chain fatty acids, such as butyrate [11].

Thus, the intake of NNS has the potential to modify the expression of genes associated with carbohydrate metabolism. This alteration can influence the proliferation and function of intestinal bacteria, resulting in metabolic shifts and inflammatory responses. These changes can further contribute to vascular abnormalities and foster the progression of cardiovascular disease [53].

However, after stratifying the analyses by sex, no associations were observed between the prevalence of SAH and the consumption of NNS in men, only in women. A similar result was observed in the longitudinal study by Malik et al. [54], in which the association between the consumption of artificially sweetened beverages and mortality from cardiovascular diseases was found more among women. Sex may be a factor in determining the degree of association with SAH and this difference may be related to sex hormones. Hormones such as oestrogen can influence the contraction or relaxation of vascular smooth muscle, increasing the release of nitric oxide [55].

The limitations of this study are its cross-sectional nature, which does not allow establishing clear cause and effect relationships, and also the possibility of reverse causality, since as it is a cross-sectional study, it is possible that people with hypertension could tend to consume more NNS trying to adopt a healthier lifestyle. On the other hand, it is worth noting that this is a well-controlled study for several important confounding factors, including those related to diet and the presence of other chronic non-communicable diseases. In addition, it was used the 24-hour recall for the food consumption assessment, which it is one of the least biased self-report instrument, especially when it incorporates procedures to improve data quality, such as the Multiple Pass Method. Furthermore, it was the first study to characterize the consumption of NNS in a representative population of adults and older adults of a city in northeastern of Brazil.

CONCLUSION

The consumption of NNS was significantly associated with the prevalence of SAH in the total sample and in females, even after adjusting for various confounding factors. Thus, considering the trend towards increased use of these substances in food products and the consequent increase in their intake by the population, both unconsciously and in search of health maintenance or improvement because they are considered healthier products compared to added sugar, It is important to continue studies investigating the health consequences of long-term consumption of these substances.

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