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Salt consumption profile and relationship with blood pressure in the indigenous population of Aracruz, Espírito Santo

Perfil de consumo de sal e relação com a pressão arterial na população indígena de Aracruz, Espírito Santo

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ABSTRACT

Objective

To evaluate salt intake and its relationship with blood pressure among adults living in the Aracruz indigenous reserve, Espírito Santo.

Methods

This cross-sectional study included 37% of the eligible population. Recruitment was conducted by invitations from researchers, indigenous leaders, and health agents. Fasting blood and urine samples were collected. Blood pressure was measured via oscillometry, whereas salt intake was estimated by the Na/creatinine ratio in urine using the Tanaka equation. The associations between salt intake and systolic and diastolic blood pressure were determined by multivariate linear analysis. The study was approved by the Research Ethics Committee (No. 22563019600005056).

Results

Of the 1,084 participants who were initially recruited, 36 were excluded from the analysis because of missing urinary data, and 248 were excluded because they were on antihypertensive medications. Thus, the final analysis included the data of 800 individuals (55.4% women; age = 37.9±13.4 years). In this sample, the average salt intake was estimated at 10.0g/day and was higher among men (10.4g/day) than among women (9.7g/day; $p<0.01$). Multivariable analysis indicated that age, body mass index and salt intake explained 24% of the variability in systolic blood pressure in the population, with age being the predominant factor. An increase of 0.11mmHg in the diastolic blood pressure was observed for the intake of each additional gram of salt.

Conclusion

High salt intake in the indigenous population of Aracruz, although modestly affecting systolic blood pressure, contributes significantly to the development of hypertension.

Keywords: Arterial Pressure. Indigenous Peoples. Salt. Urine.

RESUMO

Objetivo

Avaliar o consumo de sal e sua relação com a pressão arterial de adultos residentes na reserva indígena de Aracruz, Espírito Santo.

Métodos

Estudo transversal abrangendo 37% dos elegíveis. O recrutamento foi feito mediante convite dos pesquisadores, lideranças indígenas e agentes de saúde. Amostras de sangue e de urina foram coletadas em jejum. A pressão arterial foi medida pelo método oscilométrico, enquanto o consumo de sal foi estimado pela relação Na/creatinina na urina utilizando a equação de Tanaka. A associação entre o consumo de sal e a pressão arterial sistólica e diastólica foi realizada por análise linear multivariada. O estudo foi aprovado pelo Comitê de Ética em Pesquisa (No. 22563019600005056).

Resultados

Dos 1.084 participantes inicialmente recrutados, 36 foram excluídos da análise devido à ausência de dados urinários e 248 por estarem em uso de antihipertensivos. Assim, a análise final foi realizada com 800 indivíduos (55,4% mulheres; idade = $37,9 \pm 13,4$ anos). Nessa amostra, o consumo médio de sal foi estimado em 10,0g/dia, com valores mais elevados em homens (10,4g/dia) em comparação às mulheres (9,7g/dia; $p < 0,01$). A análise multivariada indicou que a idade, o índice de massa corporal e o consumo de sal explicam 24% da variabilidade da pressão arterial sistólica na população, a idade sendo o fator predominante. Observou-se incremento de 0,11mmHg na pressão arterial sistólica para cada grama de sal.

Conclusão

A elevada ingestão de sal na população indígena de Aracruz, embora com impacto modesto na pressão arterial sistólica, contribui significativamente para o desenvolvimento de hipertensão.

Palavras-chave: Pressão arterial. Povos indígenas. Sal. Urine.

INTRODUCTION

Chronic noncommunicable diseases, particularly Cardiovascular Diseases (CVD), are responsible for 63% of deaths worldwide and 72% of deaths in Brazil [1]. Arterial Hypertension (AH) is the main risk factor for global CVD mortality; thus, efforts to reduce cardiovascular morbidity and mortality have focused on the control of Blood Pressure (BP) in patients with hypertension. The prevalence of AH in Brazil is 32.3%, but there are important differences among regions and age groups [2]. Studies in specific populations, such as civil servants of the Longitudinal Study of Adult Health (ELSA-Brazil), have also shown differences in prevalence by education and race/color, with higher values in individuals with lower educational levels and in blacks than in white and brown individuals [3]. However, few studies on this topic have involved indigenous people. A review of local studies, most of which focused on the Amazon region, revealed a highly variable prevalence, mainly because of the degree of acculturation and exchange with the nonindigenous population [4]. Consequently, information on the behavior of BP and its determinants among Brazilian indigenous people is scarce.

Espírito Santo has only one indigenous group living in a demarcated reserve, located in the municipality of Aracruz, on the northern coast of the state. The reserve occupies an area of approximately 18,000 hectares and is home to two indigenous populations with approximately 5,000 people each. Approximately 10% of this population consists of nonindigenous people, and among the indigenous people, 90% are of the Tupiniquim ethnic group, while the other 10% are of the Guarani-Mbyá ethnic group. A study conducted in adults of this population in 2003 through 2004 revealed a prevalence of AH of 20.8% [5], while that specifically in the Guarani population was very low (<5%).

AH is a complex disease whose onset depends on nonmodifiable (family inheritance, sex, age) and modifiable risk factors, especially those related to diet, including salt intake [6,7]. Diets high in sodium and low in potassium increase BP and thus facilitate the development of hypertension [6]. High sodium intake is associated with diets rich in highly processed foods, including ready-to-eat seasonings [8,9]. The current recommendation of the World Health Organization is that salt intake should be limited to 5g/day maximum [10]. The consumption pattern of this nutrient in Brazil is almost double that recommendation, reaching an average value of 9.3g/day, according to the National Health Survey [11].

In a study conducted with the indigenous population of Aracruz (ES) in 2003 through 2004, an average salt intake of 13.7g/day was reported on the basis of sodium measurements in the urine of 12 nocturnal collections [5], a result of the long-standing incorporation of the traditional eating habits of urban populations. The impact of the adoption of Western diets high in sodium by indigenous people has rarely been studied in Brazil. The objective of this study was to determine the profile of sodium and potassium intake in the population of the villages of Aracruz and to verify its impact on the BP of this population.

METHODS

Population and study site

This study was conducted in the population residing in the Aracruz indigenous reserve, which is located approximately 80 km from Vitória, the state capital of Espírito Santo. All the residents of the 12 reserve villages aged ≥ 20 years were considered eligible for the study.

According to data from the indigenous health district, the eligible population as of February of 2023 was 2,982 individuals, the majority of whom were of the Tupiniquim ethnicity (80%), while a minority were Guarani Mbyá (10%). The remaining 10% of the population was nonindigenous (in general, married to indigenous people). The population generally subsists on agriculture and fishing, and approximately 20% of the population are salaried workers in public or private sectors in the region.

Research planning was conducted through meetings with indigenous leaders and researchers, and participants were recruited through invitations to those eligible by indigenous leaders, researchers and health agents of the 5 Basic Indigenous Health Units of the reserve. Data collection was performed via questionnaires administered in interviews and by clinical and laboratory tests on predetermined days at the UFES University Hospital in Vitória (September 2020 to July 2022) for community service. After accepting the invitation, all participants signed an informed consent form before data collection with the assistance of indigenous health agents, when necessary. The project was approved by the Research Ethics Committee of the Health Sciences Center of Universidade Federal do Espírito Santo (UFES) (CAAE 22363019.6.0000.5060, Opinion No. 3.655.623) and by the National Research Ethics Committee (CONEP Opinion No. 3.828.655).

Data collection

The participants visited the examination site (Hospital Universitário da UFES) in the morning (7–8 am) after fasting for 10–14 hours for blood and urine collection, blood pressure measurements, anthropometry, electrocardiography, and bioimpedance data collection, as well as questionnaire administration to obtain sociodemographic data and information concerning lifestyle habits.

Blood pressure was obtained according to the protocol of the Brazilian Society of Cardiology [12]. Three consecutive measurements were performed with an interval of 1–2 minutes using an oscillometric device (Omron HEM 705CPINT) after the bladder was emptied, with the patient in a seated position and having rested for at least 5 minutes. The final BP was recorded as the mean of the last two measurements. An individual was considered hypertensive when the Systolic Blood Pressure (SBP) was ≥ 140 mmHg or the Diastolic Blood Pressure (DBP) was ≥ 90 mmHg or if the participant reported using antihypertensive drugs, including diuretics [12].

Body weight was obtained during fasting and after the bladder was emptied, with the individuals barefoot and wearing the standardized study outfit, using an electronic scale (Toledo, Brazil) with 0.1 kg precision. Height was measured using a wall stadiometer (Seca, Brazil) with a precision of 0.1 cm. Body Mass Index (BMI) was calculated as the ratio of weight to height squared (kg/m^2). Nutritional status was classified according to the standardized protocol; individuals were classified as underweight ($\text{BMI} < 18.5 \text{ kg}/\text{m}^2$), normal weight ($\text{BMI} 18.5$ to $24.9 \text{ kg}/\text{m}^2$), overweight (BMI from 25.0 to $29.9 \text{ kg}/\text{m}^2$) or obese ($\text{BMI} \geq 30 \text{ kg}/\text{m}^2$). Diabetes was considered present if self-reported, if the fasting glucose concentration was $\geq 126 \text{ mg}/\text{dL}$ or $\geq 200 \text{ mg}/\text{DL}$ after the glucose tolerance test (ingestion of 250 mL of flavored solution containing 75 g of glucose), or if the participant reported the use of oral hypoglycemic agents or insulin [13].

Estimation of salt intake

A urine sample was collected before the anthropometric measurements were obtained, typically corresponding to the second urine of the day. An aliquot of the sample was sent to the laboratory for measurement of creatinine (Jaffé method) and Na and K (selective electrode). The estimated salt intake was calculated with the Na/creatinine ratio in casual urine and using the Tanaka formula [14], which was previously validated for the adult Brazilian population [15].

Data analysis

Data were analyzed using IBM®SPSS® (version 21). The *Kolmogorov–Smirnov* test was used to test the normality of continuous variables. Comparisons of categorical variables were performed using the chi-square test, comparisons of two means were performed using Student's *t* test for independent samples, and comparisons of three or more means were performed using one-way analysis of variance. Post hoc comparisons were performed using Tukey's test. Pearson's correlation (*r*) analysis was used to test the association of SBP and DBP with exposure variables (age, BMI, salt intake, Na/K and K/creatinine ratio in urine), and the correlation was considered significant at $p < 0.05$. To identify independent determinants of SBP and DBP, multivariable analysis was used with progressive input of independent variables with significant associations in the bivariable analyses. The significance level adopted was 5%. For each dependent variable (SBP, DBP), the dependent variables included in the model were age, BMI and salt intake (g/day), in that order.

RESULTS

Of the 1,084 study participants, 36 were excluded because their urine was not collected, and 248 reported being on antihypertensive medication. The data presented correspond to a sample of 800 individuals, among whom 55.4% were women, with a mean age of 37.9 ± 13.4 years. Table 1 shows the sociodemographic and clinical data of the sample, which consisted mostly of young adults

(up to 40 years old) and nonsmokers and those who consumed alcohol. In the sample, there was a predominance of Tupiniquins (79.8%) and a lower proportion of Guarani (10.5%) and nonindigenous (10.9%) individuals.

Table 1 – Sociodemographic characteristics of the sample according to sex in the indigenous community of Aracruz (2021–2022).

(Variables)	Male (n=357)		Female (n=443)		Total (n=800)		p-value
	n	%	n	%	n	%	
Age group (%)							<0.01
20–39 Years	186	52.1	296	66.8	482	60.2	
40–59.9 Years	132	37.0	122	27.5	254	31.8	
≥ 60 Years	39	10.9	25	5.6	64	8.0	
Ethnicity (%)							0.07
Tupiniquim	293	82.1	336	75.8	629	78.6	
Guarani	29	8.1	55	12.4	84	10.5	
Nonindigenous	35	9.8	52	11.7	87	10.9	
Education (%)							<0.01
Incomplete elementary education	109	30.5	110	24.8	219	27.4	
Complete elementary/incomplete secondary education	87	24.4	73	16.5	160	20.0	
Complete secondary/incomplete higher education	127	35.6	193	43.6	320	40.0	
Complete higher education	34	9.5	67	15.1	101	12.6	
Smoking status (%)							<0.01
Current	82	23.0	48	10.8	130	16.2	
Former	85	23.8	58	13.1	143	17.9	
Never	190	53.2	337	76.1	527	65.9	
Consumption of alcoholic beverages (%)							<0.01
Yes	285	79.8	265	59.8	550	68.8	
No	72	28.8	178	40.2	250	31.2	

Note: The p-value was calculated with the chi-square test. Numbers in bold correspond to $p < 0.05$.

Table 2 shows the clinical characteristics of the sample according to sex. Men had higher mean values of weight, height, SBP and DBP and a higher prevalence of AH and overweight (<0.01), whereas women had higher mean values for BMI, heart rate and prevalence of obesity.

Table 3 shows the urine characteristics of the participants. The concentration of creatinine was higher in males, as were the concentrations of Na and K. The predicted creatinine excretion

Table 2 – Clinical characteristics of the sample according to sex in the indigenous community of Aracruz (2021–2022).

Variables	Male (n=357)	Female (n=443)	Total (n=800)	p-value
Weight (kg)	77.5±15.0	74.0±16.8	75.7±16.0	<0.01
Height (cm)	168.9±7.70	157.0±6.6	162.3±9.2	<0.01
Waist circumference (cm)	91.0±11.9	91.7±15.1	91.4±13.7	0.502
Body mass index (kg/m ²)	27.0±4.3	30.0±6.3	28.6±5.7	<0.01
Systolic blood pressure (mmHg)	128±15	119±15	123±16	<0.01
Diastolic blood pressure (mmHg)	76±10	74±9	75±9	<0.01
HR (mmHg)	69±12	75±12	72±12	<0.01
Hypertension (%)	68(19.0)	49(11.1)	117(14.6)	<0.01
Diabetes (%)	36(10.1)	67(15.1)	103(12.9)	0.03
Overweight (%)	163(52.1)	150(47.9)	313(39.1)	<0.01
Obesity (%)	77(21.6)	196(44.2)	273(34.1)	<0.01

Note: The data are presented as the mean±standard deviation for continuous variables or as the number and percentage of individuals (%) for categorical variables. Continuous variables were compared with the independent-samples Student's t test, and categorical variables were compared with the chi-square test. n: Number of individuals; Numbers in bold correspond to $p < 0.05$.

over 24 hrs, calculated by the Tanaka formula [14], was approximately 18% greater in men ($p < 0.01$). The relationship between the molar concentrations of Na and K in the urine was greater than 3 and similar between the sexes ($p > 0.05$). Only 20 men (5.2%) and 23 women (5.2%) had a Na/K ratio < 1 , indicating a balanced diet between these two minerals. The estimated salt intake was on average 10.0 ± 2.7 g/day and was slightly greater for men than for women ($p < 0.01$). Only 6 women and 2 men reported an estimated daily salt intake within the current recommendation (< 5 g/day).

Table 3 – Characteristics of the sampled urine according to sex in the indigenous community of Aracruz, 2021–2022.

Variables	Male (n=357)	Female (n=443)	Total (n=800)	p-value
Creatinine (mg/dL)	120.8±52.7	104.0±51.2	111.4±52.5	<0.01
Na+ (mmol/L)	146.8±58.5	126.8±57.5	135.7±58.8	<0.01
K+ (mmol/L)	54.7±29.8	49.0±32.3	51.5±31.3	<0.01
Na+/K+ (unitless)	3.6±3.5	3.3±2.5	3.4±3.0	0.227
Creatinine 24 h (mg)	1552.5±320.9	1317.1±313.4	1422.1±337.5	<0.01
Salt (g/day)	10.4±3.0	9.7±2.5	10.0±2.7	<0.01

Note: The data are presented as the mean and (\pm) standard deviation. Student's *t* test for independent groups. n: Number of individuals; Na+: sodium; K+: potassium. Numbers in bold correspond to $p < 0.05$.

Table 4 shows the characteristics of salt intake as a function of sociodemographic and health variables. Consumption was similar across age groups and for different levels of education. It was lower, however, among the Guarani. There was a progressive increase in salt intake as BMI increased. When the eutrophic group was used as a reference (average intake of 9.4g/day), the estimated salt intake was greater in both overweight and obese patients. We detected no difference in salt intake in relation to the presence or absence of AH.

Table 4 – Estimated salt intake stratified by subgroup according to sociodemographic and health characteristics in the indigenous community of Aracruz, 2021–2022.

Variables	n	Salt (g/day)	p-value
Age group			0.06
20–39 Years	482	10.2±3.0	
40–59.9 Years	254	9.7±2.3	
≥ 60 Years	64	9.9±2.2	
Ethnicity			<0.01
Tupiniquim (Ref)	629	10.2±2.7	
Guarani	84	9.3±3.6#	
Non indigenous	87	9.7±2.3±	
Education			0.17
Incomplete elementary education	219	9.9±3.0	
Complete elementary/incomplete secondary education	160	9.9±2.3	
Complete secondary/incomplete higher education	320	10.3±2.8	
Complete higher education	101	9.6±2.5	
Nutritional Status			<0.01
Malnutrition	12	9.0±3.0	
Eutrophy (Ref)	202	9.4±2.9	
Overweight	313	10.0±2.5#	
Obesity	273	10.5±2.8#	
Normotensive	683	10.0±2.8	0.23
Hypertensive	117	10.3±2.7	

Note: The data are presented as the mean and (\pm) standard deviation. One-way ANOVA with Tukey's post hoc test or Student's *t* test was used for independent samples. #($p < 0.05$) according to the Tukey test compared with the reference group (Ref). n: Number of individuals. Numbers in bold correspond to $p < 0.05$.

The results of the multivariable regression analysis between salt intake and BP are shown in Figure 1. In the simple correlation analysis, SBP was significantly associated ($p<0.05$) with age ($r=0.468$) ($r=0.47$), BMI ($r=0.104$) ($r=0.07$) and salt intake ($r=0.100$) ($r=0.11$), whereas DBP was only significantly associated with age ($r=0.285$) ($r=0.28$) and BMI ($r=0.278$). The model including age, BMI and salt intake explained 24% of the total variability in SBP; 22% of the total variability was due to age, while BMI and salt intake each contributed approximately 1% of the total variability. For DBP, the multivariable model that included age and BMI explained 16% of the total variability; specifically, 8% was explained by age and the other 8% by BMI. The same analytical model was used to assess the correlations for SBP and DBP among only the 248 individuals who were using antihypertensive drugs. From a qualitative point of view, the values are the same, but the models lost strength, as age, BMI and salt intake explained 23% of the variability in SBP but only 9% of the variability in DBP.

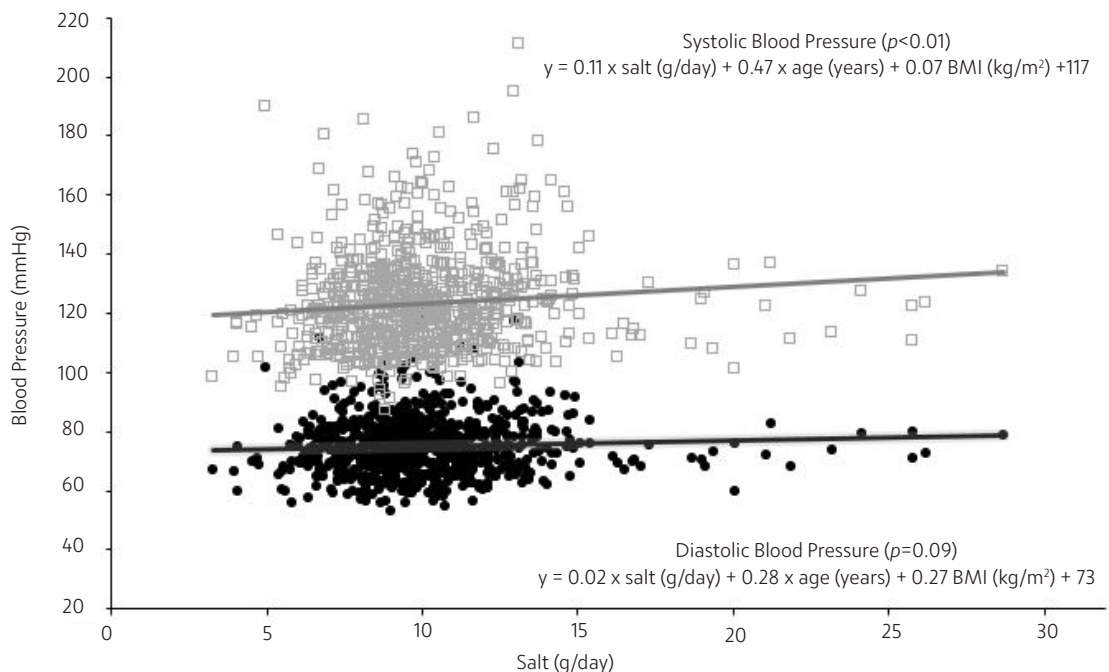


Figure 1– Relationships between salt intake and blood pressure in the village population in Aracruz, ES, 2021–2022.

DISCUSSION

The main findings of this study are that salt intake by villagers is high, at 10g/day – approximately 2 times higher than the current recommendation – and has a positive effect on SBP values. This impact, however, is small, corresponding to 0.11mmHg/gram of salt in the diet. For DBP, the impact of salt intake was not statistically significant. Considering that salt intake is normally distributed in the population, it can be estimated that almost half of the exposed population has a salt intake above the limit of 10g/day and that only a tiny portion has an intake within the current recommendation of up to 5g/day. The high consumption of salt, combined with the low consumption of fruits and vegetables, which are the main food sources of potassium, resulted in high Na^+/K^+ ratios in the urine of this population (>3), suggesting a low-quality diet, which contributes to high levels of AH in

the community, as well as to other comorbidities, such as overweight, obesity and diabetes, which also contribute to increased blood pressure.

The high values of salt intake observed in this study were also found in the Brazilian adult population in the National Health Survey (2013–2015), where a mean value of 9.7g/day was found using the same technique, i.e., casual urine and calculation of salt intake using the Tanaka formula [16]. The values suggest, therefore, that the mean salt intake in the indigenous population is approximately 10% higher than that in the Brazilian population in general. A previous study conducted in this same indigenous community approximately 20 years ago indicated even higher salt intake (13.7g/day) than that currently reported [5]. However, in the evaluation conducted in 2003/2004, salt consumption was estimated from a 12-hour urine collection at night. Considering that the Tanaka formula underestimates salt intake by approximately 1g/day [15], it can be considered that salt intake in this community is declining slightly, which likely reflects the actions implemented by the government to reduce the salt content in processed foods, the consumption of which is apparently high in the studied population.

This hypothesis is supported by the fact that the mean urine sodium concentration decreased from 154.0 ± 59.7 mEq/L in 2003–2004 to 135.7 ± 58.8 mEq/L in 2020–2022 ($p < 0.001$). If we consider water consumption and urine production similar in the two periods, it can be estimated that in the interval between the two studies, there was a reduction of between 1 and 2g in daily salt intake. Notably, a high Na^+/K^+ ratio is a stronger predictor of cerebral ischemic events than high salt intake is [17]. High levels of salt intake and a high Na^+/K^+ ratio in casual urine have also been reported in other studies using the same methods of assessment of salt intake used in this study (casual urine [18,19]).

A possible confounding factor in the analysis of the association between salt intake and BP is the fact that overweight and obese individuals consume relatively high amounts of salt, as shown in this and other studies [20]. That is, part of the effect of BMI on blood pressure may be secondary to a diet with higher salt content in these individuals. In the multivariable analysis, however, BMI and salt intake contributed independently to SBP but not to DBP, where excess fat plays an important role in determining higher blood pressure levels, as already demonstrated in several population-based studies [21,22]. Studies that relate salt intake and blood pressure in populations are well established, such as the one published by Mente et al. [23], in which, in individuals over 55 years, salt intake above 5 g/day was associated with a systolic pressure 2.5mmHg higher than that in individuals whose consumption was lower than 5g/day. A study in the Japanese population indicated that after adjusting for age, sex, BMI and smoking status, each 2.5g/day increase in salt in the diet increased the systolic blood pressure by 0.9mmHg [24], which is greater than that reported in our study, where adjustment for age or BMI showed an increase of 0.11mmHg/g of salt, which was identical to that following adjustment for both age and BMI. The impact of salt intake on blood pressure, however, does not seem to be uniform, because this association was not found in the Vietnamese population after adjustment for age, smoking status and alcohol consumption [25]. A possible reason for these apparently nonuniform results could be that the blood pressure in different populations could have different degrees of sensitivity to salt. If this is the case, the indigenous population could present a lower blood pressure response to salt than other populations for whom sensitivity to salt would be greater. Notably, our sample includes a small portion (approximately 10%) of nonindigenous people. However, the exclusion of this group from the analyses did not affect the results (data not shown). Alternatively, the greater or lesser impact of salt intake on blood pressure may be due to

the intake of other nutrients, such as K^+ , and the efficiency of pressure diuresis, whereby a higher sodium intake would lead, at first, to greater water intake and increased extracellular volume, followed by stimulation of diuresis, causing the body to eliminate the excess sodium ingested [26,27]. In such cases, increased salt intake would not contribute to increased extracellular volumes or, consequently, to increased blood pressure. The lack of association between salt intake and diastolic pressure is because fat accumulation, and not extracellular volume, is the most important factor in its determination [28,29].

The high salt intake observed in this study is due to the adoption of westernized eating habits by indigenous populations. The community that inhabits the Aracruz reserve does not function as a closed community but is open and has a high degree of interaction with the rural and urban surroundings of the municipality of Aracruz. Approximately 20% of adults are regularly employed in the public or private sector, and food is purchased in regular commercial establishments, such as bakeries and supermarkets, some of which exist within the reserve itself. Although they live in a rural area, the cultivation of food for their own consumption (including vegetables and fruits) is very rare, resulting in a low-quality diet profile that results in a high Na^+/K^+ ratio in the urine due to the consumption of processed and ultra-processed foods, which currently account for 30% of the diet of the Brazilian population [30].

Excess body fat is closely related to increased blood pressure. In this study, we clearly showed that overweight and obese individuals have higher salt intake. Multivariable analysis revealed that both factors contribute to increased systolic blood pressure. Thus, high salt intake contributes, albeit indirectly, to the onset of metabolic syndrome and insulin resistance and, consequently, type 2 diabetes [28,31], which was also highly prevalent in this population. It should be noted, however, that the prevalence of hypertension and diabetes described in this study are underestimated with respect to the actual prevalence of these conditions in the study population because, in order to relate pressure to salt intake, all individuals who were using antihypertensive drugs, many of whom also have diabetes, were excluded from the analysis.

Our study has several limitations, including the lack of evaluation of sodium excretion by the method considered the gold standard, 24-hrs urinary excretion. However, estimation of salt intake from the Na^+ /creatinine ratio in casual urine is easier to perform in large population groups, as previously reported in population-based studies in Brazil, including the National Health Survey [16]. The Tanaka formula, in turn, is adequate for estimating the average consumption in a group of individuals but is inadequate for accurately estimating individual consumption [14,15]. The validity of the application of this formula was tested in an urban population in the same age group as the sample in the current study, and it showed adequate performance with respect to 24-hour urine collection [15]. Given the cross-sectional nature of the current study, it is not possible to establish a cause and effect relationship. Another point to be considered is that the study was conducted on volunteers and not on a random sample of the population. However, the project covered approximately 37% of the entire population eligible for the study, and the demographic data of the sample are similar to those of the population as a whole in terms of age groups. There was a predominance of women, as is common in studies with volunteer samples. The adjustment for sex in the regression analyses did not affect the quality of the analytical model or the conclusions. Therefore, it can be inferred that the study data are representative of the population of the villages and should reflect, to a large extent, the characteristics of the indigenous population in view of the large predominance of this segment in the sample studied.

CONCLUSION

Salt intake in the indigenous population of Aracruz is high, with an average of 10g/day, double the recommended value established by the World Health Organization (5g/day). Although the association between salt intake and SBP was statistically significant, the observed impact was modest, with an increase of 0.11mmHg for each gram of salt consumed. This effect was more strongly observed in overweight and obese individuals, suggesting a complex interaction among diet and risk factors for hypertension. Additionally, the high Na/K ratio observed indicates a low-quality diet characterized by excessive consumption of processed and ultraprocessed foods, which contributes to the high prevalence of hypertension and other comorbidities, such as type 2 diabetes.

Nutritional education programs that address the importance of a balanced diet and a reduction in salt intake, as well as the continuous monitoring of blood pressure and eating habits of the indigenous population, should be implemented. In addition, public health policies should be promoted to encourage the production and consumption of fresh and healthy foods to reduce dependence on industrialized products. This integrated approach could contribute to mitigating the risks associated with excessive salt intake and promoting cardiovascular health in the indigenous population of Aracruz.

REFERENCES

1. Malta DC, Andrade SSCA, Oliveira TP, Moura L, Prado RR, Souza MFM. Probability of premature death for chronic non-communicable diseases, Brazil and Regions, projections to 2025. *Rev Bras Epidemiol.* 2019;22:e190030. doi: <https://doi.org/10.1590/1980-549720190030>
2. Malta DC, Gonçalves RPF, Machado ÍE, Freitas MIF, Azeredo C, Szwarcwald CL. Prevalence of arterial hypertension according to different diagnostic criteria, National Health Survey. *Rev Bras Epidemiol.* 2018;21(1):e180021. doi: <https://doi.org/10.1590/1980-549720180021.supl.1>
3. Chor D, Pinho Ribeiro AL, Sá Carvalho M, Duncan BB, Andrade Lotufo P, Araújo Nobre A, et al. Prevalence, Awareness, treatment and influence of socioeconomic variables on control of high blood pressure: results of the ELSA-Brasil Study. *Plos One.* 2015;10(6):e0127382. doi: <https://doi.org/10.1371/journal.pone.0127382>
4. de Souza Filho ZA, Ferreira AA, dos Santos B, Pierin AMG. Hypertension prevalence among indigenous populations in Brazil: a systematic review with meta-analysis. *Rev Esc Enferm.* 2015;49(6):1012-22. doi: <https://doi.org/10.1590/S0080-623420150000600019>
5. Meyerfreund D, Gonçalves CP, Cunha RS, Pereira AC, Krieger JE, Mill JG. Age-dependent increase in blood pressure in two different native American communities in Brazil. *J Hypertens.* 2009;27(9):1753-60. doi: <https://doi.org/10.1097/HJH.0b013e32832e0b2b>
6. O'Donnell M, Mente A, Rangarajan S, McQueen MJ, O'Leary N, Yin L, et al. Joint association of urinary sodium and potassium excretion with cardiovascular events and mortality: prospective cohort study. *BMJ.* 2019;364:1-14. doi: <https://doi.org/10.1136/bmj.l772>
7. Van Oort S, Beulens JWJ, van Ballegooijen AJ, Grobbee DE, Larsson SC. Association of Cardiovascular Risk Factors and Lifestyle Behaviors With Hypertension: a Mendelian Randomization Study. *Hypertension.* 2020;76:1971-9. doi: <https://doi.org/10.1161/HYPERTENSIONAHA.120.15761>
8. Oliveira LS, Coelho JS, Siqueira JH, Santana NMT, Molina MDCB. Relación sodio / potasio urinario y consumo de condimentos industrializados y alimentos ultraprocessados. *Nutr Hosp.* 2019;36(1):125-32. doi: <https://dx.doi.org/10.20960/nh.02101>
9. Porto AS, Martins HX, Faria CP, del Carmen Bisi Molina M. Impact of the mHealth strategy in sodium consumption markers: AVALIASAL Study. *Rev Nutr.* 2020;33:e200026. doi: <https://doi.org/10.1590/1678-9865202032e200026>
10. World Health Organization (WHO). Global action plan for the prevention and control of Noncommunicable diseases 2013-2022. World Health Organization; 2022.

11. Mill JG. Social determinants of hypertension. *Arq Bras Cardiol.* 2019;113(4):696-8. doi: <https://doi.org/10.5935/abc.20190220>
12. Barroso WKS, Rodrigues CIS, Bortolotto LA, Mota-Gomes MA, Brandão AA, Magalhães Feitosa AD, et al. Brazilian guidelines of hypertension - 2020. *Arq Bras Cardiol.* 2021;116(3):516-58. doi: <https://doi.org/10.36660/abc.20201238>
13. Sociedade Brasileira de Diabetes. Diretrizes-Sociedade-Brasileira-de-Diabetes-2019-2020. Brasília; 2022. [cited 2022 Jul 14]. Available from: https://edisciplinas.usp.br/pluginfile.php/5730478/mod_resource/content/0/Diretrizes-SBD-2019-2020.pdf
14. Tanaka Y, Nakamura Y, Hoshiai K. A simple method to estimate populational 24-h urinary sodium and potassium excretion using a casual urine specimen. *J Hum Hypertens.* 2002;78(5):97-105. doi: <https://doi.org/10.1038/sj.jhh.1001307>.
15. Mill JG, Rodrigues SL, Baldo MP, Malta DC, Szwarcwald CL. Estudo de validação das equações de tanaka e de kawasaki para estimar a excreção diária de sódio através da coleta da urina casual. *Rev Bras Epidemiol.* 2015;18:224-37. doi: <https://doi.org/10.1590/1980-5497201500060020>
16. Mill JG, Malta DC, Machado ÍE, Pate A, Pereira CA, Jaime PC, et al. Estimation of salt intake in the Brazilian population: results from the 2013 National Health Survey. *Rev Bras Epidemiol.* 2019;22(suppl. 2):E190009. doi: <https://doi.org/10.1590/1980-549720190009.supl.2>
17. Averill MM, Young RL, Wood AC, Kurlak EO, Kramer H, Steffen L, et al. Spot Urine Sodium-to-Potassium Ratio Is a Predictor of Stroke: the MESA. *Stroke.* 2019;50(2):321-7. doi: <https://doi.org/10.1161/STROKEAHA.118.023099>
18. Iwahori T, Miura K, Ueshima H, Tanaka-Mizuno S, Chan Q, Arima H, et al. Urinary sodium-to-potassium ratio and intake of sodium and potassium among men and women from multiethnic general populations: the INTERSALT Study. *Hypertens Res.* 2019;42(10):1590-8. doi: <https://doi.org/10.1038/s41440-019-0263-1>
19. Bhattarai S, Bista B, Yadav BK, Gynawali P, Poudyal A, Jha AK, et al. Estimation of mean population salt intakes using spot urine samples and associations with body mass index, hypertension, raised blood sugar and hypercholesterolemia: Findings from STEPS Survey 2019, Nepal. *Plos One.* 2022;17(4):1-15. doi: <https://doi.org/10.1371/journal.pone.0266662>
20. Chagas SF, Zaniqueli D, Baldo MP, Lotufo PA, Duncan BB, Griep RH, et al. The association between salt intake and blood pressure is mediated by body mass index but modified by hypertension: the ELSA-Brasil study. *J Hum Hypertens.* 2023;37(6):472-9. doi: <https://doi.org/10.1038/s41371-022-00714-9>
21. El Meouchy P, Wahoud M, Allam S, Chedid R, Karam W, Karam S. Hypertension Related to Obesity: Pathogenesis, Characteristics and Factors for Control. *Int J Mol Sci.* 2022;23(20):12305. doi: <https://doi.org/10.3390/ijms232012305>
22. Thuesen BH, Toft U, Buhelt LP, Linneberg A, Friedrich N, Nauck M, et al. Estimated daily salt intake in relation to blood pressure and blood lipids: the role of obesity. *Eur J Prev Cardiol.* 2015;22(12):1567-74. doi: <https://doi.org/10.1177/2047487314553201>
23. Mentz A, O'Donnell MJ, Rangarajan S, McQueen MJ, Poirier P, Wielgosz A, et al. Association of Urinary Sodium and Potassium Excretion with Blood Pressure. *N Engl J Med Overseas.* 2014;371(7):601-11. doi: <https://doi.org/10.1056/NEJMoa1311989>
24. Umesawa M, Yamagishi K, Noda H, Ikeda A, Sawachi S, Muraki I, et al. The relationship between sodium concentrations in spot urine and blood pressure increases: a prospective study of Japanese general population : the Circulatory Risk in Communities Study (CIRCS). *BMC Cardiovasc Disord.* 2016;16(55):1-9. doi: <https://doi.org/10.1186/s12872-016-0219-1>
25. Jensen PN, Bao TQ, Huong TTT, Heckbert SR, Fitzpatrick AL, LoGerfo JP, Van Ngoc T Le, Mokdad AH. The association of estimated salt intake with blood pressure in a Viet Nam national survey. *Plos One.* 2018;13(1):1-12. doi: <https://doi.org/10.1371/journal.pone.0191437>
26. Kim G-H. Primary Role of the Kidney in Pathogenesis of Hypertension. *Life.* 2024;14(1):119. doi: <https://doi.org/10.3390/life14010119>
27. Grillo A, Salvi L, Coruzzi P, Salvi P, Parati G. Sodium intake and hypertension. *Nutrients.* 2019;11(9):1-16. doi: <https://doi.org/10.3390/nu11091970>
28. Sangrós FJ, Torrecilla J, Giráldez-García C, Carrilla L, Mancera J, Mur T, et al. Association of General and Abdominal Obesity With Hypertension, Dyslipidemia and Prediabetes in the PREDAPS Study. *Rev Esp Cardiol.* 2018;71(3):170-7. doi: <https://doi.org/10.1016/j.recesp.2017.04.010>

29. Aung K, Ream-Winnick, S, Lane M, Akinlusi I, Ted Shi, Htay T. Sodium Homeostasis and Hypertension. *Curr Cardiol Rep.* 2023;25:1123-9. doi: <https://doi.org/10.1007/s11886-023-01931-5>
30. Louzada MLDC, Cruz GLD, Silva KAAN, Grassi AGF, Andrade GC, Rauber F, et al. Consumption of ultra-processed foods in Brazil: distribution and temporal evolution 2008-2018. *Rev Saúde Pública.* 2023;57(1):12. doi: <https://doi.org/10.11606/s1518-8787.2023057004744>
31. Bianchi MEV, Cusumano AM, Torres C, Rojas NG, Velasco GA. Prevalence of obesity and arterial hypertension and their relationship with age and gender in the city of Resistencia, Argentina, in the years 2008-2014. *Hipertens Riesgo Vasc.* 2019;36(1):14-20. doi: <https://doi.org/10.1016/j.hipert.2018.04.003>

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