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ORIGINAL RESEARCH

Sodium Intake, Blood Pressure, and Dietary Sources of Sodium in an Adult South Indian Population

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Abstract

BACKGROUND The association between prevalence of hypertension and its relationship with dietary sodium intake has never been published from large epidemiological studies in the South Indian population before.

OBJECTIVES To assess sodium intake and its association with blood pressure, and major dietary sources of sodium in an adult population in southeastern India.

METHODS This study included a representative population-based sample of 8080 individuals (57% women) >20 years of age. Individuals with previous history of hypertension and outliers for sodium intake were excluded, resulting in a sample size of 6876, with 4269 from semi-urban/urban and 2607 from rural areas. Baseline measurements included evaluation of systolic (SBP) and diastolic (DBP) blood pressures, anthropometric, sociodemographic, and psychosocial parameters. Based on 24-hour recall, we calculated total daily sodium intake and the percentage contributed by each food group to the total sodium intake. Participants were assigned based on quintiles of dietary sodium intake. Mixed-effects multivariable linear regression models assessed the association of SBP and DBP with sodium intake.

FINDINGS Men had higher mean sodium intake (4.1 $\pm$ 2 versus 3.2 $\pm$ 1.7 g/day; $P < 0.01$) with higher mean SBP and DBP (123/77 versus 117/74 mm Hg; $P < 0.01$), and higher prevalence of hypertension (22.2% versus 12.9%; $P < 0.01$) compared with women. Mean dietary sodium intake was significantly higher in the hypertensive men (4.2 $\pm$ 2 g/day) and women (3.2 $\pm$ 1.7 g/day) compared with normotensive men (4 $\pm$ 2 g/day), and women (3.2 $\pm$ 1.7 g/day; $P < 0.05$). Significant ($P < 0.01$) increases in SBP and DBP were evident in men, but not women with increasing quintile of sodium intake. After multivariable adjustments, sodium intake was independently associated with SBP, but not DBP, in both sexes. The predominant source of dietary sodium in both semi-urban/urban and rural populations was from homemade foods where salt is part of the traditional recipe.

CONCLUSION In a South Indian population, the dietary intake of sodium was higher than recommendations by major dietary guidelines and was an independent predictor of SBP.

KEY WORDS blood pressure, hypertension, Indian, sodium, south

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INTRODUCTION

Excess dietary sodium intake is associated with risk factors for cardiovascular disease (CVD), most prominently with elevated blood pressure (BP).[1-3] High BP or hypertension (HTN) is a major risk factor for CVD and accounts for about 7.6 million, or 13.5% of deaths annually worldwide.[4] Current estimates indicate that HTN is responsible for 54% of all strokes and 47% of all coronary artery disease (CAD) worldwide.[4] Most people with HTN currently live in low- and middle-income countries.[4,5]

Epidemiologic studies reveal a growing prevalence of HTN in both rural and urban India. The prevalence of HTN in India has been estimated at 33% in urban areas and 25% in rural areas.[6] In India, HTN is estimated to be directly responsible for 57% of all deaths from stroke and 24% from CAD.[7] In 2010, 1.65 million deaths from cardiovascular causes worldwide were attributed to sodium consumption of >2 g per day. Notably, 4 of 5 of these deaths occurred in low- and middle-income countries, and 2 of 5 occurred prematurely (before the age of 70 years).[8]

It has been projected that a population-wide decrease of 2 mm Hg in BP can prevent 151,000 stroke-related and 153,000 CAD-related deaths in India.[7] There is clear evidence that reducing the amount of dietary salt consumption reduces mean population BP and associated risk for cardiovascular events in both hypertensive and normotensive individuals.[9,10] Based on these findings, the World Health Organization (WHO) and other organizations have established dietary salt reduction as an important strategy to prevent CVD.[11-13]

The global effects of sodium consumption and how they vary with age, sex, and ethnicity are poorly understood. Moreover, given the global variation in foods and methods of preparation and addition of salt to indigenous recipes, estimating the dietary intake presents enormous challenges. Nevertheless, to develop public health strategies, particularly in an ethnically diverse country like India, better understanding of dietary patterns, actual sodium intake, and their relation to BP among the regional populations is crucial to patient counseling, public health interventions, and program planning.

Apart from the common table and rock salt (sodium chloride) used generally, sodium can be found in other food items as well, and the primary contributors to dietary sodium depend on the cultural context and dietary habits of a population.[14] Sodium is found naturally in a variety of foods, such as milk, meat, and shellfish. It often is found in large amounts in processed foods such as breads, crackers, meats, and snack foods.[15-18] Large amounts of sodium are found in many condiments (eg, soy and fish sauces).[15] Information on the sodium content of Indian foods is sparse. There are very limited data on the association between dietary sodium intake and BP in the Indian population.

In the present study, we assessed intake of sodium, its association with BP, and the major sources of dietary sodium among adults living in south-eastern India who are enrolled in PURSE-HIS (Population Study of Urban, Rural and Semi-urban Regions for the Detection of Endovascular Disease and Prevalence of Risk Factors and Holistic Intervention Study).

METHODS

Chennai, the fourth largest metropolitan city in India, served as the primary urban location from which the study population was recruited. The adjacent semi-urban and rural areas were in Thiruvallur and Kanchipuram districts, respectively, in the state of Tamil Nadu, India.

The detailed methodology of PURSE-HIS is published elsewhere.[19] As of June 2012, 8080 (urban: 2221; semi-urban: 2821; rural: 3038) participants >20 years of age were recruited by 2-stage cluster sampling using the 2001 India census database. In this current analysis, because both semi-urban and urban populations were very similar in their risk profile, they were combined and identified as semi-urban/urban population. After excluding individuals with previous history of hypertension (n = 961) and the outliers for sodium intake (sodium intake $\geq$10,000 mg/day; n = 260), the sample size was 6876, with 4269 from semi-urban/urban and 2607 from rural areas.

An interviewer-administered questionnaire was used to collect data on history of CVD and its risk factors. Physical activity was measured by a physiotherapist, using the Global Physical Activity Questionnaire,[20] and the sedentary score (SDS) was calculated. A clinical psychologist assessed the level of stress using the Presumptive Stressful Life Event Scale,[21] and lifetime stress score (LTSS) was computed. The Kuppussamy classification[22] was used to assess socioeconomic status and is reflected as socioeconomic score (SES); which was computed from information on education, occupation, and income status. After a general clinical examination, seated BP of participants was

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measured in the dominant arm using a validated automated oscillometric BP device (Omron Sem-1; Omron Healthcare, Singapore) with an appropriate bladder size. Three readings were taken and the mean was used in the analysis. Fasting blood specimens were collected and assayed for various putative cardiovascular biochemical risk factors.[19] All non-diabetic participants were given 75 g of glucose dissolved in 250 to 300 mL water and an oral glucose tolerance test was conducted. Blood and urine specimens were collected every 30 minutes for up to 2 hours. For participants with diabetes, a standard breakfast was provided and blood and urine specimens were collected after 2 hours to assess postprandial glucose levels.

Dietary Assessment. Trained dietitians assessed macronutrient and micronutrient intake using the 24-hour recall method. Portion sizes of foods were estimated using standard household measuring cups, spoons, and ladles. The nutritional analysis was accomplished using a comprehensive food composition table that was developed based on Indian Council of Medical Research[23] and the nutrient database from the US Department of Agriculture.[24] The foods were grouped according to the basic ingredient of the recipe (ie, as rice-based, pulse-based, vegetable-based, or milk-based dishes, etc.) Because rice and wheat were most commonly consumed, they were grouped as such; and other grains such as millets, corn, and so on, were grouped as other grain-based dishes.

To determine the amount of added salt, the recipes were standardized in the food lab. Qualified food scientists standardized the recipes based on recipes obtained from the local population. The total daily sodium intake and the percentage of sodium contributed by each food group to the total sodium were calculated for each individual. To prevent the mean percentages being biased by food items with higher percentage but low absolute contribution in the amount, we weighted the participants by their total sodium intake using the following formula:

$$\left(\textit{Sodium intake of each person}/\right.$$
$$\left.\textit{Total sodium intake of the entire sample}\right)\times$$
$$\textit{Sample size}$$

The weighted mean percentages of the sodium contributed by each food group were compared across rural and semi-urban/urban populations.

Statistical Analysis. All analyses were conducted using the statistical software package SPSS (20.0 version; SPSS Inc., Chicago IL, USA). Participants were assigned to quintiles of dietary sodium intake. The mean of each was reported and compared for the descriptive characteristic. Values are expressed as the mean ± SD. One-way analysis of variance was used to compare continuous variables, and the χ^2 test was used to compare the proportions among groups. Mixed-effects multivariable linear regression analysis were carried out using systolic (SBP) and diastolic (DBP) BPs as dependent variables and dietary salt as the independent variable with adjustment for potential confounders including age, smoking, SES, LTSS, body mass index (BMI), and energy intake. To account for multiple members possibly being from the same household, we included the unique household identifier as a random intercept. All tests of significance were 2-tailed and $P < 0.05$ was considered significant.

RESULTS

The characteristics of the study participants are shown in Table 1. There were more women than men in the study population. Male participants were older (mean age 45.3 ± 10.5 years), had higher incidence of smoking, higher SES, higher LTSS, and higher sedentary score (SDS). Women had higher BMI. Men reported higher energy intakes (3043 ± 816 kcal/day) than women (2379 ± 684 kcal/day). Men also had higher sodium intake than women (4.1 ± 2 vs 3.2 ± 1.7 g/day) and had higher mean SBP and DBP (123/77 vs 117/74 mm Hg), and a significantly higher prevalence of HTN (22.2% vs 12.9%).

Both hypertensive men and women were older and had significantly higher BMI, SDS, and LTSS scores, as shown in Table 2. Although mean energy intakes were similar in both hypertensive and normotensive populations, mean dietary sodium intake was significantly higher in hypertensive men (4.2 ± 2 g/day) than in normotensive men (4 ± 2 g/day; $P < 0.05$) and in hypertensive women (3.4 ± 1.8 g/day) than in normotensive women (3.2 ± 1.7 g/day; $P < 0.05$).

Table 3 shows sex-specific population characteristics by quintiles of daily sodium intake. In both men and women, increasing intake of sodium led to significant increases in BMI, SDS, and LTSS scores, and there was a progressive increase in total energy intake ($P < 0.01$). Increasing quintiles of sodium intake resulted in a significant increase in

Table 1. Descriptive Characteristics of the Subjects in the PURSE-HIS Cohort

	Men	Women	*P* Value
N	2964	3912	
Age (y)	45.3 ± 10.5	40.6 ± 9.5	< 0.01
Smoking (%)	30.2	2.1	< 0.01
Alcohol (%)	26.1	2.2	< 0.01
BMI	23.5 ± 4.04	25.3 ± 4.7	< 0.01
SES	14.1 ± 4.7	12.4 ± 4.2	> 0.05
SDS	4.9 ± 2.1	4.8 ± 1.9	< 0.01
LTSS	5 ± 2.9	4.6 ± 3.1	< 0.01
SBP (mm Hg)	123 ± 18	117 ± 17	< 0.01
DBP (mm Hg)	77.29 ± 10.78	74.09 ± 10.03	< 0.01
HTN (%)	22.2	12.9	< 0.01
DM (%)	21.3	15.4	< 0.01
TG (mg/dL)	146.38 ± 111.23	118.89 ± 73.33	< 0.01
HDL (mg/dL)	40.65 ± 9.5	44.19 ± 9.09	< 0.01
LDL (mg/dL)	114.63 ± 31.98	115.27 ± 32.13	> 0.05
Energy intake (kcal/d)	3043 ± 816	2379 ± 684	< 0.01
Dietary sodium (g/d)	4.1 ± 1.9	3.2 ± 1.7	< 0.01

BMI, body mass index; SES, socio-economic score; SDS, sedentary score; LTSS, lifetime stress score; SBP, systolic blood pressure; DBP, diastolic blood pressure; HTN, hypertension; DM, diabetes mellitus; TG, triglycerides; HDL, high density lipoprotein; LDL, low density lipoprotein.

SBP and DBP in men, but not women. The increase in SBP and DBP in men was statistically significant from the third quintile of sodium intake (3.96 ± 0.26 g/day) to the fourth quintile (4.9 ± 0.35 g/day). There was increase in prevalence of hypertension with increasing quintile of sodium intake in both sexes, with a prevalence of 24% among men in the highest quintile of sodium intake compared with 22% in the lowest quintile, and a prevalence of 15% among women in the highest quintile compared with 11% in the lowest quintile.

Table 4 presents the results of the mixed-effects multivariable linear regression analysis that assessed the association of sodium intake with SBP and DBP. Overall, in both sexes, sodium intake was more strongly associated with SBP than with DBP. In the unadjusted model, dietary sodium was associated with both SBP and DBP in men, and in the fully adjusted model, sodium was associated only with SBP. In both unadjusted and fully adjusted models, sodium intake was associated only with SBP in women. In the models adjusted for age, smoking, SES, LTSS, SDS, BMI, and energy intake, an extra 1 g of dietary sodium was associated with, on average, 0.58 mm Hg higher SBP in men and 0.46 mm Hg higher in women.

Table 2. Gender-specific Comparison Between Individuals With and Without Hypertension

	Women			Men		
	Normotensive	Hypertensive	*P* Value	Normotensive	Hypertensive	*P* Value
n	3407	505		2306	658	
Age (y)	39.6 ± 9.1	47.2 ± 9.2	< 0.01	44.3 ± 10.2	48.65 ± 10.84	< 0.01
BMI	25.14 ± 4.69	26.55 ± 4.4	< 0.01	23.18 ± 4.03	24.54 ± 3.9	< 0.01
SES	12.46 ± 4.22	12.13 ± 4.18	> 0.05	14.1 ± 4.8	13.94 ± 4.47	> 0.05
SDS	4.74 ± 1.85	5.42 ± 1.81	< 0.01	4.71 ± 2.06	5.33 ± 2.04	< 0.01
LTSS	4.49 ± 3.09	5.28 ± 3.05	< 0.01	4.9 ± 2.95	5.22 ± 2.83	< 0.05
Energy intake (kcal/d)	2384 ± 683	2341 ± 6889	> 0.05	3036 ± 814	3072 ± 822	> 0.05
Sodium intake (g/d)	3.2 ± 1.7	3.4 ± 1.7	< 0.05	4.0± 1.9	4.2 ± 2.0	< 0.05

BMI, body mass index; SES, socio-economic score; SDS, sedentary score; LTSS, lifetime stress score.

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Table 3. Population Characteristics Based on Quintiles of Daily Sodium Intake in Men and Women

	<20th Percentile	20th-40th Percentile	40th-60th Percentile	60th-80th Percentile	>80th Percentile	*P* Value
Men						
n	593	593	593	593	592	
Dietary sodium (g/d)	1.5 ± 0.6	2.9 ± 0.3	3.96 ± 0.3	4.9 ± 0.4	7.1 ± 1.1	< 0.01
Age (y)	46.6 ± 10.4	46.4 ± 10.5	44.2 ± 10.3	44.9 ± 10.8	44.2 ± 10.3	< 0.01
BMI	21.9 ± 3.9	23.2 ± 3.8	23.7 ± 4.1	24 ± 3.8	24.7 ± 4.1	< 0.01
SES	12.4 ± 4.5	14 ± 4.6	14.02 ± 4.5	14.9 ± 4.8	15.1 ± 4.9	< 0.01
SDS	4.6 ± 2.1	5 ± 2.04	4.8 ± 2.03	4.8 ± 2.1	5.03 ± 2.1	< 0.01
LTSS	5.27 ± 3.02	5.07 ± 3.01	4.7 ± 2.9	4.9 ± 2.9	4.9 ± 2.7	< 0.05
Energy intake (kcal/d)	2382.9 ± 593.6	2688.6 ± 550.9	2972.9 ± 565.6	3300.3 ± 620.9	3876.7 ± 802	< 0.01
SBP (mm Hg)	121.6 ± 18.1	121.5 ± 17	121.8 ± 17.2	125.7 ± 19.9	124.3 ± 17.5	< 0.01
DBP (mm Hg)	76.7 ± 10.6	76.3 ± 10.3	76.4 ± 10.4	78.8 ± 11.8	78.2 ± 10.5	< 0.01
HTN (%)	22.1	20.2	18.2	26.5	24	
Women						
n	783	782	783	782	782	
Dietary sodium (g/d)	1.2 ± 0.4	2.1 ± 0.2	2.95 ± 0.2	3.9 ± 0.3	5.9 ± 0.1	< 0.01
Age (y)	40.72 ± 9.2	41.03 ± 9.5	40.32 ± 9.7	40.84 ± 9.6	39.81 ± 9.4	> 0.05
BMI	24.2 ± 4.7	24.95 ± 4.8	25.78 ± 4.7	25.85 ± 4.6	25.83 ± 4.4	< 0.01
SES	10.89 ± 3.9	12.25 ± 4.04	12.75 ± 4.2	12.98 ± 4.3	13.22 ± 4.2	< 0.01
SDS	4.61 ± 2	4.77 ± 1.9	4.93 ± 1.9	4.96 ± 1.8	4.88 ± 1.8	< 0.01
LTSS	4.86 ± 3	4.65 ± 3.02	4.5 ± 3.2	4.57 ± 3.2	4.36 ± 3	< 0.05
Energy intake (kcal/d)	1799.6 ± 474.6	2065 ± 425.1	2303.4 ± 467.5	2617.6 ± 482.3	3109 ± 673	< 0.01
SBP (mm Hg)	116.1 ± 16.9	117.5 ± 17.1	117.5 ± 18.2	118.2 ± 17.1	117.8 ± 16.5	> 0.05
DBP (mm Hg)	74 ± 9.8	73.6 ± 10.1	74.1 ± 9.9	74.7 ± 10.3	74 ± 10.1	< 0.05
HTN (%)	11.2	12.3	13.4	13	15	

BMI, body mass index; SES, socio-economic score; SDS, sedentary score; LTSS, lifetime stress score; SBP, systolic blood pressure; DBP, diastolic blood pressure; HTN, hypertension.

Table 5 shows the major contributors of dietary sodium. The sodium contributed by each food group reflects sodium both naturally present in food and added salt. The majority of the daily sodium intake was from pulse-based dishes (29.7% ± 24.9%) followed by rice-based (27.03% ± 21.3%), vegetable-based (16.7% ± 20%), and fruit-based (7.8% ± 12.1%). However, traditional food items that are high in salt such as pap pads (preserved dry crisps) and pickles did not emerge as major contributors of sodium. The contribution of sodium differed slightly according to community type. In both semi-urban/urban and rural populations major contributors of sodium intake were pulse- and rice-based dishes. The sodium intake from fruit- and vegetable-based dishes was higher among rural than semi-urban/urban populations.

DISCUSSION

The findings of the current study emphasize the strong independent association between dietary sodium intake and BP. Epidemiologic studies reveal a rapidly growing prevalence of HTN in both rural and urban India.[6] With increasing prevalence of HTN, it is critical to examine the various determinants of BP in the Indian populations so that individualized, as well as, population-wide strategies can be developed. To our knowledge, this is the first time that a study has assessed the dietary sodium intake and sources of sodium in both semi-urban/urban and rural populations in South India.

In this study, the mean dietary intake of sodium in men (4.1 ± 2.3 g/day) and women (3.2 ± 1.7 g/day) was significantly higher than the WHO recommendation of 2 g/day.[11] Elevated sodium intakes were observed in both normotensive and hypertensive men and women. Similar epidemiologic evidence in this region estimated sodium intakes of an urban sample (N = 1902) of 3.6 g/day among normotensive individuals and 4.4-g/day among hypertensives.[25] The Global Burden of Diseases Nutrition and Chronic Diseases Expert Group (NUTRICODE)[8] estimated that in 2010, the mean level of sodium consumption worldwide was 3.95 g/day, and that regional means ranged from

Table 4. Mixed-effects Multivariate Regression Analysis to Assess the Association of Dietary Sodium (g) Intake With Systolic and Diastolic Blood Pressure in Men and Women

	SBP − β for Sodium	DBP − β for Sodium
Men		
Unadjusted	0.69*	0.38*
Model 1	0.89*	0.40*
Model 2	0.83*	0.33†
Model 3	0.76*	0.31†
Model 4	0.57†	0.12
Model 5	0.58‡	0.19
Women§		
Unadjusted	0.34‡	0.08
Model 1	0.45†	0.11
Model 2	0.45†	0.09
Model 3	0.39‡	0.06
Model 4	0.26	−0.05
Model 5	0.46‡	0.06

SBP, systolic blood pressure; DBP, diastolic blood pressure; Model 1: adjusted for age; Model 2: adjusted for age, smoking, socio-economic status (SES) and lifetime stress score (LTSS); Model 3: adjusted for age, smoking, SES, LTSS, and sedentary score (SDS); Model 4: adjusted for age, smoking, SES, LTSS, SDS, and Body Mass Index (BMI); Model 5 : adjusted for age, smoking, SES, LTSS, SDS, BMI, and energy intake.
* $P < 0.001$.
† $P < 0.01$.
‡ $P < 0.05$.
§ Models were not adjusted for smoking because only 2% of women were smokers.

2.18 to 5.51 g/day. Thus the mean intake of sodium in the present study is within the range for mean intake worldwide. The earliest data on salt intake in the Asian Indian population from a study conducted by the Indian Council of Medical Research during 1986 to 1988 in 13 states, reported an average per capita salt consumption of 13.8 g/day (ie, 5.5 g of sodium; 7-26 g/day in these different states).[26] To our knowledge, the 1988 INTERSALT (International Study of Sodium, Potassium, and Blood Pressure) study is the only investigation that has objectively assessed salt intake in 1988 by measuring 24-hour urinary sodium excretion in 2 clinical populations in Delhi and Ladakh. The daily salt intake in Delhi and Ladakh was 9 g (3.6 g sodium) and 12 g (4.8 g sodium), respectively.[1]

We observed an independent and statistically significant association of SBP levels with increasing dietary sodium intakes in both men and women in the present study. These findings concur with a previous study in urban population in South India, in which salt intake was associated with BP and higher risk for HTN, after adjusting for potential confounders.[25] Other than INTERSALT,[1] 2 other studies demonstrated a significant association between salt intake and BP in North India.[27,28] Additionally, in a larger study that included tribal communities in India living in rural (n = 4523) and urban (n = 935) settings, the mean 24-hour urinary sodium excretions were independently associated with higher BP.[29]

Several randomized trials have demonstrated the effect of reducing sodium intake on lowering BP.[30-32] However, a large meta-analysis of various intervention studies demonstrated that the effects of dietary sodium on BP varies with population characteristics such as age, race, and presence or absence of HTN.[8] Moreover, precise targets for sodium reduction remain controversial.[3,33,34] The maximum intake of sodium recommended in major dietary guidelines, range from 1.2 to 2.4 g/day.[11,35-38] We observed a statistically significant increase in SBP and DBP in men between 3.7 and 5.25 g/day of sodium intake. We were not able to see a similar significant increase in BP with increase in sodium intake in women. Further dose-response feeding trials are necessary to establish the upper limits for sodium in this population.

Although the natural presence of sodium in foods is minimal, most of the sodium in diets comes from added salt. Addition of salt is dependent on the type of cuisine and regional and cultural influences over food preparation. Food choices also can depend on place of residence, with urban centers offering more choices of processed foods and rural areas still using more traditional cooking methods and ingredients. Results from the present study found that all communities exhibited predominance in home cooking over the use of processed foods. Hence, added salt during cooking would be the primary source of extra sodium in the diets. These findings correspond with the previous findings[14] that demonstrated that in developing countries, the predominant source of sodium in homemade foods is salt that is added as part of the traditional recipe.[14]

The uniqueness and exclusivity of Indian cuisine lies in its diversity of dietary characteristics that exists between north, south, east, and west. This survey focuses on a population that lives in South India where the staple food is rice. Results from the present study found that almost the entire population consumed rice at least once a day. Salt is added as part of the recipe of all dishes, and the amount of salt added varies with the habits of the family, regardless of their place of residence. The sources for salt come from multiple dishes that form the meal. A meal most commonly comprises

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Table 5. Weighted Percentage of Sodium Contributed by Food Group and Community (n = 6876)

Food Categories*	Weighted Contribution of Dietary Sodium (%)†					
	Total (n = 6876)		Semi-Urban/Urban (n = 4269)		Rural (n = 2607)	
	Mean	SD	Mean	SD	Mean	SD
Pulses	29.7	24.9	32.64	24.97	23.76	23.66
Rice-based dishes	27.03	21.3	26.65	20.66	27.80	22.55
Vegetables	16.7	20	14.2	18.02	21.8	22.6
Fruits	7.8	12.1	7.31	11.43	8.66	13.34
Milk and milk products	4.07	5.33	4.29	5.72	3.62	4.43
Green leafy vegetables	3.20	8.57	3.24	8.48	3.13	8.76
Roots and tubers	2.87	6.07	2.91	6.09	2.79	6.04
wheat flour and products	2.20	8.23	2.52	8.72	1.57	7.09
Nuts and oil seeds	1.71	4.81	2.17	5.38	0.76	3.17
Other grains	1.35	10.38	0.61	6.09	2.85	15.71
Poultry	0.64	2.82	0.60	2.62	0.71	3.18
Fish	0.51	2.27	0.57	2.32	0.40	2.17
Eggs	0.49	1.82	0.51	1.92	0.44	1.60
Legumes	0.40	3.16	0.48	3.47	0.23	2.43
Meat	0.31	2.05	0.34	2.21	0.25	1.69
Spices	0.01	0.22	0.01	0.26	0.00	0.00
Alcoholic beverages	0.00	0.05	0.00	0.06	0.00	0.01
Sugars and jaggery	0.00	0.02	0.00	0.02	0.00	0.01
Oils and fats	0.00	0.01	0.00	0.01	0.00	0.01
Miscellaneous	1.08	3.06	1.00	2.77	1.25	3.58

* Food categories are listed in descending order of their contribution in the total sample.
† Individual's percentages were weighted by their total sodium intake.

rice/bread with vegetable-based dishes, and pulse-based dishes that have added salt. Thus, it is important to keep in mind that salt intake can increase with additional dishes that make their way into a meal. One would expect that individuals who have higher intakes of fruits, vegetables, legumes, and pulses would have a corresponding increase in potassium and fiber intake; this would probably provide benefits as described by the Dietary Approaches to Stop Hypertension (DASH) diet.[2] Sodium contributors from vegetable- and fruit-based dishes and other traditional grains were higher among rural population than the urban population in the present study. The health implications of this difference should be further explored.

Although beyond the scope of the present study, it would be important to study the effect of potassium-rich foods on a high-sodium diet and BP in this population to strengthen the evidence provided by the DASH diet trial.[2] Nonetheless, a focused strategy is required among both semi-urban/urban and rural populations. This would involve inducing the community to reduce the frequency and amount of salt added during cooking and increasing more general awareness of improving dietary habits by including more fruits and vegetables. Therefore, public health strategies must be developed that focus on sensitizing the public to the addition of salt to homemade dishes and its effects, teaching them to preserve natural flavors with better cooking methods without addition of salt or condiments that have additional salt, and to increase intake of foods low in salt (eg, fruits and vegetables).

Furthermore, findings from the present study call for educating dietitians that dietary advice to people with hypertension should focus more on these hidden salt components that are consumed in large quantities rather than on the salt-dense foods alone given that they are consumed in smaller quantities. Although processed foods or "fast foods" are not prevalent in this population, there public health initiatives should continue to promote use of traditional foods rather than processed and fast foods, which are high in salt and calories, sugar, and fat.

The design of the present analysis was cross-sectional and hence we were limited in our ability to draw definitive causal inferences of effect of dietary sodium on BP and definitive recommendations on sodium intake. Future studies using longitudinal data and/or randomized clinical trials are needed to better understand the role of dietary sodium in the development and prevention of HTN and CVD and to define precise targets for sodium reduction among the South India population.

The study has several strengths. The large study sample was the first in India to include adequate number of participants from both urban and rural areas. Thus, the findings can be applied to both urban and rural populations with similar diets in South India. Moreover, this is one of few epidemiologic studies in this population to reliably capture the quantitative data on discretionary use of salt in cooking. Finally, the use of logistic regression analysis in this study allowed for simultaneous adjustment of confounding variables to test the association between sodium intake and BP. To the best of our knowledge, this has been done previously in only one other study of an urban South Indian population.

CONCLUSION

The analysis of sodium intake in relation to BP in a South Indian population sample showed that dietary intake of sodium is higher than recommendations by major dietary guidelines and that there is an independent association between dietary sodium intake and BP. Longitudinal observational studies and randomized clinical trials are needed to confirm these findings and to establish precise targets for sodium reduction among the South Indian population.

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