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ORIGINAL ARTICLE

The relationship between hypertension and salt intake in Turkish population: SALTURK study

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Abstract

This population-based epidemiological study was aimed to evaluate the daily salt intake and its relation to blood pressure in a representative group of Turkish population. The enrolled normotensive and hypertensive individuals (n = 1970) completed a questionnaire including demographics, dietary habits, hypertension awareness and drug usage. Blood pressure was measured and to estimate salt consumption, 24-h urine samples were collected. The daily urinary sodium excretion was 308.3 ± 143.1 mmol/day, equal to a salt intake of 18.01 g/day. Salt intake was higher in obese participants, rural residents, participants with lower education levels and elderly. A positive linear correlation between salt intake and systolic and diastolic blood pressures was demonstrated ($r = 0.450$, $p = 0.020$; $r = 0.406$, $p = 0.041$; respectively), and each 100 mmol/day of salt intake resulted in 5.8 and 3.8 mmHg increase in systolic and diastolic blood pressures, respectively. Salt intake and systolic blood pressure was significantly correlated in normal weight individuals ($r = 0.257$, $p < 0.01$). The Turkish population consumes a great amount of salt; salt intake and blood pressure was positively correlated. Efforts in sodium restriction are therefore crucial in the management of hypertension as part of national and global health policies.

Key Words: *Blood pressure, body mass index, epidemiology, hypertension, salt intake, urinary sodium*

Introduction

The relationship between high sodium (salt) intake and hypertension has been under investigation since the 20th century (1), and recent evidence suggests that dietary reduction of salt is a key component in the management of hypertension.

The positive association between salt intake and blood pressure (BP) has been considered since ancient times (2). Over the last few decades, experimental, observational and clinical data have indicated that BP can significantly be reduced with reductions in salt (3). The INTERSALT study was the first worldwide epidemiological study, in which a significant relation between 24-h urinary sodium (Na^+) excretion and BP was established (4). Following INTERSALT, other epidemiological studies (5–7) and randomized controlled trials (8–10) have also detected a relation between elevated BP and high salt intake.

Some studies, however, failed to demonstrate this relationship (11,12), and it was stated that the results of observational and interventional studies cannot be interpreted to the overall population because of heterogeneity in responses to dietary salt reduction (13). Despite these arguments, reduction of salt intake has become common sense both in prevention and amelioration of hypertension (14), even in resistant hypertension cases (15). Now, there is a worldwide tendency to accomplish simple life-style modifications, including reduction of dietary sodium intake, in order to control BP (14).

The Relationship between Hypertension and Salt Intake in Turkish Population (SALTURK) study was a population-based epidemiological field study, primarily aimed at investigating daily salt intake and its relationship with BP in both hypertensive and normotensive individuals.

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Materials and Methods

Study design and participants

The SALTURK study was designed as an epidemiological field study. A two-stage stratified sampling method was used to select a nationally representative sample of the adult population over 18 years of age. The study population was first stratified by province (among seven geographical regions of Turkey), and then by urban versus rural areas. Strata were selected by a proportional sampling method according to postal-code lists in urban areas, and town and village lists 80 km away from city centers in rural areas. Each stratum has a proportional size to the selected city or village population. The participants were representative of Turkish population, taking into account population distribution across urban and rural settings (65% and 35%, respectively), male and female sex (50% for each) and BP status (normotensive and hypertensive; 70% and 30%, respectively).

A total of 1970 participants, who were ≥18 years old and able to provide a medical history and 24-h urine sample, were randomly allocated from 14 cities. A maximum of two participants from the same household were eligible. Exclusion criteria included pregnancy, diuretic usage, fasting for the last 24 h before the enrolment, and the presence of cardiac failure, renal failure, chronic liver disease and diabetes mellitus. Thus, a total of 1775 participants were eligible for the study.

All volunteers were visited in their houses by trained healthcare workers between January 2007 and April 2007. After obtaining informed consents, a questionnaire including demographic characteristics, family and hypertension history and comorbidities was given to the participants. Additionally, participants were questioned about their dietary habits, daily salt consumption, hypertension awareness and drug usage. Weight, height, BP and 24-h urinary volume were measured, and body mass index (BMI) was calculated.

Erroneous estimations of salt intake may occur according to problems in collecting 24-h urine samples. Thus, participants with urinary creatinine out of reference levels (reference intervals for 24-h urinary creatinine were accepted as 10.7–26.0 g/kg for women and 12.1–28.9 g/kg for men) (16) were excluded from the eligible 1775 participants in order to precisely determine the salt intake of the population. Additionally, the participants who are aware of their hypertension may consciously reduce their salt intake, which may affect the determination of salt intake and BP values. Participants on antihypertensive medication and/or those who were aware of their hypertension were also excluded from the eligible 1775 participants, to clearly separate the normotensive and hypertensive individuals. The remaining 816 participants constituted the core study population.

The present study was conducted according to the Declaration of Helsinki (17) and Good Clinical Practices. All volunteers willing to participate in the study were informed about study objectives and procedures. Written permission was obtained from the Republic of Turkey Ministry of Health.

BP measurements

BP measurements were performed using the Stabil-O-Graph SBPM Control upper arm sphygmomanometer (I.E.M, Stolberg, Germany) (18) with an adjustable cuff, at rest in sitting position with 5-min intervals. Patients were not allowed to smoke, exercise, overeat, consume caffeine and have full bladder within the 30 min preceding the measurements. Participants were considered hypertensive in the case of an average systolic BP≥140 mmHg or diastolic BP≥90 mmHg, or a prior hypertension diagnosis and/or receiving an antihypertensive drug, regardless of BP readings.

Laboratory measurements

An explanatory leaflet along with necessary equipments was given to all participants and they were verbally instructed carefully about the method of urine sampling. Beginning from the first urine sample of the day (in the morning), urine was collected over 24 h and was transferred into the urine container. The first urine sample of the next morning was taken as the spot urine. During the sampling period, participants were instructed to keep urine samples in a cool and dark place. At the end of the collection period, healthcare workers measured the urine volume collected. The urine samples were then placed into cooler bags (+4°C) (Igloo Products Corporation, USA) and within 24 h were sent to the central laboratory, where analyses were performed immediately.

Urinary analysis of sodium (Na^+), potassium (K^+), calcium (Ca^+), urea and creatinine were performed by using Roche Cobas Integra 800 analyzer (Roche Instrument Centre AG, CH 6343 Rotkreuz, Switzerland). Measurements of Na^+ and K^+ were performed with the ion selective electrode (ISE) unit of analyzer in urine samples, which were diluted automatically. Urinary Ca^+ was analyzed by the method of *o*-cresolphtalein complex (o-cpc) with Roche-Cobas kit (Roche Diagnostics GmbH, D68298 Mannheim, Germany) according to Schwarzenbach (19).

Statistical analysis

All statistical analyses were performed by using SPSS 11.0 (SPSS Inc., Chicago, IL, USA) statistical software package program. In the comparison of normally distributed numeric and categoric variables, Student's *t*-test and chi-square test were used, respectively. To investigate the effect of urinary Na^+ on systolic and diastolic BP, a multiple linear regression analysis was performed to account for significant subject characteristics. The linear model fit was assessed using detrended normal Q–Q plots of residuals and partial regression plots, heteroskedasticity was investigated by a scatterplot of regression predicted values by standardized residuals and problems of co-linearity were evaluated using tolerance statistics. All tests were evaluated at 5% type-I error level to infer statistical significance.

Results

A total of 1970 participants were eligible for the present study. After pregnant participants and participants with cardiac/renal failure, chronic liver disease and diabetes mellitus were excluded, a total of 1775 participants were enrolled. The mean daily urinary Na^+ excretion of these participants was 308.3 ± 143.1 mmol/day, which was equal to a salt intake of 18.01 g/day. Participants on anti-hypertensive medication (n = 192; 11.8%) and/or participants who were aware of their hypertension (n = 267; 15.1%), and/or participants with urinary creatinine levels outside the reference values were excluded; the remaining 816 participants constituted the core study population. The descriptive analysis of main characteristics and laboratory parameters of the study population are presented in Table I (20).

The factors associated with salt intake in the study population are presented in Table II. The mean daily salt intake was significantly higher in obese participants ($p < 0.001$), participants living in rural areas ($p < 0.001$) and participants with lower education levels ($p < 0.001$). The mean daily salt intake of males was higher than females; however, the difference was not significant. Salt intake increased significantly with increasing age ($p = 0.002$). The mean daily salt intake of the hypertensive participants was significantly higher than the normotensive individuals ($p = 0.028$) (Figure 1).

Two separate linear regression analysis models, adjusted for BMI, age, sex and residence, were used to investigate the effect of urinary Na^+ on systolic and diastolic BP (Tables III and IV). The models also accounted for the significant interaction of BMI and urinary Na^+. The models clearly demonstrated a positive linear correlation between Na^+ intake and systolic and diastolic BPs ($r = 0.450$, $p = 0.020$; $r = 0.406$, $p = 0.041$; respectively) (Figure 2). Linear regression analysis indicated that each 100 mmol/day salt intake results in a 5.8-mmHg increase in systolic BP and a 3.8-mmHg increase in diastolic BP.

Linear regression models also indicated a positive linear correlation between BMI and systolic and diastolic BPs ($r = 0.306$, $p < 0.001$; $r = 0.301$, $p < 0.001$; respectively). A positive linear correlation was found between salt intake and systolic BP according to BMI groups ($r = 0.168$, $p < 0.01$) (Figure 3), and this correlation was significant in normal-weight individuals ($r = 0.268$, $p < 0.01$).

Table I. Descriptive analysis of main characteristics and laboratory parameters of the study population (n = 816).

Variable	Male (n = 373)	Female (n = 443)	Total (n = 816)
Age (years) (mean ± SD)	46.3 ± 13.2	43.9 ± 12.6	45.0 ± 12.9
Age groups, n (%)			
18–35	80 (21.4)	122 (27.5)	202 (24.8)
36–64	257 (68.9)	290 (65.5)	547 (67.0)
≥65	36 (9.7)	31 (7.0)	67 (8.2)
Weight (kg) (mean ± SD)	79.2 ± 12.3	70.6 ± 14.1	74.5 ± 13.9
Height (cm) (mean ± SD)	171.3 ± 6.9	158.9 ± 6.7	164.6 ± 9.2
BMI (kg/m^2) (mean ± SD)	27.0 ± 3.8	27.9 ± 5.5	27.5 ± 4.8
BMI groups (kg/m^2), n (%)			
Normal weight (≤24.9)	112 (30.1)	143 (32.6)	255 (31.5)
Overweight (25–29.9)	183 (49.2)	156 (35.6)	339 (41.9)
Obese (≥30)	77 (20.7)	139 (31.7)	216 (26.7)
Hypertension, n (%)			
Absent	265 (71.0)	338 (76.3)	603 (73.9)
Present	108 (29.0)	105 (23.7)	213 (26.1)
BP (mmHg) (mean ± SD)			
Systolic BP	133.2 ± 15.8	128.8 ± 16.2	131.8 ± 16.2
Diastolic BP	81.8 ± 10.5	78.9 ± 12.3	80.3 ± 11.6
BP status,[a] n (%)			
Optimal	55 (14.7)	128 (28.9)	183 (22.4)
Normal	100 (26.8)	102 (23.0)	202 (24.8)
High-normal	110 (29.5)	108 (24.4)	218 (26.7)
Stage 1	77 (20.6)	76 (17.2)	153 (18.8)
Stage 2	21 (5.6)	24 (5.4)	45 (5.5)
Stage 3	10 (2.7)	5 (1.1)	15 (1.8)
Laboratory parameters (mean ± SD)			
Urinary sodium (mmol/day)	290.9 ± 112.9	274.3 ± 135.1	281.9 ± 125.6
Urinary potassium (mmol/day)	77.8 ± 30.5	75.6 ± 25.5	76.6 ± 27.9
Urinary calcium (mg/day)	232.5 ± 146.8	205.9 ± 131.1	218.1 ± 139.1
Urinary urea nitrogen (g/day)	13.2 ± 4.07	11.8 ± 3.9	12.5 ± 4.07
Urinary creatinine (mg/day)	1698.2 ± 421.3	1312.5 ± 351.9	1488.8 ± 430.3

BMI, body mass index; BP, blood pressure.

[a]BP status is presented according to the 2007 Guidelines for the management of arterial hypertension of ESH-ESC (20).

Table II. Factors associated with salt intake in the study population (n = 816).

Variable	Salt intake (g/day), mean ± SD	p
Age (years)		
18–35	15.0 ± 6.6	0.002
36–65	17.1 ± 7.4	
>65	17.6 ± 8.9	
Sex		
Male	17.1 ± 6.6	0.060
Female	16.1 ± 7.9	
Education		
University	13.7 ± 7.0	<0.001
High school	14.9 ± 6.4	
Secondary school	16.4 ± 6.7	
Elementary school	17.0 ± 7.7	
Literate	17.2 ± 6.4	
Illiterate	19.0 ± 7.8	
Residence		
Urban	15.4 ± 6.2	<0.001
Rural	18.8 ± 8.8	
Weight status (by BMI)		
Obese (≥30 kg/m^2)	19.1 ± 8.9	<0.001
Non-obese (<30 kg/m^2)	15.7 ± 6.5	
Blood pressure		
Hypertensive	17.5 ± 6.9	0.028
Normotensive	16.2 ± 7.5	

BMI, body mass index.

Discussion

The present study demonstrated that Turkish population consumes the highest amount of salt reported so far. In the INTERSALT study, the highest urinary Na^+ excretion was found in North China (242 mmol/24 h) (4). In small-scale studies conducted in Italy and Britain, the mean daily Na^+ excretion rate was 170 and 132.2 mmol, respectively (21,22); and in the National Health and Nutrition Examination Survey (NHANES) (23), estimated daily sodium excretion was reported as 135–204 mmol for men and 100–135 mmol for women in the USA; all of which are lower than the findings of the present study. The International Study on Macronutrients and Blood Pressure (INTERMAP) (5,24) is a cross-sectional epidemiological study investigating the relations of dietary variables with BP in 4680 men and women aged 40–59 years in Japan, China, the UK and the USA. Besides mean BP values (131.8/80.3 mmHg), urinary Na^+ excretion was also higher in the present study population, compared with China having the highest urinary Na^+ excretion (227.5±100.3 mmol/24 h) and the highest BP values (121.3/73.2 mmHg) among the INTERMAP populations (24). The high BP values detected in Turkish population may be attributed to high salt consumption.

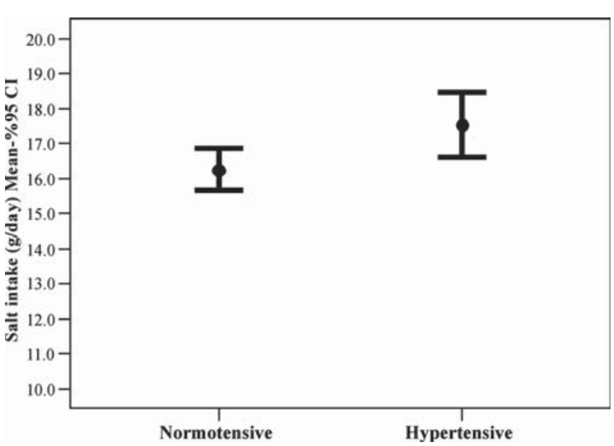

Figure 1. The mean daily salt intake of normotensive and unaware hypertensive individuals (n = 816, p = 0.028).

Table III. Significant predictors of systolic blood pressure per multiple linear regression analysis.

	B	r	p
Constant	87.595		<0.001
BMI	1.030	0.306	<0.001
Age	0.263	0.210	<0.001
Urinary sodium mmol/day	0.058	0.450	0.020
BMI–urinary sodium	−0.002	−0.496	0.025
Sex	−4.219	−0.130	<0.001
Residence (urban–rural)	6.018	0.177	<0.001

BMI, body mass index.

Consumption of traditional foods with high salt content, such as white cheese, olives, pickles, home-made pasta and fermented cereal foods (e.g. tarhana) (25), and the high consumption of bread may be the potential reasons for high salt intake in Turkey. In a study conducted in Turkey, it was reported that the mean daily bread consumption for an individual is 400 g/day/person, and the daily consumption of bread can lead to an individual salt intake of approximately 7.28 g from bread (26). The present study was carried out in wintertime between January and April; thereby along with the dietary habits in Turkey, consumption of preserved foods might have increased the salt intake seasonally. Lack of dietary recall, which could provide valuable information on this issue, was a relative limitation of the present study.

One of the advantages of the present study is its larger sample size representing the whole population. The INTERSALT study was limited to 200 individuals for each of the 52 centers across 32 countries (4). Although the INTERMAP study investigated a larger sample size, both INTERMAP (5,24) and other studies performed in Italy, Portugal and Britain were regional studies (21,22,27).

Proper urine collection is an important factor affecting the determination of the amount of salt

Table IV. Significant predictors of diastolic blood pressure per multiple linear regression analysis.

	B	r	p
Constant	53.349		<0.001
BMI	0.729	0.301	<0.001
Age	0.152	0.169	<0.001
Urinary sodium (mmol/day)	0.038	0.406	0.041
BMI–urinary sodium	−0.001	−0.492	0.031
Sex	−2.700	−0.116	0.001
Residence (urban–rural)	3.131	0.128	<0.001

BMI, body mass index.

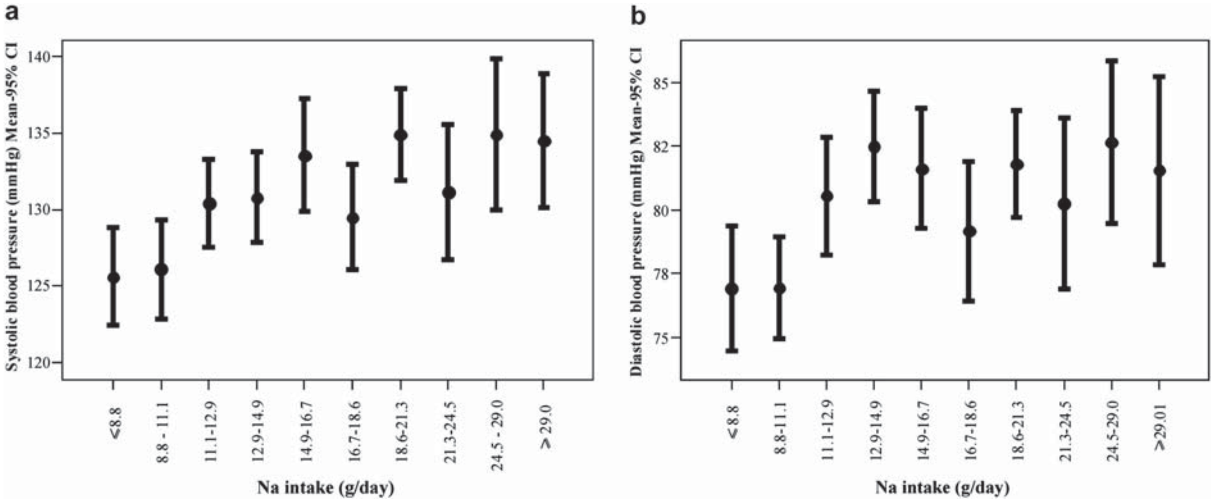

Figure 2. The association between sodium intake and (a) systolic; (b) diastolic blood pressures (n = 816).

intake. In such population-based epidemiological field studies, proper urine collection is a challenging process, despite all precautions. Meticulous attempts have been performed to obtain a proper urine collection in this study, and urine samples that were beyond the reference levels of creatinine excretion were excluded. Daily variability, however, can also be observed in urinary Na^+ excretion of the individuals (28), and the collection of urine samples only once can be a relative limitation similar to INTERSALT (4). Participants who were aware of their hypertension were excluded as they might reduce their salt intake on purpose; this may affect both the estimation of salt intake and its relation to BP. To our knowledge, none of the studies investigating the relation between salt intake and BP clearly separated the individuals based on hypertension awareness. In this respect, the present study clearly demonstrated that mean daily salt intake of unaware

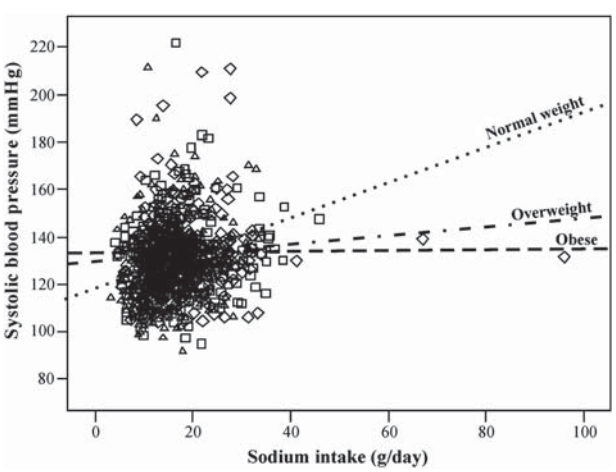

Figure 3. The correlation between sodium intake and systolic blood pressure in the body mass index (BMI) groups (n = 816), (r = 0.168, p < 0.01); normal weight individuals: BMI(24.9 kg/m^2 (r = 0.268, p < 0.001); overweight individuals: BMI = 25–29.9 kg/m^2 (r = 0.063, p = 0.250), obese individuals: BMI ≥ 30 kg/m^2 (r = −0.11, p = 0.867).

hypertensive participants was significantly higher compared with normotensive individuals.

Linear regression models clearly demonstrated a positive linear correlation between Na^+ intake and systolic and diastolic BPs in this study. Accordingly, it was estimated that each 100 mmol/day increase in sodium intake statistically corresponded to an average increase of 5.8 mmHg in systolic BP and 3.8 mmHg in diastolic BP. In the original INTERSALT study (4), no significant association was demonstrated between Na^+ intake and median BP or prevalence of hypertension; sodium intake was only found to be significantly related to the slope of BP. In the present study, the association between sodium intake and systolic and diastolic BPs was clearly visualized.

Sex, age, BMI and residence were the significant predictors of both systolic and diastolic BPs. Consistent with the previous studies, BMI was positively correlated with both systolic and diastolic BPs (4,29,30). Na^+ excretion of the obese participants, which may reflect high amount of food consumption, was significantly higher than non-obese participants (31,32). A significant positive correlation between salt intake and systolic BP was found in normal weight individuals, but not in overweight and obese individuals. This intriguing finding suggests that the dominant role of obesity in hypertension pathogenesis may attenuate the effect of salt in overweight and obese individuals.

In conclusion, a great amount of salt consumption was observed in Turkey. In this population-based epidemiological field study, an association between salt intake and mean systolic and diastolic BPs has been evidently introduced. If a 3-g reduction in daily salt consumption should result in similar degrees of benefit as eliminating smoking in terms of cardiovascular disease risk (33) and should lead to a decrease of 50 billion dollars a year in the economic burden of hypertension (34), the reduction in salt consumption must be considered a global health policy in the management of hypertension.

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