

Original Article

Is the Association between Salt Intake and Blood Pressure Mediated by Body Mass Index and Central Adiposity?

Fahimeh Haghghatdoost MSc^{1,2,3}, Nizal Sarrafzadegan MD⁴, Alireza Khosravi MSc¹, Fatemeh Noori MSc⁵, Maryam Boshtam MD⁴, Noushin Mohammadifard MSc⁴, Zahra Abdolli MD⁶, Leila Azadbakht PhD^{2,3}

Abstract

Objective: To assess the amount of salt intake among normotensive (NT) and prehypertensive (PHT) subjects and to determine whether the association between salt intake and blood pressure is correlated with body weight and waist circumference (WC) or is independent.

Methods: A total of 806 NT and PHT subjects from Isfahan Healthy Heart Program (IHHP) were enrolled in the study. A standard questionnaire was used to assess sociodemographic characteristics. The amount of salt intake was measured by the 24-hour urine collection method. Blood pressure, height, weight, and WC were measured based on standard protocols.

Results: The mean ages (\pm SD) of NT and PHT subjects were 35.9 (\pm 11.9) and 44.7 (\pm 12.5) years, respectively ($P < 0.001$). The mean values of body mass index (BMI) and WC were greater among PHT than NT subjects (BMI: 27.9 ± 3.8 vs. 25.1 ± 4.3 g/m²; $P < 0.001$ and WC: 90.2 ± 8.6 vs. 81.2 ± 11.2 cm; $P < 0.001$, respectively). PHT subjects had higher amount of salt intake than NT ones (10.3 ± 6.2 vs. 12.7 ± 7.1 g/d, respectively; $P = 0.003$). Odds ratio (OR) for being PHT increased significantly across the tertiles of salt intake in crude model and sociodemographic-adjusted model. Further adjustment for BMI and WC values weakened the OR for being PHT and showed nonsignificant trend (OR (and 95% CI) for BMI across tertiles of salt intake: 1, 1.26 (0.59 – 2.69), 1.69 (0.93 – 3.87); $P = 0.063$ and OR (and 95% CI) for WC across tertiles of salt intake: 1, 1.22 (0.58 – 2.57), 1.79 (0.89 – 3.56); $P = 0.082$).

Conclusion: The findings of this study suggest that the association between salt intake and blood pressure is related to body weight and WC.

Keywords: Blood pressure, body mass index, body weight, salt intake, waist circumference

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Introduction

Existing epidemiologic evidence shows a growing trend in the prevalence of obesity and overweight worldwide.¹ It has been well established that excess body weight is positively associated with various chronic diseases, including type 2 diabetes, hyperlipidemia, coronary heart diseases (CHD), and hypertension (HTN).^{4,5} Although general obesity is considered as a risk factor of various chronic diseases, it has been frequently shown that central obesity is a better predictor of chronic diseases, such as HTN.^{6,7}

However, the etiology of chronic diseases is a multi factorial fact which might be affected by several lifestyle components like physical activity levels, tobacco smoking, dietary habits, and salt intake.^{8–11} Previous studies have suggested that higher amount of salt intake is directly associated with the incidence of stroke, renal disease, osteoporosis and HTN.^{10–12}

Nationally representative data from Iran have shown a grow-

ing prevalence of HTN, an important risk factor of CHD events, as well as obesity over recent years.^{13,14} Previous studies suggest that overweight and obese subjects, especially abdominal obese, are more likely to be affected by HTN than normal-weight subjects.^{6,7,15} The favorable effect of weight loss on blood pressure has been reported by a meta-analysis on clinical trials studies.¹⁶ Furthermore, the amount of salt intake is more than the physiologic need worldwide,¹⁷ which is considered as another concern to increase the prevalence of HTN. Available data in respect to the etiology of HTN have mostly been limited to the association of either body weight or salt intake with HTN. To the best of our knowledge, there are limited studies which assessed the amount of salt intake among subjects with different categories of body mass index (BMI). On the other hand, few investigations have concomitantly assessed salt intake and the above-mentioned risk factors. It is not clear that high amount of salt intake leads to HTN by its own or might be depended on the body weight and waist circumference (WC). Notably, it has been thought that overweight and obese subjects have higher amount of salt intake due to higher consumption of foods. Therefore, in the present study we assessed the amount of salt intake among normotensive (NT) and prehypertensive (PHT) subjects and determined whether the association between salt intake and blood pressure is correlated with body weight and WC or is independent.

Methods

Study population

This cross-sectional study was conducted among a subsample of

Authors' affiliations: ¹Hypertension Research Center, Isfahan Cardiovascular Research Institute, Isfahan University of Medical Sciences, Isfahan, Iran, ²Food Security Research Center, Isfahan University of Medical Sciences, Isfahan, Iran, ³Department of Community Nutrition, School of Nutrition and Food Science, Isfahan University of Medical Sciences, Isfahan, Iran, ⁴Isfahan Cardiovascular Research Center, Isfahan Cardiovascular Research Institute, Isfahan University of Medical Sciences, Isfahan, Iran, ⁵Cardiac Rehabilitation Research Center, Isfahan Cardiovascular Research Institute, Isfahan University of Medical Sciences, Isfahan, Iran, ⁶Nutrition Department, Under Secretary for Health, Ministry of Health and Education, Tehran, Iran.

Corresponding author and reprints: Leila Azadbakht PhD, Department of Nutrition, School of Nutrition and Food Sciences, Isfahan University of Medical Sciences, Isfahan, Iran. Tel: (+98) 3117922719, Fax: (+98) 311 6682509, E-mail: azadbakht@hlth.mui.ac.ir.

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Isfahan Healthy Heart Program (IHHP) in Isfahan in 2007. IHHP is a community trial which was performed by Isfahan Cardiovascular Research Center (a WHO collaborating center).^{18,19} IHHP was started in 2001 and included three counties Isfahan and Najafabad (as interventional areas; which included 2,170,940 subjects) and Arak (as reference areas; which included 668,531 subjects). Detailed information regarding the methods of this program has been described elsewhere.^{18,20} In the current study, participants were selected using a randomized systematic method and a total of 806 subjects were included in this analysis. The present study was approved by the Ethical Committee of Isfahan Cardiovascular Research Center.

We excluded subjects with one of the following risk factors: HTN, type 2 diabetes, diabetes insipidous, consuming diuretic medicines, renal disorders, being in the menstrual period at the time of the study, bleeding disorders, and the nonavailability of 24-hour urinary specimen.

Information regarding the sociodemographic status was obtained using a standard questionnaire which was completed by trained and professional health interviewers at home. In order to estimate the amount of salt intake, all participants provided a 24-hour urinary specimen according to INTERSALT (INTERNational study of SALT and blood pressure) protocol.²⁰ The accurate method of urinary specimen collection was educated to all participants using both oral and written instructions by clinic staff. After voiding the spot urine, the collection of 24-hour urine was started. Twenty-four-hour urinary samples were collected on the day of blood sampling for those who were not capable to deliver the urinary specimens to the Health Centers, data were collected by interviewers at home.

Anthropometric Assessments

Body weight was evaluated to the nearest 100 g using a balance scale while subjects were minimal clothing without shoes. Height was measured using a wall-fixed meter while subjects were standing without shoes and shoulders were in normal state and recorded to the nearest 0.5 cm. BMI was calculated as dividing body weight (kg) by the square of height (m). WC was measured at the narrowest level over light wearing by using an unstretched tape without any pressure to body surface and recorded to the nearest 0.1 cm. Blood pressure assessment: To measure blood pressure, the subjects were initially asked to rest at least for five minutes. Then, a professional clinic staff evaluated blood pressure using a standard mercury sphygmomanometer. Blood pressure was measured two times while the participants were sitting and their arms were placed at the heart level. We considered 30 seconds interval between two measurements. First blood pressure measurement was done on both hands while second measurement was done only on the one with higher blood pressure. Finally, the mean values of two measurements were considered as the participant's blood pressure. The systolic blood pressure (SBP) was considered as the onset of first phase of Korotkoff sound while the disappearance of sound (the fifth phase of Korotkoff sound) was considered as diastolic blood pressure (DBP).

Biochemical Assessments

Blood samples were collected to measure the concentration of sodium, potassium, blood urea nitrogen (BUN), and creatinine. In order to assess the accuracy of urinary samples as 24-hour specimens, we measured the concentration of creatinine using Jaffe

method (Technical SMA 12 – 60).²¹ To avoid underestimating dietary sodium intake, the content of sodium in urinary samples was determined using the flame photometry technique.²²

Definition of Terms

The status of body weight was categorized according to the BMI values as follows: overweight was defined as $25 \leq \text{BMI} \leq 29.9$ and obese was defined as $30 \leq \text{BMI}$. Abdominal obesity was defined using the measures of WC. Women with WC more than 88 cm and men with WC more than 102 cm were considered as abdominal obese. The classification of blood pressure was done based on JNC-7 (Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure) cut off.²³ Accordingly, PHT was defined as which SBP was 120 – 139 mmHg or DBP 80 – 89. Healthy and unhealthy diets were defined according to dietary score which described in details elsewhere.²⁴

Statistical Analysis

Data entry was carried out using EPI 2000. Data were analyzed by SPSS (SPSS Inc., Chicago, IL, USA, Version 15). Quantitative variables were expressed as mean \pm SD, and qualitative variables as frequencies. Qualitative variables were compared between NT and PHT subjects using the chi-square test and quantitative variables were compared by using Student t-test. Logistic regression was performed between PHT vs. NT status as dependent variable and tertiles of salt intake as independent variables. To determine P-values for trend across tertiles of salt intake, we assigned the mean intake of salt to individuals variable as continuous variable in logistic regression model for PHT vs. normal status. P-values < 0.05 were considered as statistically significant.

Results

General characteristics of this population-based sample of Iranians are shown in Table 1. The mean age was 35.92 ± 11.97 years in NT and 44.73 ± 12.55 years in PHT ($P < 0.001$). The mean values of BMI and WC were significantly higher in PHT than NT (BMI: $27.95 \pm 3.83 \text{ kg/m}^2$ and WC: $90.19 \pm 8.59 \text{ cm}$ vs. BMI: $25.09 \pm 4.28 \text{ kg/m}^2$ and WC: $81.19 \pm 11.23 \text{ cm}$, respectively). Furthermore, PHT participants were significantly less educated than NT.

The distribution of subjects based on various variables by blood pressure status is presented in Table 2. While most of the NT participants had normal weight, most of the PHT were overweight. Conversely, the lowest prevalence rate among NT and PHT were related to the obese and normal weight, respectively. The prevalence of central obesity was also higher among PHT (13.4% vs. 31.0; $P < 0.001$). Compared to NT subjects, PHT had higher amount of salt intake (10.38 ± 6.19 vs. $12.76 \pm 7.11 \text{ g/d}$; $P = 0.003$) and higher mean values of SBP and DBP (SBP: 101.01 ± 8.68 vs. $124.76 \pm 6.48 \text{ mmHg}$; $P < 0.001$ and DBP: 67.27 ± 7.10 vs. $82.09 \pm 4.98 \text{ mmHg}$; $P < 0.001$, respectively). Urinary concentrations of sodium and creatinine were significantly higher in PHT subjects.

Multivariate-adjusted odds ratios (ORs) for PHT across salt intake tertiles are reported in Table 3. Model 1 presents the crude model. In model 2, the effects of age, sex, education, and occupation were adjusted. Model 3 is a further adjusted model for smoking, physical activity, and dietary score, which increased ORs than model 1. In models 4 and 5, we adjusted the effect of BMI and

Table 1. General characteristics of the Isfahan Healthy Heart Program participants in 2007 by blood pressure status

	NT	PHT	P-value
Sex (men)(%) ¹	42.2	54.1	0.05
Education (year)(%) ¹			< 0.001
5-0	23.3	47.9	
12-6	54.6	32.9	
> 12	22.1	19.2	
BMI (kg/m ²) ²	25.09 ± 4.28	27.95 ± 3.83	< 0.001
WC(cm) ²	81.19 ± 11.23	90.19 ± 8.59	< 0.001
Job(%) ¹			0.91
Employed	38.1	42.5	
Housewife	49.2	45.2	
Retired	6.0	5.5	
Unemployed, student	6.6	6.8	
Physical activity ³ (active) (%) ¹	35.3	30.1	0.38
Ever smoke ^{**} (no)(%) ²	84.4	84.7	0.95
Diet ^{***} (consuming healthy diet) (%) ¹	20.1	15.1	0.30

¹Data are expressed as percentage and P-values obtained from chi-square test; ²Data are expressed as mean ± SD and P-values obtained from t-test; ³Physically one having > 30 minutes of leisure time physical activity ≥ 5 days/week; ** No smoker: Subjects who did not smoke at least one cigarette/day at the active; Any time of the study; ***Healthy diet: A dietary score classified as healthy.

Table 2. Distribution of the subjects based on BMI; central obesity; BUN; dietary intake; and urinary concentrations of Na, K and creatinine by blood pressure status

Variables	Blood pressure status		P-value
	NT (N = 732)	PHT (N = 74)	
BMI categories			< 0.001
Normal-weight (%) ¹	50.3	24.3	
Overweight (%) ¹	38.0	48.7	
Obese (%) ¹	11.7	27.1	
Abdominal obese²			< 0.001
Yes (%) ¹	13.4	31.0	
No (%) ¹	86.6	69.0	
intake (mg/d)³ Sodium	139.02 ± 3.17	139.70 ± 3.16	0.08
Urinary sodium (mg/d)³	164.81 ± 67.40	192.91 ± 78.39	0.004
Potassium intake (mg/d)³	4.0 ± 0.1	4.13 ± 0.37	0.10
Urinary potassium (mg/d)³	61.5 ± 2.03	65.63 ± 34.09	0.32
Sodium intake /potassium intake	34.45 ± 0.1	34.05 ± 2.65	0.19
Urinary sodium: potassium	3.04 ± 1.39	3.29 ± 1.39	0.14
Blood urea nitrogen (BUN) (mg/d)³	11.3 ± 3.60	15.39 ± 3.31	0.54
Creatinine (mg/d)³	0.96 ± 0.19	1.02 ± 0.20	0.017
Urinary creatinine (mg/d)³	1318.33 ± 474.59	1446.85 ± 525.47	0.029

¹P-values obtained from chi-square test; ²Abdominal obese was defined as WC more than 102 cm in men and more than 88 cm in women; ³Data are expressed as mean ± SD and P-values obtained from t-test.

WC values that weakened ORs and did not show significant trend.

Discussion

Our findings show higher prevalence of PHT among overweight, obese, and abdominal obese subjects. Furthermore, the amount of salt intake and risk of PHT was positively related; however, further adjustments for potential confounders such as BMI and WC in separated models attenuated the risk of PHT. Therefore, it seems that the positive association between salt intake and PHT is related to body weight, BMI, and WC.

The positive associations between HTN and general as well as central obesity have been frequently shown in earlier studies^{6,7,15,16} and in longitudinal studies a dose-response association have been suggested for the incidence of HTN with BMI. Neter, et al.¹⁶ in a meta-analysis of randomized controlled trials showed that a reduction of 5.1 kg in body weight resulted in a reduction of -4.4 mmHg and -3.57 mmHg in SBP and DBP, respectively. Furthermore, the prevalence of high SBP among central obese boys and girls (WC > 75th percentile) were 3.9 and 2.2 times more than noncentral obese ones (WC < 75th percentile), respectively. The prevalence of

high DBP was 3.4 and 2.0 times more among central obese boys and girls, respectively.²⁵ The exact mechanism underlying higher blood pressure in obese subjects rather than normal-weight subjects is unclear. It seems that the hyperactivity of renin-angiotensin-aldosterone system and consequently higher levels of renin and aldosterone²⁶⁻²⁸ in obese subjects is a probable mechanism. Furthermore, the sympathetic nervous system is hyperactivated in obese subjects²⁸⁻³⁰ which may inhibit the vasodilatation and natriuresis effects of natriuretic peptides system.^{28,31,32} Leptin and insulin resistance, and high levels of inflammation may also be considered as further mechanisms.^{33,34} However, comparing the amount of salt intake between normal-weight and overweight subjects might be another mechanism which has poorly been assessed. Consuming salty snacks or fast food and drinking more soft drinks may lead to excess body weight and higher blood pressure in consumers.³⁵

We reported higher salt intake and urinary creatinine among overweight and obese subjects in our previous study using the same sample.^{36,37} Although both studies were based on the same data, the aims of these studies were different. In the present study, we aimed to assess if the risk of PHT in different tertiles of salt

Table 3. Multivariate-adjusted ORs and 95% CIs for prehypertension across tertiles of salt intake

Models	Tertiles of salt intake			P – value for trend
	1 (< 7.05)	2 (7.05–11.95)	3 (≥ 11.95)	
Model 1	1	1.26 (0.65 , 2.44)	1.94 (1.04 , 3.59)*	0.028
Model 2	1	1.35 (0.67 , 2.71)	1.97 (1.03 , 3.77)*	0.036
Model 3	1	1.36 (0.67 , 2.77)	1.97 (1.02 , 3.81)*	0.04
Model 4	1	1.26 (0.59 , 2.69)	1.89 (0.93 , 3.81)	0.063
Model 5	1	1.22 (0.58 , 2.57)	1.79 (0.89 , 3.56)	0.082

Model 1: Unadjusted ORs; Model 2: ORs adjusted for age, sex, education, occupation; Model 3: ORs adjusted for age, sex, education, occupation, smoking, physical activity and dietary score; Model 4: All the adjusted variables in model 3 + further adjustment for BMI; Model 5: All the adjusted confounders model 3 + further adjustment for WC; * Indicates: P-value < 0.05.

intake is affected by BMI and WC or not, whereas the aim of our previous study was assessing the relation between salt intake and PHT among different categories of BMI.^{36,37} However, inconsistent with some earlier studies^{23,38} we did not find any significant difference in dietary intake of sodium between NT and PHT groups. In a meta-analysis of 11 long-term and controlled clinical trial studies, the median of SBP decreased 1.1 mmHg after a reduction in dietary sodium intake.³⁸ Additionally, it has been well established that salt consumption (sodium chloride) is associated with HT not sodium by itself.

High amount of salt intake is considered as a worldwide concern for public health.¹⁷ Consistently, in this subsample of Iranians we found that the mean intake of salt is higher than recommended amounts by WHO.³⁹ Additionally, Toghiani, et al.³⁶ in this sub-sample showed that the probability of being PHT increased by 5% per one gram increment of daily salt intake.

Although in many populations¹⁷ like Iranians,³⁶ dietary intake of sodium is higher than recommended values by WHO, the present study suggests that the association of salt intake and SBP and DBP are related to body weight status and WC. In our previous study,³⁶ we assumed that it might be related to consuming more foods. However, Radhika, et al.⁴⁰ showed that adjusting the effects of energy intake and dietary fat did not significantly change the amount of salt intake in adults and after further adjustment for the effects of sociodemographic characteristics and some potential confounders such as physical activity and dietary score, the ORs for PHT did not change significantly.

This study has several limitations. First of all, the cut off points for categorizing BMI and WC may affect the findings, since it has been shown that Asian ethnicities have higher amount of total body fat,^{41,42} abdominal, and visceral body fat^{43,44} than other ethnicities. Hence, the cut off points for incidence of HT may be defined in lower amount among Asian ethnicities.⁴⁵

Overall, our findings suggest that the positive association between salt intake and high blood pressure is modified by BMI which may be related to consumption of more foods and consequently higher amount of salt consumption.

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