

ORIGINAL ARTICLE

The taste of salt measured by a simple test and blood pressure in Japanese women and men

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Salt intake is an important risk factor for hypertension. Because it has been reported that increased salt intake dulls the taste of salt, measuring the sense of taste might be a good way of identifying individuals who consume excessive salt. Using a recently developed simple salt taste test, we investigated the relationship between the taste of salt and blood pressure. The subjects in this cross-sectional study were 823 Japanese adults (479 women and 344 men) 40 years old or older. Following a taste test with salt-impregnated taste strips, the subjects were divided into two groups: normal (recognition threshold of salt at <1.0% concentration) and taste impaired ($\geq 1.0\%$). We determined hypertension from the measured blood pressure. In women, the multi-adjusted odds ratio (95% CI) of hypertension in the impaired group was 2.47 (1.53–3.99) compared with the normal group, whereas no significant difference was observed between the two male groups. When we excluded subjects with moderate and severe hypertension, similar findings were observed. A sub-analysis of couples living alone showed a higher prevalence of hypertension among men whose wives were in the impairment group (58.8%) than in the normal group (36.7%, $P=0.10$). In conclusion, the taste of salt is associated with blood pressure in Japanese women, but not in men. Because most family meals in Japan are prepared by women, educating women about salt reduction may contribute to the prevention of hypertension, not only among women but also among their husbands and family members.

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INTRODUCTION

Hypertension is a clear risk factor for cardiovascular disease.¹ In 2001, 7.6 million premature deaths and 92 million disability-adjusted life years worldwide were attributed to high blood pressure.² In Japan, the population-attributable fraction of hypertension for all-cause mortality is reported to be approximately 20%.³ The findings of the INTERSALT and INTERMAP studies indicated a positive association between salt intake and blood pressure in multiethnic populations,^{4–7} and evidence from randomized controlled trials has shown that a low sodium diet reduces blood pressure.^{8–10} Although public health recommendations in most developed countries suggest reducing salt intake to 5–6 g day⁻¹,¹¹ the average salt intake in Japan is still higher than the recommendations (10.8 g day⁻¹, according to a national health and nutrition survey in 2006¹²).

In an attempt to modify lifestyles to include a reduction in salt intake, several health education tools, such as measurement of 24-h urinary sodium excretion and evaluation of diet with regard to salt content, have been developed. These methods are reliable, but they are not widely used in either clinical or community settings for practical reasons.¹³

Because evidence exists that increased salt intake dulls the taste of salt,¹⁴ measuring the taste of salt might be useful as a screening tool to identify individuals with elevated salt intake who are, therefore, at high risk for hypertension. In fact, the taste recognition threshold for salt is elevated in hypertensive patients.^{15,16} A simple and convenient taste test using salt-impregnated taste strips has been developed recently.^{17,18} To date, however, few epidemiological studies have taken advantage of this test to investigate the association of salt taste with blood pressure. It is logical to assume that the salt taste of the primary cook in a family is the key determinant of the entire household's salt intake, so it makes sense to investigate the relationship between that person's salt taste and the blood pressure of other members of the household.

With this in mind, our aim was to investigate the relationship between salt taste, using a recently developed simple test, and blood pressure in Japanese community-dwelling women and men.

METHODS

Study population

The rural town of Kurabuchi in Takasaki City, Gunma prefecture, Japan, conducted annual health check-ups on residents aged 40 years or older

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(3175 residents in 2007), in accordance with the Japanese Health and Medical Services Law for the Elderly. In 2007, 579 women and 450 men attended the health examinations, at which time they were all invited to participate in a salt taste test. Of the women, 479 (83% of 579) accepted our invitation and gave informed consent for us to use the data collected. Together with the 344 (76% of 450) men who accepted, they constituted the subjects for this study. The characteristics of the study population are shown in Table 1. This study received ethics committee approval (Keio University School of Medicine, Tokyo, Japan).

Data collection

For the assessment of salt taste, we used a salt-impregnated taste strip, Salsave (Advantech Toyo Co., Tokyo, Japan), which has been validated using the whole-mouth method as a standard.¹⁷ The strips are impregnated with sodium chloride at concentrations of 0, 0.6, 0.8, 1.0, 1.2, 1.4 and 1.6%. The test-retest reliability of the strips was acceptable, and Spearman's rank correlation coefficient was 0.6 when 20 volunteer subjects were tested with a mean interval of 7 days. To determine the taste recognition threshold for salt, we used a modified version of the method developed by Maruyama¹⁸ and Nishimoto.¹⁷ The subjects were first asked to rinse their mouths with distilled water to neutralize oral conditions as much as possible. They were then asked to place a strip saturated with 0% sodium chloride on their tongue for three seconds to familiarize themselves with the taste of a blank strip. They then sequentially tasted the remaining taste strips in the same way, beginning with the lowest concentration. They were asked to

report any taste and to say what it was. The concentration at which they identified the salt taste was taken as the recognition threshold. Subjects who could not recognize salt, even at the highest concentration level (1.6%), were assigned a recognition threshold of 1.6%. We prepared a manual for the procedure and trained a number of field staff. The trained staff were blinded to the subjects' medical conditions, including blood pressure.

The health examination included blood pressure measurements, blood tests and face-to-face interviews. Trained nurses took two blood pressure readings 60 s apart, using an automatic sphygmomanometer (Colin BP-103i, Tokyo, Japan) after each participant had been seated for 5 min at rest. The average of the two measurements was used for the analysis. Hypertension was defined as a systolic blood pressure (SBP) of 140 mmHg or higher, a diastolic blood pressure (DBP) of 90 mmHg or higher, the use of antihypertensive agents, or any combination of the above.

Total cholesterol and blood glucose were measured enzymatically from non-fasting blood samples in one laboratory (Harunaso Hospital, Gunma, Japan). Body mass index was calculated as weight (kg) divided by the square of height (m). Information on smoking, alcohol consumption, the presence of artificial teeth and living situation was obtained during interviews with trained nurses.

Statistical analysis

All statistical analyses were performed with Stata 9 software (Stata Corporation, College Station, TX, USA).

We applied stratification analysis by sex to assess the relationship between the taste of salt and hypertension, because a statistically significant interaction between the taste of salt and sex on hypertension was observed ($P < 0.05$ for interaction by likelihood ratio test). For each taste recognition threshold for salt, a χ^2 test and Student's *t*-test or one-way analysis of variance were used for comparisons of frequencies and mean values. Using a recognition threshold of 0.6% as the reference level, we applied logistic regression to obtain the age-adjusted odds ratios (OR) and 95% confidence interval (95% CI) for hypertension at each recognition threshold. Adjustment for age (continuous), body mass index (continuous), casual blood glucose (continuous), total cholesterol (continuous), the presence of artificial teeth (no, yes), smoking (none, < 20 , ≥ 20 cigarettes per day) and alcohol consumption (none, < 23 , ≥ 23 g of ethanol per day) was done by multivariate logistic regression. Trend tests were performed by allocating scores of 1, 2, 3, 4, 5 and 6 for each recognition threshold. Although smoking and alcohol consumption may modify taste,¹⁹ statistical methods such as stratification and a likelihood ratio test for interaction did not show any evidence that the association of the taste of salt with blood pressure varied according to smoking status or alcohol intake in this population. In addition, to examine the association of salt taste with milder stages of hypertension, we excluded subjects with moderate and severe hypertension (SBP ≥ 160 mmHg or DBP ≥ 100 mmHg, as defined by the Japanese Society of Hypertension guidelines for the management of hypertension (JSH2004)²⁰). Subgroup analyses excluding subjects taking antihypertensive drugs or those of 70 years of age or older were also performed.

In Japan, women generally prepare meals for the family, so it is likely that their taste for salt influences the blood pressure of their family members, particularly their husbands. Indeed, it is probable that a woman's salt taste has a stronger influence on her husband's blood pressure than her own. We restricted the subjects to 77 couples living alone and investigated whether women's salt taste influenced their husbands' blood pressure as well as their own. Conveniently, because options for dining out are limited in this rural town, men usually eat at home. Therefore, this population seemed suitable for examining such an association.

RESULTS

The salt taste test took about three minutes to perform per person. The percentage of the subjects with each taste recognition threshold for salt (0.6, 0.8, 1.0, 1.2, 1.4 and 1.6%) was, 62.2, 17.1, 6.9, 5.4, 3.3 and 5.1% among women, and 49.4, 18.3, 7.8, 6.7, 4.9 and 12.9% among men, respectively.

Table 2 shows the association between the taste recognition threshold for salt and blood pressure. For both sexes, the prevalence of the use of hypertensive agents increased along with elevation of the recognition threshold. Among women, elevated recognition thresholds were related

Table 1 Characteristics of the study population by sex

Characteristics	Women (n=479)	Men (n=344)
	Number (%) ^a	Number (%)
Age (years)		
40–49	48 (10.0)	37 (10.8)
50–59	117 (24.4)	78 (22.7)
60–69	133 (27.8)	93 (27.0)
70–79	135 (28.2)	103 (29.9)
80–	46 (9.6)	33 (9.6)
Body mass index (kg m⁻²)		
< 18.5	39 (8.1)	21 (6.1)
18.5–24.9	332 (69.3)	223 (64.8)
≥ 25.0	108 (22.6)	100 (29.1)
Total cholesterol (mmol l⁻¹)		
< 5.7	315 (65.9)	273 (79.4)
≥ 5.7	163 (34.1)	71 (20.6)
Casual blood glucose (mmol l⁻¹)		
< 11.1	471 (98.5)	327 (95.1)
≥ 11.1	7 (1.5)	17 (4.9)
Presence of artificial teeth		
No	233 (48.6)	174 (50.6)
Yes	246 (51.4)	170 (49.4)
Smoking (cigarettes per day)		
None	456 (95.2)	234 (68.0)
< 20	11 (2.3)	33 (9.6)
≥ 20	12 (2.5)	77 (22.4)
Alcohol consumption (grams of ethanol per day)		
None	427 (89.1)	134 (39.0)
< 23	41 (8.6)	57 (16.6)
≥ 23	11 (2.3)	153 (44.4)

^aNumber of cases may not add up to 479 because of missing data.

Table 2 The prevalence and adjusted ORs of hypertension in relation to the taste recognition threshold for salt

Recognition threshold (%)	n	Mean age (s.d.)	Mean values (s.d.) of SBP	Mean values (s.d.) of DBP	Prevalence of the use of antihypertensive agents n (%)	Prevalence of hypertension ^a n (%)	Age-adjusted OR (95% CI)	Multi-adjusted OR ^b (95% CI)
Women (n=479)								
0.6	298	64.2 (10.9)	124.7 (16.9)	73.3 (10.8)	63 (21.1)	98 (32.9)	1.00	1.00
0.8	82	65.4 (12.1)	124.7 (16.1)	71.6 (10.1)	22 (26.8)	29 (35.4)	1.06 (0.63–1.79)	1.03 (0.59–1.78)
1.0	33	66.7 (10.5)	129.0 (19.7)	75.7 (10.4)	10 (30.3)	16 (48.5)	1.79 (0.85–3.75)	1.91 (0.89–4.08)
1.2	26	71.3 (10.7)	123.7 (13.3)	68.7 (9.7)	16 (61.5)	17 (65.4)	3.04 (1.28–7.22)	3.15 (1.29–7.69)
1.4	16	65.9 (10.5)	131.9 (17.1)	74.7 (11.2)	9 (56.3)	12 (75.0)	6.16 (1.90–19.96)	6.64 (1.99–22.16)
1.6	24	62.2 (10.1)	126.6 (17.1)	73.5 (10.8)	6 (25.0)	10 (41.7)	1.62 (0.68–3.85)	1.58 (0.65–3.84)
		<i>P</i> =0.54 ^c	<i>P</i> =0.09 ^c	<i>P</i> =0.76 ^c	<i>P</i> <0.01 ^c	<i>P</i> <0.01 ^c	<i>P</i> for trend <0.01	<i>P</i> for trend <0.01
Normal ^d	380	64.4 (11.2)	124.7 (16.7)	72.9 (10.7)	85 (22.4)	127 (32.9)	1.00	1.00
Impairment ^d	99	66.7 (10.8)	127.5 (18.0)	73.2 (10.7)	41 (41.4)	55 (55.6)	2.37 (1.50–3.77)	2.47 (1.53–3.99)
		<i>P</i> =0.07 ^c	<i>P</i> =0.15 ^c	<i>P</i> =0.85 ^c	<i>P</i> <0.01 ^c	<i>P</i> <0.01 ^c		
Men (n=344)								
0.6	170	64.8 (11.7)	129.2 (15.9)	77.9 (11.0)	37 (21.8)	72 (42.4)	1.00	1.00
0.8	63	64.7 (11.7)	127.9 (17.1)	76.6 (11.9)	8 (12.7)	19 (30.2)	0.58 (0.31–1.09)	0.56 (0.29–1.09)
1.0	27	65.8 (9.9)	125.5 (16.7)	77.1 (10.9)	8 (29.6)	12 (44.4)	1.06 (0.47–2.43)	0.95 (0.39–2.29)
1.2	23	65.7 (10.8)	126.7 (14.4)	76.8 (10.9)	10 (43.5)	11 (47.8)	1.23 (0.51–2.96)	1.40 (0.55–3.56)
1.4	17	65.4 (12.2)	127.1 (16.4)	77.7 (9.4)	7 (41.2)	9 (52.9)	1.52 (0.55–4.18)	1.92 (0.66–5.55)
1.6	44	64.8 (11.6)	130.3 (14.1)	77.6 (9.4)	7 (15.9)	17 (38.6)	0.85 (0.43–1.70)	0.92 (0.45–1.88)
		<i>P</i> =0.57 ^c	<i>P</i> =0.28 ^c	<i>P</i> =1.00 ^c	<i>P</i> <0.01 ^c	<i>P</i> =0.43 ^c	<i>P</i> for trend=0.82	<i>P</i> for trend=0.56
Normal ^d	233	64.7 (11.7)	128.9 (16.2)	77.5 (11.2)	45 (19.3)	91 (39.1)	1.00	1.00
Impairment ^d	111	65.3 (11.0)	127.9 (15.1)	77.3 (10.0)	32 (28.8)	49 (44.1)	1.22 (0.77–1.94)	1.32 (0.81–2.14)
		<i>P</i> =0.68 ^c	<i>P</i> =0.60 ^c	<i>P</i> =0.88 ^c	<i>P</i> =0.05 ^c	<i>P</i> =0.37 ^c		

Abbreviations: CI, confidence interval; DBP, diastolic blood pressure; SBP, systolic blood pressure; s.d., standard deviation; OR, odds ratio.

^aHypertension was defined as a systolic blood pressure ≥ 140 mm Hg, a diastolic blood pressure ≥ 90 mm Hg, the use of antihypertensive agents, or any combination of these.

^bAdjusting for age (continuous), body mass index (continuous), casual blood glucose (continuous), total cholesterol (continuous), presence of artificial teeth (no, yes), smoking (none, <20, ≥ 20 cigarettes per day) and alcohol consumption (none, <23, ≥ 23 g of ethanol per day).

^cThe χ^2 -test for categorical variables, and student's *t*-test or one-way analysis of variance for continuous variables.

^dSubjects were categorized into normal (<1.0%) and impairment (≥ 1.0 %).

Table 3 Association between the women's taste of salt and blood pressure not only of women's own but also of their husbands (77 couples living alone)

Women's salt taste ^a	Prevalence of hypertension ^b (%)	P-value ^c	Prevalence of hypertension except moderate and severe hypertension ^d (%)	P-value ^e
<i>For women's own blood pressure</i>				
Normal	18/60 (30.0)		16/58 (27.6)	
Impairment	12/17 (70.6)	<0.01	10/15 (66.7)	<0.01
<i>For women's husbands' blood pressure</i>				
Normal	22/60 (36.7)		20/58 (34.5)	
Impairment	10/17 (58.8)	0.10	10/17 (58.8)	0.07

^aWith regard to the taste of salt, we categorized 77 women into normal (recognition threshold of salt at <1.0% concentration) and impairment ($\geq 1.0\%$).

^bHypertension was defined as a systolic blood pressure (SBP) ≥ 140 mm Hg, a diastolic blood pressure (DBP) ≥ 90 mm Hg, the use of antihypertensive agents or any combination of these.

^cThe χ^2 test.

^dFrom hypertension, we excluded subjects with moderate and severe hypertension (SBP ≥ 160 mm Hg or DBP ≥ 100 mm Hg).

to an increased prevalence of hypertension (age-adjusted OR (95% CI) for each 1-unit increase in the recognition (1.26 1.10–1.44). The inclusion of several potential confounders in the models did not change the results substantially. Compared with a recognition threshold of 0.6%, the recognition threshold of 1.4% showed the highest OR for hypertension (multi-adjusted OR (95% CI)=6.64 (1.99–22.16)). Among men, however, no constant tendency was observed regarding the relationship between the recognition threshold and hypertension. We conducted the following three subgroup analyses: (1) excluding subjects with moderate and severe hypertension; (2) excluding subjects taking antihypertensive agents; and (3) excluding subjects 70 years old or older. These analyses produced results similar to those obtained for the full study population (data not shown).

Because no universally accepted cutoff point for the taste recognition threshold for salt in relation to hypertension has been established, we classified the subjects as normal (<1.0%) or taste impaired ($\geq 1.0\%$), as shown in Table 2. Among women, the multi-adjusted OR (95% CI) in the impairment group was 2.47 (1.53–3.99) for hypertension when compared with the normal group. Among the men, there was no significant relationship between the taste threshold categories and hypertension.

Table 3 summarizes the results of the secondary analysis of 77 couples living alone. As with the main analysis presented in Table 2, a relationship between the women's salt taste and their own blood pressure was demonstrated. For the women in the impairment group, the prevalence of hypertension in their husbands (58.8%) tended to be higher than in the husbands of women in the normal group (36.7%, $P=0.10$). Even after excluding subjects with moderate and severe hypertension, the association between women's salt taste and their husbands' blood pressure was similar ($P=0.07$).

DISCUSSION

In this cross-sectional study of Japanese community-dwelling adults 40 years old or older, we found that an elevated taste recognition threshold for salt was associated with an increased prevalence of hypertension in women, but not in men. These associations did not change after adjusting for several potential confounders. Interestingly, our findings also suggest that a woman's salt taste might influence her husband's blood pressure.

Making people aware of their own taste of salt has been reported to be helpful in educating them to reduce their salt intake.^{21,22} A simple

taste test using salt-impregnated taste strips overcomes the disadvantages of the standard taste tests, such as the whole-mouth method, the micropipette method and the paper filter disk stimulation method in the following respects: the test is less time-consuming, administering it requires no special training and there is no need to prepare a testing solution, for example, salt solution.²³ This makes it possible to use the test repeatedly in clinical and community settings; the effects of dietary salt restriction can be evaluated by the subjects' taste threshold for salt both before and after health education. This is useful because it has been reported that salt restriction improves the taste threshold.²⁴ In addition, subjects are able to receive their test results on site and interpret them easily, without any special knowledge. Although no clear cutoff value for the taste recognition threshold for salt has been established, we proposed 1.0% based on our finding that the odds of hypertension were elevated in women at thresholds above 1.0%. This tentative cutoff point, however, should be examined in other populations to determine whether it is generally applicable. We found that the prevalence of hypertension did not increase when the taste recognition threshold was 1.6%. It is possible that the participants in this category included subjects who did not understand the procedure or who had a taste dysfunction caused by factors other than excessive salt intake.

The present study found no clear association between the taste threshold for salt and blood pressure among the male subjects, possibly because Japanese men are not accustomed to the act of tasting for culinary purposes because they rarely prepare meals in everyday life. This result is consistent with the findings of Minohara *et al.*²⁵; in taste tests involving the dropping of solutions on the tongue, they found that hypertensive women had elevated taste recognition thresholds for salt, whereas men did not. On the other hand, in a study using salt-impregnated taste strips, Maruyama *et al.*¹⁸ reported an association between elevated taste recognition thresholds for salt and hypertension in men. Although some early studies performed in Western populations suggested a relationship between salt taste and blood pressure, the studies were performed in clinical settings and did not show the results stratified by sex.^{15,16,26–28} Therefore, it is difficult to compare those results with the results of our study. Because this was a cross-sectional study, prospective studies regarding the connection between the taste of salt and blood pressure are needed.

To promote a reduction in salt intake, health education programs dealing with the household as a basic unit for intervention have been attempted. Yokota *et al.*²⁹ conducted a community-based blood pressure control program in which they evaluated the salt concentration of soybean soup in each household. Our findings may support the household intervention strategy, where the main cook of the family is the key target for intervention. Because the results of the INTERSALT study suggest that maintaining low salt intake leads to no or minimal increase in blood pressure with age,^{6,30} success in persuading the main cook in a family to reduce the salt content of meals could contribute to not only lowering the family members' current blood pressure, but also preventing the development of hypertension. This knowledge may motivate Japanese women to reduce the use of salt in their meals.

When interpreting the results of this study, some methodological issues should be discussed. First, outcome misclassification may have occurred because we adopted casual blood pressure due to the feasibility of screening for hypertension in the health check-up setting. Home blood pressure and ambulatory blood pressure are more closely associated with cardiovascular mortality and stroke morbidity than conventional blood pressure³¹ and can be used to detect white coat hypertension and masked hypertension.³² We assumed outcome misclassification to be non-differential with respect to exposure status.

Thus, our results are likely to underestimate the relationship between salt taste and blood pressure because they are biased toward the null. Second, although we adjusted for several potential confounders, there is a possibility of residual confounding by factors known to influence blood pressure, for example, several dietary factors such as vegetable proteins, polyunsaturated fatty acids, phosphorus and iron.^{5,7,33–35} Finally, although earlier research has provided evidence that increased salt intake dulls the taste of salt,¹⁴ epidemiological evidence of the association between the salt taste and salt intake is limited. Additional studies are needed.

In conclusion, salt taste impairment was associated with an increased prevalence of hypertension in Japanese women 40 years old or older, but not in men. For women, measuring the taste threshold for salt seems to be a promising screening tool to detect individuals at high risk for hypertension caused by excessive salt intake. Furthermore, health education on salt restriction aimed at Japanese women, generally the main cook in the family, may contribute to hypertension prevention not only among the women themselves, but also among their family members.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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