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Intensity of Salt Taste and Prevalence of Hypertension Are Not Related in the Beaver Dam Offspring Study

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Abstract

BACKGROUND—Standard clinical advice for the prevention and treatment of hypertension includes limitation of salt intake. Previous studies of the association between perception of salt taste and hypertension prevalence have not reported consistent results and have usually been conducted in small study populations.

PURPOSE—To determine the cross-sectional relationship between intensity of salt taste, discretionary salt use, and hypertension. **METHODS:** Subjects (n=2371, mean age=48.8 years) were participants in the Beaver Dam Offspring Study (BOSS), an investigation of sensory loss and aging conducted in 2005–2008. Salt taste intensity was measured using a filter paper disk impregnated with 1.0 M sodium chloride and a general Labeled Magnitude Scale (gLMS). Hypertension was defined as systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg, or use of high blood pressure medication.

RESULTS—Nearly 32% of the participants rated the salt disk as weak or having no taste while approximately 10% considered it to be very strong or stronger. The intensity was reported to be less strong by males ($P < 0.001$) and college graduates ($P = 0.02$) and was inversely associated with frequency of adding salt to foods ($P = 0.02$). There was no significant association between hypertension and the intensity of salt taste, before and after adjustment for covariates. Exclusion of subjects with a history of physician diagnosed hypertension did not appreciably alter these findings.

CONCLUSIONS—The perception of salt taste was related to the frequency of discretionary salt use but not to hypertension status or mean blood pressure.

Keywords

high blood pressure; hypertension; population; salt taste; salt use; taste intensity

INTRODUCTION

The link between salt intake and blood pressure has been studied extensively in animal studies, observational investigations and intervention trials (Elliot et al., 1996; Frost et al., 1991; Geleijnse et al., 2003; He and MacGregor, 2009; Hypertension Prevention Trial Research Group, 1990; Law et al., 1991; Sacks et al., 2001; The Trials of Hypertension Prevention Collaborative Research Group, 1992; Whelton et al., 1998) with the results often supporting the hypothesis of a causal relation between salt intake and blood pressure. Consequently, limitation of salt intake plays a prominent role in the Dietary Guidelines for Americans 2010 (U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2010) and is part of standard clinical advice given for the prevention and treatment of high blood pressure.

Salt intake is a consequence of overall caloric intake, consumption of high-sodium foods, and discretionary use. Of these sources, processed foods comprise an estimated 75% of sodium intake while only 5–10% is discretionary (Mattes and Donnelly, 1991). Salt is consumed primarily because of taste preference rather than physiological need and a number of studies have suggested that salt preference, under need-free conditions, is affected by changes in dietary sodium (Bertino et al., 1982, Bertino et al., 1986; Chan et al., 1985; Mattes, 1990, 1997; Shepherd et al., 1984). After 2–3 months of sodium restriction, acceptance of low-sodium foods increases and the level of preferred salt in food decreases (Bertino et al., 1982; Mattes, 1990, 1997). In contrast, rising dietary sodium leads to an elevated level of preferred salt in food (Bertino et al., 1986).

Crucially, some studies have found that the driving force behind these hedonic changes is exposure to salt taste. Diets that alter discretionary salt but not total sodium intake generate a hedonic shift, but those that change total sodium intake without affecting discretionary salt use do not (Beauchamp et al., 1987; Mattes, 1990). Likewise, in a study of a small group of volunteers, when total sodium intake, and not just discretionary use, was considered, results suggested that salt preference and perception at less than suprathreshold concentrations were not related to total intake (Drewnowski et al., 1996). In contrast, recent evidence has suggested that the perception of the intensity of salt is related to salt hedonics and total sodium intake (Hayes et al., 2010; Lucas et al., 2011).

Studies have generally found no difference between hypertensives and normotensives in ability to detect salt taste (Fallis et al., 1962, Schechter et al., 1974) but some studies observed higher salt recognition thresholds in hypertensives (Barylko-Pikielna et al., 1985; Fallis et al., 1962; Michikawa et al., 2009). With respect to suprathreshold intensity ratings, results have not been consistent with some investigations suggesting no difference in sodium chloride responsiveness between hypertensives and normotensives (Mattes et al., 1983; Zunkley et al., 1987) while other investigations have reported that hypertensives demonstrated reduced sensitivity (Contreras, 1978). However, many of the studies were conducted in small, clinic or hospital-based groups or convenience samples where the age range of participants varied as did the definition and use of clinical diagnoses of hypertension.

The purpose of this study was to determine the cross-sectional relationship between intensity of salt taste, presented as sodium chloride at a suprathreshold concentration, discretionary salt use and hypertension in a large population spanning a wide age range. The hypothesized path of association was that a relationship between salt taste intensity and salt preference exists and is related to a higher total sodium intake and therefore, a higher prevalence of hypertension.

MATERIALS AND METHODS

Subjects

Subjects were participants in the baseline examination for the Beaver Dam Offspring Study (BOSS), an investigation of sensory loss and aging, conducted in 2005–2008. BOSS members (n=3285, ages 21–84 years) are the adult children of participants in the population-based Epidemiology of Hearing Loss Study (EHLS). Additional details have been published (Cruickshanks et al., 1998, 2009; Zhan et al., 2010). The Health Sciences Institutional Review Board of the University of Wisconsin approved the study and informed consent was obtained.

Of the 2843 BOSS participants who were examined (442 participants chose to complete a questionnaire only), 40 (1.4%) did not attempt the taste test (19 of these because of pregnancy), 429 did not successfully learn the intensity scale, and 3 had no hypertension information. Further details on the administration of the taste test and the training in the use of the intensity scale have been reported (Cruickshanks et al., 2009).

Measurements

Salt taste intensity was measured using a filter paper disk impregnated with 1.0 M sodium chloride (prepared in the laboratory of LM Bartoshuk) and a general labeled magnitude scale (gLMS) with a range of “No sensation” (0) to “Strongest imaginable sensation of any kind” (100) (Bartoshuk et al., 2004). The intensity scores were categorized according to labels given on the scale: 1. < Moderate (0–16), 2. Moderate (17–34), 3. Strong (35–52), and 4. Very strong+ (53–100).

To obtain the resting blood pressure, after the participant was seated for 5 minutes, three blood pressures were recorded at approximately 1 minute intervals by a trained examiner. Data from the third seated blood pressure measurement were used. Hypertension was defined as a systolic blood pressure ≥ 140 mmHG, or a diastolic blood pressure ≥ 90 mmHG, or current use of blood pressure medication. A history of physician diagnosed high blood pressure was self-reported. Covariates included age, sex, education, smoking, and obesity.

Frequency of added salt was determined with the question, “How often do you add salt to foods?” There were 9 possible responses, ranging from “Never” to “4+ times per day” which were grouped as never, less than daily, and daily or more. This grouping was done to allow us to compare the extremes of the distribution, i.e. approximately the 1st quartile, the middle 50%, and the 4th quartile of the distribution, and to help in reducing misclassification due to variation in how much salt a participant added week to week.

Statistical Analyses

Differences between the taste intensity groups for the blood pressure measures and covariates were tested using the F, Chi-square, or Cochran-Armitage Trend test. The association between hypertension status and the frequency of added salt was evaluated using the Chi-square test statistic. Multiple logistic regression was used in modeling salt taste intensity and hypertension with covariate adjustment. A Generalized Estimating Equation (GEE) model was fit to adjust for familial correlation. For categorical variables, a reference group was chosen and indicator variables were created for remaining levels. For salt taste intensity, the reference category was the ‘< Moderate’ group. To test for trends, the salt intensity category number was entered as ordinal in the model. Odds ratios (OR) and 95% confidence intervals (CI) were computed from the parameter estimates and standard errors.

Analyses were performed during 2010 and 2011 using SAS, version 9.1 (SAS Institute, Inc., Cary, NC).

RESULTS

There were 2371 participants (ages 21–84 years, mean = 48.8 years) included. Approximately 32% of participants characterized the intensity of the salt taste disk as being less than moderate while 10% rated the salt taste as very strong or stronger (Table 1). Salt taste intensity was significantly associated with age, gender, and education. The salt intensity was reported as being less strong by men ($p < 0.001$) and by those with a college degree ($p = 0.02$).

The frequency of adding salt to foods varied significantly by salt taste intensity group ($p = 0.02$) (Figure 1). The percentage of subjects who reported never adding salt was higher in the ‘strong’ and ‘very strong+’ intensity groups (30.6%) compared to the ‘moderate’ and ‘< moderate’ groups (24.0%). In addition, the frequency of adding salt to food was significantly ($p < 0.01$) related to hypertension status. Among the hypertensives, 30% never added salt while among the non-hypertensives, 24% never added salt to food. However, when the analysis was restricted to those who did not have a reported history of physician diagnosed hypertension, the relationship between hypertension status and discretionary salt use was no longer significant. In this restricted group, the percentage of the hypertensives who never added salt to food was 24%, the same level as in the non-hypertensives.

No significant association between hypertension and the intensity of salt taste was observed. This was found both in the unadjusted analyses and in the analyses adjusted for covariates. Mean systolic and diastolic blood pressures did not differ by intensity groups (Table 2). After adjustment for covariates, participants reporting the intensity as very strong or stronger had 1.24 times higher odds (95% CI = 0.88, 1.74) of hypertension as those reporting the intensity as less than moderate (Table 3). When the analysis was restricted to participants without a reported history of physician diagnosed hypertension ($n = 1591$), this odds ratio increased to 1.61 (95% CI = 0.97, 2.68) but remained nonsignificant. In this restricted sample, there was a suggestion of a positive trend ($p = 0.06$) in the adjusted odds of being hypertensive as intensity of salt taste increased. Adjustment for familial correlation, analysis of the intensity data as continuous, and normalization of the taste intensity data by adjusting for the perceived intensity of the brightest light ever seen did not alter the results. In addition, excluding frequency of added salt as a covariate in the models produced no change in the results.

DISCUSSION

In this cross-sectional analysis, the hypothesized path of association involved a relationship between salt taste intensity and salt preference leading to a higher total sodium intake, and consequently, a higher prevalence of hypertension. A recent report, consistent with our hypothesized path, suggested that greater intensity of salt taste was directly associated with the liking of salty foods and sodium intake (Hayes et al., 2010). However, our study did not find a significant relationship of intensity of salt taste with hypertension status or with mean blood pressure. There was indication of a weak trend in the odds of hypertension as salt intensity increased, particularly in participants with no history of physician diagnosed hypertension, but the trend was not significant.

Our finding of no significant association between intensity of salt taste and hypertension is similar to previously reported results (Mattes et al., 1983; Zunkley et al., 1987). In a study conducted at a workplace blood pressure screening, no difference in intensity magnitudes

were found between hypertensives, pre-hypertensives and normotensives (Mattes et al., 1983). Observed associations between salt taste and hypertension have focused primarily on recognition thresholds, but these effects have not always been consistent.

Our study found that intensity of salt taste was related to frequency of discretionary salt use. The finding that a larger percentage of the participants who rated the salt intensity as strong or greater never used discretionary salt is compatible with a previous study where perceived saltiness of crackers increased after a reduction in dietary sodium, and studies showing that changes in salt preference are driven largely by the taste of salt rather than its postingestive consequences (Beauchamp et al., 1987; Bertino et al., 1982). Similarly, it has been reported that individuals who have an oral sensory phenotype leading to greater taste intensities, were less likely to add salt to foods (Hayes et al., 2010). It was postulated that those tasting salt more intensely may be satisfied by the saltiness of foods and thus, tend not to add salt frequently.

Among all participants, including those with a previous history of hypertension, frequency of added salt was related to hypertension (a significantly greater percentage of the hypertensives never added salt). However, in the group of participants without a prior history of hypertension, where there would be no effect of dietary restraint in response to medical advice, discretionary salt use was not related to hypertension. But discretionary salt use is a limited measure of sodium intake since it accounts for only 5 -10% of total intake (Mattes and Donnelly, 1991).

The strengths of the study include having a very large number of participants with a wide age range. Rigorous methods were used to define hypertension and measure taste intensity. During the intensity testing, participants sipped water before the introduction of the filter paper disk and kept the disk in his/her mouth for 10 seconds to ensure the dissolving and delivery of the sodium chloride. This approach was used to help reduce variation in the concentration being tasted between participants. The gLMS was used for measuring intensity so comparisons could be made across hypertension groups.

A limitation of the study was the cross-sectional design with taste intensity and hypertension being measured at the same time. But through adjustment and restriction an attempt was made to address any influence a previous diagnosis of hypertension may have had on salt taste intensity and salt usage through dietary restraint following medical advice. A limitation of the taste testing was the use of single filter paper disks only and not solutions due to constraints at the field site with respect to the availability of laboratory and clean sink areas. We do not know if our results would have varied if we had used solutions, but a previous study which used solutions reported results compatible with our findings (Mattes et al., 1983). A number of participants were unable to learn how to use the intensity rating scale (Cruickshanks, 2009). When we evaluated the relationship of hypertension status with the factors related to salt taste intensity, in those who successfully learned the scale and in those who did not, we observed no appreciable differences. Therefore, bias, due to the absence of the participants who were unable to learn the scale, is not likely. Regarding salt usage, although discretionary salt intake appears to influence salt preference over time, it was the only measure of current sodium intake taken, making it difficult to fully adjust for intake. Finally, while we attempted to minimize random misclassification of hypertension status or salt taste intensity group through a well-defined protocol used by trained examiners, it is possible that some misclassification occurred.

This study did not find a significant relationship between salt taste intensity and hypertension but did find an association between discretionary salt use and intensity of salt taste. Recent guidelines have suggested that individuals at higher risk of hypertension or

over age 50 restrict daily sodium intake to 1500 mg and that all other individuals restrict intake to 2300 mg per day (U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2010). The source of the majority of sodium intake is processed foods. Understanding the sensory and hedonic effects of salt taste on total sodium intake, including discretionary intake, is of fundamental importance in the campaign to have the general population reduce sodium intake and thereby impact the risk of hypertension.

CONCLUSIONS

Salt taste intensity was found to be related to the frequency of discretionary salt usage but not to hypertension status in a large population of persons aged 21 through 84.

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ABBREVIATIONS

BMI	Body Mass Index
BOSS	Beaver Dam Offspring Study
CI	Confidence Interval
EHLS	Epidemiology of Hearing Loss Study
GEE	Generalized Estimating Equation
gLMS	general Labeled Magnitude Scale
kg	kilogram
M	molarity
m	meter
mg	milligram
mmHg	millimeter of mercury
OR	Odds Ratio
S.D	Standard Deviation

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Figure 1.
Frequency of Added Salt by Salt Taste Intensity Group

Table 1

Study Subject Characteristics by Salt Taste Intensity Beaver Dam Offspring Study

Characteristic	Total	Salt Taste Intensity			p-value
		< Moderate (0–16)	Moderate (17–34)	Strong (35–52)	
N	2371	748	909	469	
Mean age (S.D.) ^a	48.8 (9.8)	48.0 (9.7)	48.9 (9.7)	49.7 (10.1)	0.03
Sex (% Male)	46.6	53.3	48.0	40.5	< 0.001
Education (%)					0.02
< 12 years	2.1	2.0	2.2	1.1	
12	28.0	26.8	27.4	28.9	
13–15	34.2	32.8	33.0	37.0	
16+	35.7	38.4	37.4	33.0	
Smoking (%)					0.94
Never	54.3	55.0	53.4	54.6	
Past	29.2	27.8	30.6	29.2	
Current	16.5	17.1	16.1	16.2	
Obese (BMI ≥ 30.0 kg/m ²) (%)	43.7	43.7	44.4	42.5	0.93

^aS.D. = Standard Deviation

Table 2
Hypertension and Blood Pressure Status By Salt Taste Intensity Group, Unadjusted Beaver Dam Offspring Study

Hypertension Status	Salt Taste Intensity				p-value, trend
	< Moderate (0–16)	Moderate (17–34)	Strong (35–52)	Very Strong + (53–100)	
Hypertensive (%)	33.4	34.9	37.7	37.1	0.12
Mean systolic blood pressure (S.D.) ^a	125.6 (17.3)	125.4 (18.0)	126.3 (17.4)	126.3 (18.3)	0.40
Mean diastolic blood pressure (S.D.)	73.9 (9.9)	73.7 (9.9)	73.7 (9.7)	73.5 (9.6)	0.56
Current Use of Blood Pressure Medications (%)	19.2	20.9	23.3	23.0	0.08
History of Physician Diagnosed Hypertension (%)	32.8	31.2	34.8	34.8	0.37

^aS.D. = Standard Deviation

Salt Taste Measures and Hypertension Status Multivariable Model^a Odds Ratios (OR) & 95% Confidence Intervals (CI) Beaver Dam Offspring Study

Table 3

Salt Taste Intensity Group	All ^b (n = 2371)				No Hypertension History ^c (n = 1591)			
	Hypertensive		OR	95% CI	Hypertensive		OR	95% CI
	Yes	No			Yes	No		
< Moderate (0–16)	250	498	1.00	-	65	437	1.00	-
Moderate (17–34)	317	592	1.02	0.81, 1.28	86	539	1.07	0.75, 1.53
Strong (35–52)	177	292	1.18	0.90, 1.55	47	258	1.24	0.81, 1.91
Very Strong + (53–100)	91	154	1.24	0.88, 1.74	28	131	1.61	0.97, 2.68

^a Adjusted for age, sex, education, current smoking, obesity and frequency of added salt.

^b P_{trend} = 0.13

^c Restricted to participants without a reported history of physician diagnosed hypertension; P_{trend} = 0.06