Failure to Compensate Decreased Dietary Sodium With Increased Table Salt Usage

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This study tested the extent to which individuals placed on a lowered sodium diet would compensate for the reduced dietary sodium by adding table salt to their food. Eleven students, unaware that their use of saltshakers was being studied, consumed all their meals and snacks in a clinical research center for 13 weeks. During the first three weeks and the last week (week 14), the diet contained approximately 135 mmol/d (135 mEq/24 h) of sodium, which was reduced to approximately 70 mmol/d (70 mEq/24 h) during weeks 4 through 13. A preweighed saltshaker was available for use throughout the entire 14-week period. Evaluations of salt taste preference and intensity scaling were conducted at regular intervals. Subjects compensated only slightly for the reduction of dietary sodium, making up less than 20% of the decrement with increased saltshaker usage. No changes in taste function were found. A substantial reduction in dietary sodium is possible if lowered-sodium foods are consumed in conjunction with ad libitum table salt.

(*JAMA* 1987;258:3275-3278)

USUAL consumption of sodium chloride in the United States (6 to 18 g of sodium chloride per day) is believed to be substantially above requirement.[1] Reduced sodium intake has been recommended for individuals suffering from hypertension,[2] as well as for the general populace,[3] although this latter point is somewhat controversial.[4] However, the loss of sensory pleasure associated with reduced salt in food has often been cited as a major impediment to lowered sodium consumption.[5] Salt (sodium chloride) is an almost universal food additive, and experimental studies,[6-8] as well as consumer research, have demonstrated that foods with lower than customary amounts of salt are less acceptable than the same foods with more salt.

For editorial comment see p 3298.

It has been stated that of the sodium consumed, approximately one third occurs naturally in food, one third is added by the manufacturer during processing (these two sources forming the obligate salt), and one third is added by the consumer (discretionary salt) either during cooking or at the table.[1] If one is to reduce sodium consumption, avoidance of the latter two sources are the most obvious routes. Most sodium reduction diets require reduced salt in cooking, prohibit saltshaker usage at the table, and restrict certain highly salted foods. Since it is seemingly easiest to cease using the saltshaker, the usage of which may be due to habit unassociated with the sensory impact of the salt placed on the food,[9] cessation of saltshaker usage is often recommended as the first step in salt reduction.[10] However, some more recent studies indicate consumer addition of salt may be substantially less than one third of sodium intake,[11-14] requiring meaningful reduction of dietary salt intake to include a reduced intake of salted, usually processed, foods. While much of the salt from a shaker is placed on top of food, and thereby has the opportunity to impart its taste in a most economical fashion, a portion of the salt in food is never available to the taste receptors.[15]

In a previous study (G.K.B., M.B., K.E., unpublished data, 1984), we noted that normal volunteers given a very low-salt diet and ad libitum usage of saltshakers seemed to use much less additional salt than would have been required to compensate for the dietary reduction. As these data were limited, the purpose of the current study was to test the extent to which individuals consuming a lowered sodium diet but allowed ad libitum usage of a saltshaker would fully replace the reduced dietary sodium. Furthermore, we tested whether subjects' taste preferences would also decrease as we had previously reported with dietary sodium reduction.[16]

METHODS

Subjects

Subjects were 11 undergraduate and graduate students (eight male and three female; age range, 19 to 31 years) of the University of Pennsylvania, Philadelphia. They were recruited through advertisements and word of mouth and were informed that the study would investigate diet and taste and that they would be eating meals with a lowered salt content. Subjects were paid for their participation, and all meals were provided without cost. Only individuals who were not currently on a lowered-sodium diet, who had 24-hour urine sodium ion excretions of at least 90 mmol/d (90 mEq/24 h), and who claimed to use saltshakers were selected. Approximately one third of individuals answering our advertisements were rejected because they reported not using saltshakers. Very few potential subjects were rejected for not meeting the 90-mmol/d (90-mEq/24 h) criterion. All selected subjects were normal medically, as defined by history, physical examination, and laboratory tests. Their mean ($\pm$SD) qualifying urinary sodium ion excretion was 152.9 ± 73 mmol/d (152.9 ± 73 mEq/24 h). All provided informed consent as approved by the Committee on Studies Involving Human Beings of the University of Pennsylvania.

Procedure

Following recruitment, each subject was required to collect a 24-hour urine specimen while he/she was on his/her normal diet. Each subject was also required to complete a salt attitude and usage survey.[17] Starting approximately one week later, subjects were required to eat all their meals and obtain all snacks from the General Clinical Re-

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search Center (CRC) at the Hospital of the University of Pennsylvania. Three meals and snacks were available daily although virtually no one came for breakfast. Subjects often took pastries and fruit with them in the evening to eat for the next morning's breakfast. For the next two weeks, they were fed a normal hospital diet in the CRC that was not restricted in sodium content. During this period, each subject provided two to three, 24-hour urine specimens. Each subject was also given a labeled opaque saltshaker that they used throughout the study. The amount of salt used was recorded daily by hospital staff. Subjects were never told their usage of the saltshaker was being studied. The weight of the filled saltshaker was approximately 115 g. The daily discretionary salt usage was determined by the change in weight, and the shakers were refilled frequently so that change in usage was not readily apparent.

After this baseline period, for the next ten weeks, the diet was changed so that sodium content would be reduced by approximately 50% to an estimated 70 mmol/d (70 mEq/24 h). Lunch consisted of sandwich foods, such as turkey, roast beef, lettuce, etc. To meet this decrease in dietary sodium, it was necessary to limit male subjects to four slices of regular bread and female subjects were permitted two. Unlimited additional low-sodium bread was allowed. Subjects had a choice of at least two, sometimes three, entrées for dinner. Salad was available (with low-sodium dressing), as were at least two vegetables. Subjects had steak once each week. For snacks, subjects had fresh fruit and were allowed to make sandwiches to take with them. Ice cream, sodas, fruit juices, milk, and low-sodium peanut butter were permitted ad libitum. Subjects obtained all their food from the research diet kitchen. During this ten-week period, it was repeatedly emphasized to the students that they were permitted continued ad libitum usage of their saltshakers. When subjects had to eat away (some religious holidays, unavoidable absences, etc), they were required to keep a dietary record of all the foods consumed and were instructed to avoid foods high in salt. They took their saltshakers with them.

During the ten weeks on the reduced-sodium diet, 24-hour urine specimens were collected once weekly. The days of collection were randomly selected, with the subjects being informed of the next day's collection after the evening meal of the previous day. Blood pressures and body weights were recorded weekly. Following the conclusion of the low-salt diet period, subjects were again fed regular food for one week with continued ad libitum saltshaker usage. Approximately one month after leaving the study, eight subjects collected a 24-hour urine specimen. During this time, they again filled out the questionnaire.

Taste Tests

Taste tests were conducted weekly throughout the study and were similar to those used previously.[16] Using the method of magnitude matching, subjects estimated the saltiness of a sodium chloride concentration series in crackers (0.95% to 4.0% sodium chloride) and in low-sodium soup broth (0.06- to 0.99-mol/L sodium chloride). They also rated the pleasantness of these foods using nine-point category-rating scales. The crackers were tested first, followed by the soup samples. At the end of both the cracker and soup tests, subjects were again given all concentrations and told to taste each and pick out which concentration they liked the best. Finally, at the end of the soup taste testing, subjects were given 50 mL of soup and a saltshaker and instructed to add salt to their preferred taste.

Data Analysis

Urine specimens were analyzed for volume and content of creatinine, sodium, and potassium. Sodium intake was estimated from the 24-hour urine specimens, and discretionary salt was measured by the change in saltshaker weight. Changes in sodium intake during the course of the study were evaluated with repeated measures analysis of variance. To evaluate individual consistency, correlation coefficients were calculated. Taste data were evaluated with parametric statistical tests.

RESULTS

The discretionary usage of salt from saltshakers is shown in the Table. There was no indication of consistent trends in the amount of salt used during the low-sodium diet period (as determined by repeated measures analysis of variance). Consequently, for the main analysis, a one-way repeated measures analysis of variance was computed with three treatments: salt usage during the prediet period (weeks 2 and 3 collapsed), salt usage during the low-sodium diet period (weeks 4 through 13 collapsed), and salt usage during the week of return to the standard and salt diet (week 14). The analysis revealed a significant effect of treatment ($F=10.8$; $df=2,20$; $P<.001$). Pair-wise comparisons indicated that more salt from the saltshaker was used during the lowered-sodium diet period than during either the prediet or postdiet periods ($P<.01$, Newman-Keuls test). As seen in the Table, all but subject 10 increased usage of the saltshakers from the two prediet weeks to the first two weeks on the diet. Similarly, on resumption of the normal diet (week 14), all but subject 10 showed a reduction in saltshaker usage.

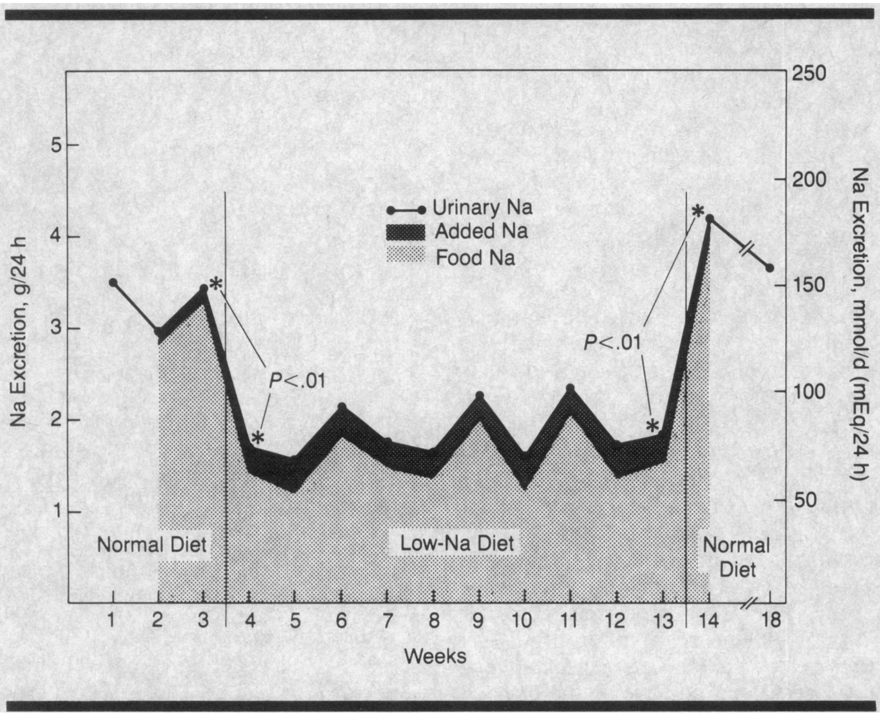
Total sodium excretion for the entire group is plotted in the Figure. Mean ($\pm$SEM) sodium ion excretion decreased from the prediet control period (136 ± 7.0 mmol/d [136 ± 7.0 mEq/24 h]) to the first two weeks on the low-sodium diet (71 ± 4.6 mmol/d [71 ± 4.6 mEq/24 h]). On resumption of food with regular levels of sodium, all subjects increased their salt consumption (183 ± 18.0 mmol/d [183 ± 18.0 mEq/24 h]). An identical set of statistical analyses was performed on these data. Again, there was no consistent trend in the data during the ten-week lowered-sodium diet period. The repeated measures analysis of variance indicated that the amount of sodium excreted in the urine was influenced by treatment ($F=22.4$; $df=2,20$; $P<.001$). Pair-wise comparisons indicated that there was less sodium excretion during the lowered sodium diet periods ($P<.01$, Newman-Keuls test). Furthermore, there was an indication that the postdiet excretion tended to be greater than the prediet excretion, but this did not reach an acceptable level of statistical significance. The mean urinary sodium ion excretion for the eight subjects studied one month following the end of the formal study (Figure, week 18) was 165 ± 26 mmol/d (165 ± 26 mEq/24 h). Analysis of the ratios of sodium to creatinine yielded similar results.

Before initiating the diet, saltshaker sodium accounted for approximately 2% (approximately 3 mmol/d [3 mEq/24 h]) of sodium ion excretion, whereas this figure increased to approximately 15% (approximately 12 mmol/d [12 mEq/24 h]) during the reduced sodium diet (Figure). For each subject, saltshaker usage declined when subjects resumed eating the regular sodium diet. However, only one subject (No. 6) approached total compensation for the lowered-sodium diet by adding enough salt from the shaker to make up for the amount removed from the diet. Individuals were relatively consistent in the amount of salt used from the shakers over the course of the study (Table). For example, Pearson's correlation coefficient between the prediet weeks and the first two weeks of the diet was noted as follows: $r=+.79$ ($P<.01$). There were no significant changes in either body

Amount of NaCl Added to Food Each Day From Saltshakers by Individual Subjects*

	NaCl Amount, g/d						
		Lowered-Na Diet					
Subject	Normal-Na Diet, wk 2+3	wk 4+5	wk 6+7	wk 8+9	wk 10+11	wk 12+13	Normal-Na Diet, wk 14
1	0.18	0.47	0.24	0.31	0.20	0.29	0.13
2	0.14	0.45	0.68	0.35	0.30	0.24	0.04
3	0.09	1.09	2.12	2.04	1.52	2.19	0.02
4	0.08	0.75	1.36	1.03	1.26	1.23	0
5	0.07	0.63	0.65	0.44	0.59	0.46	0.06
6	0.75	1.34	0.83	0.81	1.91	2.06	1.16
7	0.56	1.60	1.26	1.22	1.10	1.04	0.25
8	0.01	0.09	0.07	0.01	0.05	0.08	0
9	0.17	0.63	0.49	0.26	0.47	0.48	0.11
10	0.03	0	0.02	0.01	0	0	0
11	0.03	0.45	0.29	0.46	0.46	0.62	0.09
Mean	...	0.19	0.68	0.73	0.63	0.71	0.17

*Except for the postdiet week, all values represent the average during 14 days. For postdiet week 14, the average is for seven days. NaCl indicates sodium chloride; Na, sodium.



Mean daily urinary excretion of sodium (Na) and mean daily amount of Na ion used from saltshakers in subjects while fed their meals at the Clinical Research Center (hatched area) and when they were on their usual ambulatory diets (weeks 1 and 18). All points represent 11 subjects, except for week 18 (n=8); asterisks, significant difference between comparison weeks.

weight or blood pressure during the 14 weeks of this experiment.

No significant changes in taste perception were found. No significant changes occurred in the slopes or intercepts of functions describing the growth of saltiness with sodium chloride concentration. No changes in preference or pleasantness were observed. The amount of salt added to the soup was consistent across all weeks, except during the prediet weeks. There was a significant increase in salt added to soup from the first (mean ± SEM, 0.11 ± 0.1 mol/L) to second (0.17 ± 0.03 mol/L) prediet week (t_{10} = 2.41, $P<.05$), possibly as a consequence of unfamiliarity with the task.

Before initiating the study, questionnaire responses given generally characterized the subjects as having moderate attitudes toward salt, in part since subjects who consumed little salt were excluded. The group's responses to the questions concerning frequency of salt usage and concerning the role of salt in health averaged in the midrange of the nine-point scale. The only question where the group's averaged response was at an extreme was, "Have you deliberately decreased your salt intake because of health considerations?" The average response was 2.3, with a 1 being "not at all" and 9 "very much so." On retest, responses to two questions changed significantly. Subjects considered themselves to be lighter salt users (although this was not corroborated by their urinary sodium level), and they thought the current concern over salt and health was more justified (ie, less overblown).

COMMENT

When dietary sodium in food was reduced by approximately 50%, 11 normal subjects increased discretionary usage of salt to compensate for only approximately 20% of the deficit. These data are consistent with the hypothesis that acceptable dietary saltiness can be attained with less salt if lowered sodium foods are used and saltshaker usage is permitted. However, several other explanations need consideration. First, it has been shown that some proportion of the salt placed with a saltshaker in food may represent habit and has little to do with the resulting sensory attributes of the food. Thus, when the size or number of holes in the saltshaker was reduced, the amount of salt used declined.[9] Perhaps the sensory quality of the food declined but not to the extent necessary to break the individual's habitual shaker usage patterns. Two points are relevant here. First, for all but one individual saltshaker usage increased during the lowered-sodium diet but not in sufficient degree to compensate for the decreased sodium content of the food. Second, many subjects recognized and reported that the lowered-sodium foods did not taste as good as the higher-salt foods, and these subjects responded to this decrease in palatability with increased usage of added salt.

Subjects' expectations about an experiment, such as this, may influence outcomes. It is possible that the subjects were fulfilling the experimenters' expectations and, thus, were willing to accept a less palatable diet by using less salt than desired. This is probably not an adequate explanation for the results obtained. First, subjects were repeatedly told to use as much salt from the shakers as they wanted. Second, subjects were not told the purpose of the experiment, and the distraction of the taste tests likely enhanced the confusion. Third, during the relatively long period of time on the lowered-sodium diet, one might have expected a gradual shift toward increased table salt usage if subject expectations, rather than truly preferred levels of sensory stimulation, were important.

We have no data comparing the relative palatabilities of the lowered-salt diet with and without salt, nor in comparison with the normal-salt diet. Mattes[15] has reported that food acceptability is greater if the salt is added during cooking rather than after cooking. Since it is difficult to obtain certain foods without salt, some subjects did miss some items that could not be served during this period. In particular, bread with normal salt levels had to be limited during the low-salt diet.

Our subjects consumed approximately 2% of their sodium from saltshaker usage before initiating the lowered-sodium diet. This is substantially lower than is commonly reported. For example, Fregly and Fregly[1] cited a variety of studies indicating that discretionary usage of salt makes up to one third of sodium consumption. In contrast, several more recent studies have indicated that a lower percentage of sodium from shaker usage may be common. In the first six weeks of a study with adult men on a constant, relatively high-sodium diet, Kumanyika and Jones[11] reported an average daily salt consumption of salt from shakers of 1.1 g (n=24), approximately 12% of sodium intake. Other studies have reported salt from shakers accounting for 8%,[12] 6% (2% for blacks),[13] and 5.2%[14] of sodium consumed. Apparently there is a wide range in table salt usage that may reflect different subject populations and different types of food commonly eaten, as well as changing attitudes about salt. Subjects in our study were college students accustomed to eating in dormitories and at fast-food restaurants where the food is probably usually heavily salted when served. Furthermore, changing attitudes toward salt during the past several years may have played a role in the low saltshaker usage that we observed.

Possibly our subjects' failure to compensate fully for a reduction in dietary salt was a consequence of their initial low usage of table salt. Are the results with these subjects representative? Since a large number of potential subjects were not eliminated due to the selection criteria enumerated in the "Methods" section, we believe these subjects do accurately represent the student population at the University of Pennsylvania. More generally, however, this question can only be answered definitively with further studies in other populations. The study by Mickelson et al[18] provides some indication that our results have general validity. In this study, ten men who ate a standard diet consumed 1.35 g of sodium daily from a preweighed shaker. Following their placement on a lowered-sodium diet, this value rose to 2.20 g, an increase of 0.85 g. This increase in table salt usage of 37 mmol/d (37 mEq/24 h) would be insufficient to offset the decline in sodium in food following assumption of the lowered-sodium diet if, as seems likely from the description in the article, this diet were similar to the one that we used. Our low-sodium diet resulted in a decline in dietary sodium levels (determined by subtracting saltshaker usage from urinary excretion) of approximately 70 mmol/d (70 mEq/24 h).

While there were substantial differences between individuals in the amount of salt contributed from shakers, each individual was quite consistent during the course of the lowered-salt period (Table). This is in agreement with the work of Kumanyika and Jones,[11] who also reported large individual differences in salting habits but substantial consistency for any particular individual.

The absence of any taste changes following assumption of the lowered-sodium diet contrasts with our own[15] and other[19] results. Peak preference for salt in foods is reported to decline after consumption of a lowered-sodium diet. There are several possible explanations for this difference. For example, taste changes may not occur unless subjects are required to change their food selection actively toward lowered-sodium foods; in the present case, all food was selected for the subjects by the CRC staff. However, the explanation we favor is that since the saltshaker places salt on rather than in the food, subjects retained enough sensory experience with salty tastes to prevent preference changes. If this is true, it suggests, as we have previously hypothesized,[16,20,21] that changes in taste perception following changes in dietary sodium are due to changes in the amount of sensory experience with salty tastes and not to the change in amount of sodium ingested per se.

Previous work in our laboratories, and others', has demonstrated that when individuals go on a diet that decreases sodium consumption by 30% to 50%, their taste preferences change. Food with less salt comes to be preferred over more salty food that used to be optimal.[15,20] Thus, confirming clinical impression, a lowered-sodium diet can become tolerable. The study reported here suggests another way to lower sodium consumption and yet retain a palatable diet: consume foods with lowered salt while using a saltshaker. Only further studies, using larger numbers of individuals with different salting habits during longer periods of time, will permit a judgment as to the best way(s) to reduce sodium intake.

This study was supported by grant RO1 HL 31736 and Clinical Research Center grant RR00040 from the National Institutes of Health, Bethesda, Md.

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