Effect of Dietary Sodium Restriction
on Taste Perception of Sodium Chloride

By

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THESIS

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SUMMARY

The effect of dietary sodium restriction on perceived intensity of and preference for the taste of salt was evaluated in 76 adults, 25-49 years, with diastolic blood pressure between 79-90 mmHg. Participants were volunteers from clinical Hypertension Prevention Trials (HPT), at the University of California, Davis and the University of Minnesota, Minneapolis.

Participants followed one of four HPT diets: 1600 mg Na^+/day (NA, n=15), 1600 mg Na^+ plus 3200 mg K^+/day (NK, n=15), 1600 mg Na^+/day plus energy restriction to achieve weight loss (NW, n=13) and weight loss only (WT, n=13). All participants attended regularly scheduled nutrition intervention meetings designed to help them achieve the HPT dietary goals. A fifth, no-intervention group, consisted of 20, no-diet-change controls (CN).

Sodium, potassium and energy intakes were monitored by analysis of single, 24-hour food records and corresponding overnight urine specimens, obtained at baseline and after 12 and 24 weeks of intervention. Hedonic responses to sodium chloride in a prepared cream of green bean soup were assessed by two methods : 1) scaling of like/dislike for an NaCl concentration series on 10-cm graphic line scales and 2) ad libitum mixing of unsalted and salted soups to maximum level of liking. Salt content of the mixes was analyzed by sodium ion-selective electrode. The concentration series was also rated for perceived saltiness-intensity on similar graphic line scales. Tests were conducted at baseline and after approximately 1, 3, 6, 8, 10, 13 and 24 weeks of intervention.

Reduction in sodium intake and excretion in NA, NK and NW participants was accompanied by a shift in preference toward less saltiness in soup. The pattern of hedonic responses changed over time: scores for high NaCl concentrations decreased progressively while scores for low concentrations increased. Hedonic maxima shifted from a concentration of 0.55% at the onset to 0.1-0.2% added NaCl at week 24. During the same time period, the preferred concentration of ad libitum mixes declined 50%. These shifts occurred independently of changes in saltiness intensity ratings, potassium or energy intakes, and were consistent across the two participating study sites. Like/dislike and ad libitum responses were similar after 13 and 24 weeks of diet, as were measures of sodium intake and excretion. These findings suggest that after three months of sodium restriction, preference for salt had readjusted to a lower level, reflective of lower sodium intake. Mechanisms underlying the change in preference are unclear, but may include sensory, context, physiological as well as behavioral effects.

In contrast, few changes were noted within WT and CN groups. The pattern of hedonic responses varied little in controls while the WT group showed increased liking for mid-range NaCl concentrations. Small, but significant fluctuations in ad libitum mix concentration occurred in both of these groups, but the differences appeared to be random rather than systematic.

The results of this study indicate that preference for the taste of salt declines progressively toward a new baseline following reductions in sodium intake. These alterations may enhance maintenance of low-sodium diets for the treatment and prevention of hypertension. Further

investigation is needed to establish the degree to which long-term compliance is contingent upon variation in salt taste preference.

INTRODUCTION

In 1980, prevalence of hypertension in the U.S. was estimated at 16 to 20 percent (White and Crocco, 1980). Hypertension is a major risk factor for cerebrovascular, renovascular and cardiovascular diseases. Although the specific causes of essential hypertension are unclear, genetic and environmental factors, including diet, are known determinants of blood pressure (Pickering, 1981).

Reduction in dietary sodium has been used successfully in the management of patients with high blood pressure and is now being recommended for the primary prevention of hypertension (Dahl, 1972; Freis, 1976; Tobian, 1979; U.S. Senate Select Committee on Nutrition and Human Needs, 1977). A major obstacle in developing a dietary program that will achieve and maintain the desired restriction in sodium intake, is long-term acceptability. It is often assumed that gradual reduction in sodium intake will lead to greater acceptance of low-sodium foods over time, but there is little evidence available to support this view.

Studies have demonstrated that animals made sodium deficient exhibit a large increase in salt appetite (as reviewed by Contreras, 1978 and Denton, 1982). Also, salt craving has been reported in some, but not all humans suffering from experimentally induced sodium deficiency (McCance, 1936; DeWardener and Herxheimer, 1958; Yensen, 1959) and adrenalcorticoid insufficiency (Wilkins and Ritcher, 1940), while heightened salt appetite has been reported in treated (Langford et al., 1977; Rock and Hall, 1978) and untreated hypertensives (Schechter et al., 1973).

A distinction should be drawn between the appetite for salt that occurs when an organism is sodium deficient and when an organism is sodium replete, but ingesting less salt than usual, as in the case of low-sodium diets. Dahl (1960) was among the first to suggest that patients on sodium restricted diets had reduced salt appetite and preferred less salty food. At least two controlled studies lend support to this contention. Bertino et al. (1982) and Gillum et al. (1981) independently found that individuals maintained on low-sodium diets for five months showed a trend toward greater perceived intensity and decreased liking for salt in selected foods. However, in an earlier study, Bertino et al. (1981) reported opposite trends, while in a similar study by Chan et al. (1984), no shifts in intensity or preference were observed.

Although these studies suggest that the taste for salt may be modified by alterations in sodium intake, the nature and direction of the changes have not been adequately defined. The question of whether there is, as some preliminary data suggest, an initial increased attraction to sodium, or whether preference for salt decreases linearly toward a new baseline needs to be addressed. If preference for salt is reduced, the question becomes whether it can be maintained over time.

To answer these questions, the present study examined salt taste perception and preference in non-hypertensive individuals following sodium-reduced diets for a period of six months as part of a national clinical trial of non-pharmacological approaches to the prevention of hypertension. Results on the nature and pattern of taste changes may provide valuable insight into the feasibility of adapting to and main-

taining a low-sodium diet. If reduction in dietary sodium causes taste preferences to shift to lower levels of salt in food, compliance with the low sodium regimen may be enhanced. Conversely, a heightened liking for the taste of salt during periods of sodium restriction may undermine the efficacy of this dietary approach to the treatment and prevention of hypertension.

LITERATURE REVIEW

A. Sodium Intake and Hypertension

Hypertension is generally defined as a level of blood pressure exceeding 140 mm Hg systolic and 90 mm Hg diastolic (White and Crocco, 1980). Arterial pressure depends on factors which affect blood flow such as cardiac output, arterial elasticity, neural control of peripheral resistance, blood volume and viscosity (Landau, 1976). Secondary hypertension is associated with pre-existing medical conditions (i.e., kidney disease), while essential hypertension, for which there is no known primary cause, accounts for over 95 percent of all cases (Frohlich, 1982).

Early interest in the relation between salt intake and essential hypertension was prompted by the observation that an extremely low sodium diet could lower blood pressure in hypertensive patients (Ambard and Beaujard, 1904; Allen and Sherrill, 1922). Porter (1983) published an excellent chronology of studies linking sodium intake to hypertension. Indirect evidence implicating sodium in the development of essential hypertension has since accumulated as a result of work in three general areas: epidemiologic observations, animal studies and clinical trials. Critical reviews of the evidence have been published by Dahl (1972), Freis (1976), Tobian (1979), Frohlich and Messerli (1982) and Laragh and Pecker (1983), and are examined briefly here.

A major cornerstone in the salt-hypertension hypothesis has been epidemiologic studies correlating sodium intake and the level of blood pressure. In cross-cultural studies, low sodium intake has been associ-

ated with a low prevalence of hypertension and often with a pattern of no rise of blood pressure with age. Furthermore, when societies with low-salt intakes have been introduced to high-sodium foods, the incidence of hypertension has usually increased (Freis, 1976). As pointed out by Laragh and Pecker (1983), these studies have varied widely in design and are weakened by inaccurate measurements of salt intake and their failure to account for other factors such as stature, weight, physical activity, longevity and potassium intake, which are known to affect blood pressure.

While studies of different populations support the salt-hypertension link, intra-population studies generally do not. Dahl and Love (1954, 1957) found a highly significant correlation between salt consumption and the incidence of hypertension among 1,346 employees of the Brookhaven National Laboratory who were divided into low-, average- and high-salt intake groups based on salt shaker usage only. However, similar studies conducted in other locations, including Ohio (Swaye et al., 1972), Germany (Schlierf et. al., 1980) and New Zealand (Thaler et al., 1982) were inconclusive. Failure of these studies to find correlations between salt intake and hypertension has been attributed to the relatively small variations in salt intake within populations, compared to that between populations (Frohlich and Messerli, 1982) and more importantly, to large individual variation in genetic susceptibility to sodium-sensitive hypertension (Tobian, 1979; Laragh and Pecker 1983).

Animal research has served to underline the importance of a genetic component in sodium-induced hypertension. By selectively inbreeding Sprague-Dawley rats, Dahl et al. (1962) isolated two strains; one sensi-

tive (S), and one resistant (R) to chronic excess salt feeding. When fed a high salt diet (7.3% NaCl), none of the 39 R rats developed hypertension while 46/60 of the S rats were hypertensive after only 3 months. Further experiments showed greater sodium sensitivity in younger than in older S rats. When the S or R rats were maintained on a control diet, hypertension did not develop. Thus it was shown that both genetic determinants and salt feeding were necessary to produce hypertension. The underlying defect of the S strain appeared to be failure of the kidneys to achieve maximum natriuresis (Tobian, 1979, 1983). Based on these and other data, Tobian conjectured that 9 to 20% of the human population may be genetically predisposed to hypertension, similarly to Dahl's rats.

Identification of the "salt sensitive" segment of the population is difficult. Kawasaki et al. (1978) classified 19 hypertensives into distinct "salt-sensitive" and "salt-resistant" groups based on changes in serial blood pressure readings when subjects went from low (9 meq or 200 mg/day) to high (249 meq or 5700 mg/day) sodium diets. While blood pressure in both groups increased, the salt sensitive subjects experienced a greater percent rise in blood pressure and retained significantly more sodium than the salt-resistant subjects while on the high-salt diet. These results indicate that possible differences exist between salt-sensitive and salt-resistant individuals in their ability to handle sodium loads.

It has been proposed that taste response to NaCl might be a marker for susceptibility to hypertension, based on evidence that hypertensives have higher taste recognition thresholds for NaCl than normotensives

(Fallis et al., 1962; Wotman et al., 1967; Bisht et al., 1971; Viskoper and Lugassy, 1979) or NaCl preferences (Schechter at al., 1973; Bernard et al., 1980). However, Mattes (1983) found no relationship between NaCl taste functions (perceived intensity, preference and ad libitum salting), blood pressure and salt consumption among 87 normotensive, prehypertensive and hypertensive adults. In an extensive review of the salt taste and hypertension literature, Mattes (1984) emphasized that although salt taste sensitivity may be reduced in hypertensives, studies have demonstrated that sensitivity bears little relation to actual salt preference and intake.

A third line of evidence linking salt to hypertension has involved clinical trials on the effect of dietary sodium restriction on blood pressure, as reviewed by Dahl (1972), Tobian (1979), Luft and Weinberger (1982) and Laragh and Pecker (1983). A blood pressure-lowering effect of extremely low sodium diets was first demonstrated by Kempner (1944), who introduced the well-known rice-fruit diet. Several additional investigators (Parijs et al.,1973; Morgan et al. 1978; Gillum et al., 1981; Beard et al., 1982; MacGregor et al., 1982a) have reported that moderate sodium restriction (1600-2000 mg/d) significantly reduced blood pressure by approximately 8 to 10 mm Hg systolic and/or 4 to 6 mm Hg diastolic in mild hypertensives. Furthermore, the sodium restriction allowed substantial reductions in antihypertensive drug requirement (Parijs et al., 1973). Silman et al. (1983) noted that the blood pressure-lowering effect of sodium restricted diets may be related to increased consultation and monitoring activity, rather than to the dietary manipulation itself. Their conclusion was based on a study on blood pressure in which the effect of sodium restriction was compared

with that of health education alone. After 12 months, blood pressure fell equally in both treatment groups, despite significant differences in mean sodium intake.

Although results of clinical trials have been inconsistent, sodium restriction alone or in combination with drug therapy, has been recommended in the treatment of hypertension (Committee on Sodium Restricted Diets, 1979). However, difficulties in compliance, i.e., acceptance of low-sodium foods and long-term adherence, have been reported as major obstacles to effective treatment (Kris-Etherton et al., 1982; Borhani, 1982).

Based on the lines of evidence outlined above, several authorities have recommended moderate reductions in sodium intake by the U.S. population at large (Dahl, 1972; Freis, 1976; Tobian, 1979; Select Committee on Nutrition and Human Needs, 1977; Food and Nutrition Board, 1980a; Select Committee on GRAS Substances, 1978; American Medical Association, 1979; U.S. Dept. of Agriculture, DHEW, 1980). Recommended intakes range from 2 to 8 g of NaCl a day, including sodium naturally present in food. That such reductions are safe and will benefit the entire population by preventing the development of hypertension has been questioned by Langford (1977), Pickering (1981), Laragh and Pecker (1983) and Brown et al., (1984). However, most have agreed that present levels of sodium intake are in considerable excess of metabolic needs.

Although the actual requirement for sodium is not known, the Food and Nutrition Board of the National Academy of Sciences (1980b) has established that 1,100 to 3,300 mg sodium/day (3 to 8 g sodium chloride) is a safe and adequate intake for healthy adults. In contrast, actual

total daily sodium intake in the United States has been estimated at 4000 to 4800 mg, or 10-12 g of salt (Select Committee on GRAS Substances, 1979; Fregly, 1983). Based on salt production, sales and food analysis data, it was found that 3.5 to 4.5 g of the salt consumed derives from natural constituents in food, 4 to 6 g of NaCl is added during commercial processing, while discretionary intake, or salt added in cooking or at the table by consumers, accounts for 3.4 to 6.5 g or 25 to 50% of the total estimated NaCl intake. Others (Altschul and Grommet, 1982), have estimated discretionary salt at less than 10% of total intake. These findings indicate that in order to reduce dietary sodium to the recommended levels of intake, major changes in both food selection and salting habits are required.

To increase low sodium options in the market place, the Food and Drug Administration has recommended that industry reduce sodium in processed foods and develop low-sodium product lines (Shank et al.,1983). In addition, by June 1985, all products with nutritional labeling must declare sodium content (Federal Register, 1985).

In summary, although the salt-hypertension hypothesis is contested, the majority of the evidence agrees that sodium restricted diets may be useful in the treatment of some, but not all hypertensives, and that the general population, especially those predisposed to hypertension, may also benefit from reducing sodium intake.

B. Other dietary factors and hypertension

1. Potassium

Meneely and Battarbee (1976) proposed that a high sodium, low potassium intake, coupled with genetic susceptibility may be the most important determinants in the genesis and perpetuation of hypertension. Their argument is based on a review of epidemiologic evidence and direct clinical and experimental studies showing that potassium may have antihypertensive effects.

Cross-cultural studies have shown that hypertension-free societies with low-salt intake have higher potassium intake than industrialized, hypertension-prone populations. The greater incidence of hypertension among U.S. Blacks than Caucasians also may be due to a lower potassium intake, rather than to differences in dietary sodium intake (Langford, 1983). Recently, Khaw and Barrett-Connor (1984) found that dietary potassium intake estimated from 24-hour recalls was negatively correlated with systolic blood pressure across the entire blood pressure range in 685 Caucasian men and women (20-79 years).

In animal studies, supplemental potassium generally decreases blood pressure and/or increases survival rate in salt-sensitive rats (Dahl et al., 1972; Meneely and Battarbee, 1976). Similar responses to potassium have been observed in humans. Parfrey et al. (1981) achieved 3 to 7% reductions in blood pressure in 16 hypertensives, but not in eight normotensive adults, by administering a diet with no added salt but high in potassium (100 meq or 3900 mg K^+ as KCl tablets) for 12 weeks. Using a similar protocol, MacGregor et al. (1982b) obtained an average 4% reduction in blood pressure after only four weeks. The mechanisms

responsible for the antihypertensive effect of potassium are not clearly understood, but may include natriuresis and decreased plasma renin activity (Tannen, 1983).

Fewer data are available on potassium than on sodium intake. In 1977, 1978 and 1979, mean potassium levels in the Food and Drug Adult Market Basket Surveys were 1200, 1166 and 1214 mg per 1000 Kcal respectively, or approximately 2400 mg per day, based on a 2000 Kcal diet (Shank, 1980; Fregly, 1983). Halbrook et al., (1984) recently found that mean daily potassium intake was 3300 and 2300 mg/day for 12 men and 16 women, respectively, based on four series of 7-day food records.

2. Overweight

The association between overweight and hypertension is well recognized and has been reviewed extensively by Chiang et al. (1969). For an excellent review of the mechanisms of hypertension associated with obesity, see Dustan (1983). Larsson et al. (1981) stated that hypertension is more prevalent among overweight individuals and that even moderate obesity appears to enhance the risk of hypertension. However, as emphasized by Berchtol and Sims (1981), not every overweight individual becomes hypertensive, nor is the absence of obesity a decisive factor in the prevention of hypertension.

In clinical studies, weight loss by caloric restriction significantly lowered blood pressure (Chiang et al., 1969; Stamler et al., 1980) but the mechanisms involved remain poorly defined. Dahl (1972) argued that reductions in blood pressure with weight loss are due primarily to a concomitant decrease in sodium intake. To test this thesis, Reisen et al. (1978) studied the effect of weight loss without salt

restriction in 81 hypertensive overweight adults. All patients lost at least 3 Kg, and all but two showed a substantial reduction in blood pressure, despite liberal salt consumption. In contrast, a recent randomized, controlled, clinical trial by Fagerberg et al. (1984) showed blood pressure reductions with weight loss occurred only when combined with restriction of sodium intake. Fagerberg et al. (1984) also reported significant reductions in heart rate and urinary adrenaline excretion during the energy restricted periods, indicating changes in sympathetic nervous system activity with weight loss. The discrepancy between these studies may be the result of confounding factors such as differences among subjects in age, severity of overweight and hypertension, distribution of body fat, level of compliance to the dietary regimen and genetic susceptibility to sodium-sensitive hypertension.

Although the extent to which the antihypertensive effect of a low calorie diet is independent of reduced sodium intake is controversial, weight loss has been recommended as the initial step in the treatment for many hypertensive patients who are above ideal weight (Tobian, 1979; Stamler et al., 1980).

3. Other Dietary Factors

Relatively new areas of nutrition research are bringing other dietary factors to light as potentiel contributors to blood pressure control. Calcium, (McCarron et al., 1982, 1984; Belizan et al., 1983), magnesium (Altura et al., 1984), polyunsaturated fats (Iacono et al., 1983) and chloride (Kurtz and Morris, 1983; Whitescarver et al., 1984) are among several nutrients currently under investigation. As with sodium, potassium and weight, examination of these nutritional factors

shows an increasingly complex relationship between diet and the development of hypertension. In addition to diet, personality i.e., type A (aggressive, cynical, hurried) or type B (relaxed, unhurried, trusting) (see Stone, 1984), exercise habits and response to psychological stress (Light et al., 1983) are thought to affect blood pressure.

C. Relationship Between Dietary Sodium Intake and Taste Perception of Sodium Chloride

The relationship between sodium intake and taste responses to salt may have some bearing on the feasibility of altering the diet for the treatment and prevention of hypertension. Taste responsiveness to various salts has been studied in physiologic states of need and non-need, in both animals and humans.

Sodium deficiency in rats, produced by adrenalectomy (Ritcher, 1936; Carr, 1952) peritoneal dialysis (Falk, 1966) or sodium-free diets (Contreras et al., 1975) has been shown to cause increased "salt appetite" or salt intake of both low and high concentrations of sodium chloride solutions. Similar behavior has been observed in wild herbivores, birds, sheep and other ruminants suffering from varying degrees of sodium deprivation (as reviewed by Denton, 1982).

Contreras and Frank (1979) and Contreras et al. (1984) have found neurophysiological evidence for these changes in consummatory behavior. Electrophysiological recordings from the chorda tympani of the rat showed that after salt deprivation, responses from whole nerve and sodium-best fibers to very high suprathreshold concentrations of NaCl were smaller, while responses to threshold concentrations did not

change. Stimulus response functions for sucrose, HCl and quinine did not differ between salt-deprived and control animals. Contreras et al. (1984) postulated that sodium deprivation alters salt receptors simply by disuse and that the resulting decrease in sensitivity to high NaCl concentrations may be an adaptive mechanism to increase salt consumption.

Studies of salt taste in sodium-deficient humans are rare, but generally parallel animal studies. A classic case of salt craving was described by Wilkins and Ritcher (1940) in a child who was sodium deficient due to adrenal insufficiency. Although sodium intake was not measured, the child reportedly ate a teaspoon of salt a day, in addition to highly pre-salted foods. Using himself and three other volunteers, McCance (1936) experimentally induced sodium deficiency within seven days by combining extremely low sodium diets with episodes of sweating. All subjects reported generalized hypogeusia, while one experienced salt cravings.

DeWardener and Herxheimer (1958) reported increased salt consumption in two individuals forced to drink large volumes of water to induce negative sodium balance, despite the observed decrease in taste threshold for NaCl. Yensen (1959) used a protocol similar to that of McCance to induce loss of body salt in two subjects. Neither reported salt cravings or taste changes, but salt taste thresholds were significantly decreased while sensitivity to sweet, sour and bitter solutions was unchanged.

Sodium-wasting diuretics have provided means of studying the effect of moderate sodium depletion on salt taste in humans. Digiesi (1961)

and Langford et al. (1977) have reported lower salt thresholds in diuretic-treated patients. Langford et al. (1977) also noted increased salt appetite as evidenced by elevated urinary sodium excretion. It was observed that a group of 27 U.S. Black women receiving diuretics excreted significantly more sodium in a steady state than did non-treated patients ($p<0.02$). Similarly, Rock and Hall (1978) reported a 28% increase in sodium excretion in a group of Black patients after six months of thiazide therapy. Langford et al. (1977) postulated that the diuretic-treated human, like the salt-deprived rat, responds to sodium loss by increasing salt intake. However, the relation between the observed lowered thresholds and increased salt consumption is not known. Using a different approach, Levine and Chan (1983) failed to note change in sodium intake or taste preference in a group of hypertensives who were withdrawn from diuretics after five years of treatment. Salt intake, as determined by urinalysis, measured before and after four months of withdrawal from the diuretics, remained stable despite shifts that occured in sodium balance.

In an extensive review of salt hunger, Denton (1982) emphasized that the taste changes and salt appetite which follow sodium deficiency are important mechanisms in the organization of sodium homeostasis, whereas liking for salt is an appetite unrelated to need. Dahl (1960) was of the opinion that salt appetite in the non-need state is induced rather than innate, since it bears no relationship to sodium requirement. There is a growing body of evidence which suggests that moderate changes in dietary sodium intake within the non-need range, modify salt taste preferences. This was first suggested in an anecdotal report by Dahl (1960) that patients adapted to low-sodium diets within weeks and

came to prefer less salty food. Similar observations were reported by Thaler et al. (1982). Eighty participants reduced their sodium intake by one-half to approximately 1600 mg. After eight months, attitudes toward the diet varied but 87% found it acceptable. Although salt taste responses were not measured formally, participants reportedly found highly-salted foods unappealing.

Several controlled studies have sought empirical evidence for reported changes in salt preference by measuring taste responses to sodium chloride. While three independent investigators showed that taste thresholds for sodium chloride were unchanged with moderate dietary sodium restriction (Gillum et al., 1981; Bertino et al., 1981; Teow et al., 1984), preferences for salt either increased or decreased.

Gillum et al.(1981) measured sodium chloride preference in 15 middle aged Caucasians with labile blood pressure elevations, before and after a five-month intervention program aimed at lowering sodium intake to 1600 mg per day (70 meq). Peak preference ratings for salted broth and tomato juice samples fell from 98.3 to 64.6 meq/l, but failed to reach statistical significance ($p<0.10$). Teow et al. (1984) also reported decreased preference for sodium when nine normotensive young adults were changed from high to low sodium diets. In ad libitum preference tests, subjects added significantly less NaCl to salt-free tomato juice during the low-sodium diet period. However, the levels of sodium intake and duration of the diets were not specified.

In contrast, Chan et al. (1984) found no differences in perceived intensity and preference tests of salt in solution, broth and rice after ten weeks of self-monitored sodium restriction in twelve healthy young

adults. The authors speculated that the testing period was not sufficiently long for taste changes to occur, and that dietary sodium intakes, although not specified, were too low at the onset for further reductions to have an effect.

In the first of two related studies, Bertino et al. (1981) reported that three individuals maintained on low sodium diets (1700 mg/day) for three and one half weeks, rated highly salted soup as less salty and more pleasant compared to pre- and post-diet periods. However, these data should be interpreted with caution since only three subjects were tested and no statistical analyses were applied to the sensory responses. In a later, long-term study, Bertino et al. (1982) tested nine healthy young adults on self-maintained low-sodium diets for five months. Perceived intensity and preference tests for a salt concentration series in water, soup and crackers were performed periodically and compared to pre-diet responses. Perceived intensity of salt in crackers, but not in water or soup, increased, while the salt concentration of maximum pleasantness in soup and cracker samples decreased significantly within two months. No changes were noted in five controls on ad libitum salt diets. These results differed from those of their previous study. The authors postulated that there is a biphasic response to decreases in salt consumption, with an initial period of attraction to the taste of salt followed by a decrease in pleasantness. Although this hypothesis conciliates the results of their separate studies, it has not been adequately tested by recording taste responses at regular intervals, throughout the length of the dietary sodium-restriction period.

In summary, it appears that a distinction can be drawn between salt appetite which occurs in need vs. non-need states. The majority of the evidence agrees that experimentally-induced episodes of acute sodium deficiency increase the appetite for salt, while moderate reductions of salt intake generally decrease preference for salty foods over the long term. However, the pattern of taste changes with time has not been adequately defined.

D. Measurement of Dietary Sodium Intake

Methods of measuring total salt intake often are inaccurate due to the difficulty of estimating both discretionary and non-discretionary consumption.

Altschul and Grommet (1982) measured discretionary sodium intake by weighing salt shakers used by subjects before and after meals. Although simple, this method may affect spontaneous use of salt, thereby underestimating usual intake. Questions on salt shaker usage were used by Dahl and Love (1954, 1957) and later adapted by Swaye et al. (1972) to classify subjects into low-, average- or high-salt intake groups based on whether salt was never added to food at the table, added after tasting or added routinely before tasting, respectively. Dahl and Love (1954) noted several defects of this classification system, including lack of precision and failure to account for salt used in cooking. Despite these limitations, they believed that the conceptual implications of a "low" versus a "high" salt intake might be tested, provided a large number of subjects (>500) was used.

Pecore (1978) and Stone (1984) used questions relating to salt shaker usage in cooking and at the table as well as a food frequency questionnaire with numerical weightings to estimate total salt intake. Braddock (1982) expanded this method by recording the portion size usually eaten. Subjects were divided into low, medium and high intake categories according to weighted, composite scores. The validity of a food frequency questionnaire was recently tested by Mullen et al. (1984) with 31 college students. Each subject's actual intake (determined by unobtrusive observation) was highly correlated ($p<0.002$) with results of the frequency questionnaire. As emphasized by Mullen et al. (1984) and Block (1982), frequency questionnaires provide a reliable, expedient, inexpensive method for estimating and comparing usual intake of groups, but are limited by the number of food items included and their failure to account for past dietary practices.

Seven-day food records (Thaler et al., 1982; Bertino et al., 1982), three-day food records (Chan et al., 1984) and 24-hour diet recalls (Schlierf et al., 1980) also have been used to assess sodium intake. These methods are inexpensive, simple to use and provide useful estimates of other nutrients as well. However, food diaries may cause subjects to modify their normal eating habits due to increased awareness of their behavior, while 24-hour recalls may be more objective but only one day is measured. Balogh et al. (1971) compared random, repeat 24-hour recalls over a 12 month period and found that intra-subject variability was very high. Furthermore, Madden et al. (1976) and Gersowitz et al. (1978) showed that recall methods were prone to over-reporting low intakes and under-reporting high intakes, thus increasing the probability of error. As emphasized by Garn et al. (1978) and Todd et al.

(1983), 1-day diet records or recalls are adequate as a group measure but not for assessing individual intakes or assigning subjects to broad intake categories unless several random measurements are taken.

The most accurate method of assessing total salt intake is by measuring sodium excretion. Under normal circumstances, the kidneys are the sole route for sodium excretion although negligible losses occur in feces, tears and through the skin when sweating is not excessive (Moses, 1982). Urinary sodium output does not always equal sodium intake of the previous day due to wide fluctuations in intake and the delay required for balance to occur. However, when used as a group measure, or with individuals on controlled sodium diets, mean sodium excretion does not deviate from average sodium intake by more than 2 to 5 percent (Schachter et al., 1980). Based on this relationship, 24-hour urine collections have been used to estimate total sodium intake (Langford et al., 1977; Schlierf et al., 1980; Altschul and Grommet, 1982), to validate estimates obtained by other measures (Mattes, 1983) and to check compliance with sodium restricted diet protocols (Gillum et al., 1981; Bertino et al., 1982; Silman et al., 1983; Chan et al., 1984). This method is limited by laboratory expenses and difficulties encountered in obtaining complete and accurate sample collections. Cost of the analysis can be cut by using chloride titrator sticks (Luft et al., 1983), while overnight urine specimens may be used to simplify the collection procedure. Overnight sodium excretion has been found to correlate closely with corresponding 24-hour excretion, (Watson and Langford, 1979; Lui et al., 1979; Luft et al., 1982, 1983), and may be converted to a 24-hr value by means of a multiplier. Dyer et al. (1984) obtained a factor of 2.72 per eight hours, based on a study involving 50 adults.

However, as in the case of 1-day diet records, a single sodium excretion measure cannot be used to represent an individual's usual sodium intake.

In summary, although most dietary sodium intake assessment methods are useful in determining relative averages of a group, caution must be taken in estimating individual intakes or ranking subjects into low, medium or high intake categories, unless a representative number of measurements is taken.

E. Sensory Methodology

1. Preference Tests

a) Hedonic scaling: The hedonic scale, as a quantitative measure, was developed by Peryam and Girardot (1952) who used a nine-point category scale of like/dislike. Numerical scales have been criticized for their finite end-points and because the intervals are of unequal psychological width (Moskowitz and Sidel, 1971). Unstructured or graphic line scales, where judges mark a continuous line anchored at both ends, have been used to partially alleviate the latter deficiency (Giovanni and Pangborn, 1983; Braddock, 1982; Mattes, 1983).

Because of wide intersubject variability in taste preferences (Ekman and Akesson, 1964; Pangborn, 1970, 1981), hedonic functions derived from group averages may be misleading or altogether artificial. For example, in studies in which increasing concentrations of salt in broth (Stone, 1984), sucrose in lemonade (Sontag, 1978; Stone, 1984), or sucrose in water (Pangborn, 1970) were rated for degree of liking, individual subjects generally followed one of at least three distinct patterns of response: "uppers", or subjects preferring the most concen-

trated stimuli, "peakers", or subjects preferring mid-range concentrations and "downers", those preferring the least concentrated solutions. Mean hedonic functions, however, peaked at mid-range concentrations.

Other limitations of hedonic scaling include exposure and context effects. Repeated exposure to unfamiliar foods or stimuli may cause pleasantness ratings to increase, reflecting an enhancement of the subject's attitude toward the product (Murphy, 1982). Context effects are defined as shifts in preference ratings depending on the frequency with which stimulus concentrations occur in a series i.e., low concentrations are judged more pleasant in the context of many low concentrations than when presented with higher concentrations (Riskey, 1980). Heredity may also play a role in the development of taste preferences, but it's relative contribution is poorly defined (Greene et al., 1975). For a further review of taste hedonics, see Moskowitz and Sidel (1971) and Sontag (1978).

b) Ad Libitum Mixing: Also called the method of adjustment, ad libitum mixing has been used in experimental psychology to match the perceived intensity of a standard stimulus (Stevens, 1951). This method was first applied to sensory analysis by Woskow (1967) to determine the taste sensitivity of prospective subjects or to investigate the effect of additives on flavor intensity. For a review of the advantages and limitations of the ad libitum procedure, see Pangborn (1984).

Ad libitum mixing has been used as a measure of preference for sweetness in lemonade (Stone, 1984), saltiness in tomato juice (Bartoshuk et al., 1974; Lauer et al., 1976; Pangborn and Pecore, 1982; Mattes, 1983; Teow et al., 1984) saltiness in broths (Braddock, 1982;

Stone, 1984) and fatness in milk (Pangborn et al., 1985). Subjects are allowed to mix a low- and a high-intensity stimulus until the desired strength of taste is achieved. The resulting mix is then analyzed to determine the concentration of the stimulus of interest. In the case of NaCl, the sodium content of the mix is analyzed by electrical conductivity (Mattes, 1983) or by atomic absorption (Braddock, 1982; Pangborn and Pecore, 1982; Stone, 1984).

In independent studies of university students, Braddock (1982) and Stone (1984) found that the preferred level of NaCl in broths by ad libitum mixing was highly correlated ($p<0.001$) with peak preference ratings for salt by hedonic scaling of concentration series. These findings confirmed the usefulness of the ad libitum procedure as a preference measure. In addition, Stone (1984) found that both preference measures were significantly correlated with dietary sodium intake. However, results from earlier studies on similar populations either did not support this relationship (Braddock, 1982) or were inconclusive (Pangborn and Pecore, 1982).

2. Intensity Scaling

Intensity scaling is used as a quantitative measure of the perceived strength of a stimulus, such as brightness of colors or concentration of taste and odor compounds (Amerine et al., 1965).

As emphasized by Sontag (1978), intensity judgements, although less variable than hedonic judgements, are not immune to attitude and scaling biases. Although generally linear, individual intensity functions vary slightly in slope and range across concentrations. Variations in general form or alterations over time have not been shown to occur unless

perceptual abilities have changed.

Scoring of the perceived intensity of a stimulus, on structured or unstructured scales, has been used to evaluate the effects of flavor, color or texture additives on sensory properties of foods, and in clinical studies to examine perceptual differences between control and test populations. In the latter case, intensity scaling has been used to study lean vs. obese individuals, using concentration series of cream in milk (Pangborn et al., 1985; Drenowski et al., 1983), sucrose in milk (Drenowski et al., 1983) and sucrose in fruit drinks (Witherly, 1978; Rodin et al., 1976). Hypertensive vs. normotensive subjects also have been examined using intensity scaling of salt series in tomato juice or cooked rice (Mattes, 1983), while anorectic vs. nonanorectic cancer patients have been compared using scaling of sweet, sour, salty and bitter stimulus in model food systems (Trant et al., 1982). No differences in intensity judgements of the stimuli of interest were found between control and test participants in any of the above studies.

Other investigations have sought relationships between diet and perceived intensity of a stimulus. Pangborn and Pecore (1982) compared low-, medium- and high-sodium intake groups and found no significant difference in intensity judgements of salt in tomato juice. Dietary sodium restriction has been shown to either increase (Bertino et al., 1982), decrease (Bertino et al., 1981) or not affect (Chan et al., 1984) the perceived saltiness intensity of selected test products.

METHODS AND MATERIALS

This research was conducted as an ancillary study of the Hypertension Prevention Trial (HPT) supported by the National Heart, Lung and Blood Institute. The HPT is a two-year, randomized, unmasked, controlled clinical trial designed to test the hypothesis that alterations in intake of sodium, potassium and energy would affect the level of blood pressure in healthy, non-hypertensive adults.

The present ancillary study was designed to determine the effect of a sodium-restricted diet on salt taste responses in HPT participants.

A. Design of the Hypertension Prevention Trial

1. Participants

Table 1 lists the main eligibility and exclusion criteria used for participant recruitment in the HPT. The recruitment phase involved three "baseline" clinic visits for screening and data collection. Questionnaires were used to obtain demographic data and baseline information on salting habits and knowledge about sodium. Weight ($\pm$ 1 lb) and height ($\pm$ 1 in.) were measured without shoes or outdoor garments on an approved, balance-beam scale with measurement rod. Blood pressure was taken by certified technicians, using a Hawksley random-zero sphygnomanometer, according to HPT protocol. Two blood pressure measurements were recorded at each baseline visit. Eligible screenees were randomly assigned to either a control or to one of four dietary intervention treatment groups.

2. Dietary Intervention Groups

The four HPT dietary intervention treatments were low-sodium diet

TABLE 1. Major HPT inclusion and exclusion criteria for participants.

INCLUSION CRITERIA	EXCLUSION CRITERIA
- Age 25 through 49	- Evidence of hypertension, cardiovascular disease or diabetes
- Initial diastolic blood pressure ≥ 76 but < 100 mmHg[1]	- Abnormal electrocardiogram, lab results
- Qualifying diastolic blood pressure ≥ 78 but < 90 mmHg[2]	- Gross obesity: QI[3] ≥ 0.05 lb/in^2
- Informed consent	- Special dietary requirements
	- Pregnancy
	- Heavy alcohol user: > 3 drinks/day
	- Uncooperative behavior
	- Inability to comply with diet regimen or visit schedule

[1]Mean of two blood pressure readings at first and second baseline clinic visits.

[2]Mean of two blood pressure readings at third baseline clinic visit.

[3]QI = Quetelet Index, weight (lb)/height(in)^2.

(NA); low-sodium, high potassium diet (NK); low-sodium, weight loss diet (NW) and a weight loss diet alone (WT). Specifics of each diet are shown in Table 2. Dietary counseling was provided by HPT nutritionists. All participants except controls attended weekly group meetings for the first ten weeks of the trial, then at two week intervals for one month, then bi-monthly throughout the first year. Participants were asked not to change their dietary habits between meeting 1 (Week 0) and meeting 2 (Week 1) in order to establish their baseline sodium, potassium or caloric intake. Subsequent intervention meetings provided guidelines for shopping, cooking and eating out as well as a support system (goal setting, rewards, group activities) designed to help participants achieve and maintain specific dietary goals.

3. Dietary Intake Assessment

Participants kept seven-day food records for the first 10 weeks of the trial to self-monitor adherence to their diets. These records were reviewed by the staff nutritionists. For official data analysis, the level of compliance to the assigned dietary regimen was assessed via single, random-day, 24-hr food records and analysis of a corresponding overnight urine sample obtained at approximately weeks 0 (baseline), 12, 24 and every six months thereafter. Urinary sodium, potassium and creatinine were analyzed blindly by the HPT Central Laboratory (Oakland, CA). The 24-hr food records were reviewed by HPT personnel with each participant, for accuracy and completeness. A second independent review was conducted by another staff member before the records were shipped to the HPT Central Food Coding Center (Pittsburg, PA) for analysis. Participants and the HPT staff nutritionists were blind with respect to results of these analyses.

TABLE 2. HPT dietary treatment groups and goals.

DIETARY TREATMENT GROUP (CODE)	GOALS	ELIGIBLE WEIGHT STRATA[1]
Sodium restriction (NA)	- 1600 mg (70 mEq) Na^+/day	N and H
Sodium restriction Potassium supplementation (NK)	- 1600 mg (70 mEq) Na^+/day 3200 mg (80 mEq) K^+/day	N and H
Sodium and caloric restriction (NW)	- 1600 mg (70 mEq) Na^+/day Achieve "normal" body weight	H stratum only
Caloric restriction (WT)	- Achieve "normal" body weight	H stratum only

[1]N denotes normal weight stratum and H denotes high weight stratum.
H = Quetelet Index ≥ 0.0356 for men and ≥ 0.0328 for women.

B. Materials and Methods of the Ancillary Study

1. Participants

The University of California, Davis (UCD), and the University of Minnesota, Minneapolis (UMN), were the two HPT centers participating in the ancillary study. A total of 76 volunteers were recruited at both sites. These included 56 "diet" participants (15 women, 41 men, aged 25-48 years), selected from among the NA, NK, NW, and WT dietary intervention groups, and 20 "controls" (7 women, 13 men, aged 22-47) selected from among individuals screened for the HPT but ineligible for randomization into the trial. All participants read and signed an informed consent (Appendix I and II), but were not aware that the purpose of the ancillary study was to examine salt taste perception.

Controls were requested not to modify their eating habits, thereby serving as a true "no diet change" control group. Although participants in the weight loss group were not instructed or required to reduce their dietary sodium intake, they were included to serve as a "treatment control" and to allow the examination of the effects of weight loss alone on salt taste response.

Demographic and sodium intake data concerning the NA, NK, NW and WT subjects were extracted directly from HPT data files, in consultation with the HPT Data Coordinating Center. Since comparable information concerning Controls was not on file, a questionnaire (Appendix III) concerning age, height, weight, ethnic origin, education, occupation, meals eaten away from home, salting habits and knowledge about sodium was adapted from official HPT forms and administered to all CN participants.

2. Sodium Intake Assessment

Controls were instructed to complete a random-day, 24-hr food record and collect a corresponding overnight urine sample at baseline (week 0) and at approximately 12 and 24 weeks from baseline in the manner described previously for the dietary treatment group participants (Appendix IV). The food records and urine specimens were processed for analysis by HPT technicians according to HPT protocol. Urine was analyzed for sodium and creatinine excretion by the HPT Central Laboratory, while food records were analyzed for sodium, potassium, calcium and caloric intake by the HPT Central Food Coding Center. Food record and urine sample analyses at weeks 0, 12 and 24 for NA, NK, NW and WT participants were provided by the HPT Data Coordinating Center.

3. Tasting schedule

Participants were tested over a six-month period as specified in Table 3. Slight variations in timing of the tests occurred due to group cancellations, official holidays, changes in HPT protocol or organizational differences between UCD and UMN. Two groups were tested. The first group (UCD only), involving 14 diet and 4 control subjects was tested from June to November, 1983. The second group (UCD and UMN), involving 42 diet and 16 control subjects was tested from October, 1983 to April, 1984.

All participants were tested between 6:00 and 9:00 pm. Diet subjects were tested immediately prior to or following their previously scheduled group intervention meetings. Tests were conducted at the UCD-HPT and UMN-HPT laboratories. Individual booths were temporarily constructed in rooms where interruptions and distractions could be kept

TABLE 3. Tasting schedule at UCD and UMN[1] study sites by diet group[2].

DIET GROUP	(n)	TEST SESSION NO. 1	2	3	4	5	6	7	8
		Weeks from baseline[3]							
UCD:[4] NA	(18)	0	1	3	5	7	9	12	23
NK		0	2	4	6	8	11	--	23
NW		0	2	4	6	8	11	--	23
WT		0	2	4	6	8	11	--	23
CN		0	2	4	6	8	10	13	24
UCD:[5] All groups	(32)	0	1	3	6	8	10	13	24
UMN:[5] All groups	(26)	0	1	3	6	9	10	14	24

[1]UCD, UMN refer to University of California, Davis and University of Minnesota, Minneapolis.

[2]NA, NK, NW, WT, CN refer to low sodium, low sodium-high potassium, low sodium-weight loss, weight loss and control, respectively.

[3]Baseline = week 0.

[4]Tested from June-November 1983.

[5]Tested from October 1983 - April 1984.

to a minimum. Rooms were illuminated with white, fluorescent light and the ambient temperature was kept at 21± 2°C.

4. Sensory Methodology

All sensory methods and procedures were developed and standardized at UCD. A manual of operations, which provided detailed, written instructions, was developed to assure uniformity of data collection between the UCD and UMN Centers. In addition, two UMN-HPT technicians participated in a two-day training program at UCD prior to initiation of the study in Minneapolis.

a) Materials

The test medium used throughout the study was an unsalted, cream of green bean soup, containing approximately 40 mg of naturally occuring Na^+ per 100 g. The soup base was prepared by blending 300 ± 1 g of canned, drained, "No Salt Added" green beans (Del Monte Corp., San Fransisco CA) with 400 ± 1 g of homogenized whole milk at a standardized speed for 90 seconds. Soup was heated to 60 ± 5°C in stainless steel pots and simmered with occasional stirring for 20 minutes. A concentration series of 0.0, 0.1, 0.2, 0.35, 0.55, 0.8, 1.1 and 1.5% added NaCl (w/w) was prepared by weighing reagent grade NaCl (Mallinckrodt Inc., Paris, KY) to ± 0.01g and adding to pre-weighed portions of unsalted soup base. Two of the highest NaCl samples, 0.8 and 1.1%, approximated the concentration of commercial, salted cream soup (0.8-1.15% NaCl). The NaCl concentration series was chosen by six laboratory personnel to range from slightly to extremely salty, and was pre-tested on four UCD-HPT employees. Soupd were stored at 5± 2°C in covered, labeled plastic containers and used within five days. Aliquots of each concentration were reserved for future sodium analysis.

b. Sensory Methods

Participants completed each of three sensory tests at every session, in the following order: ad libitum mixing, hedonic scaling and saltiness-intensity scaling. Detailed verbal instructions were given during the first session and written instructions were provided on all ballots (Appendix V, VI).

i) Ad Libitum Mixing: Samples containing 0.0 and 1.5% added NaCl were used for the ad libitum mixing test. At UCD, 40-ml portions were poured into 80-ml, opaque blue glasses. Glasses were covered with aluminum lids and placed in heated water baths (60± 2°C) approximately 30 min. prior to serving. Subjects received a white enameled tray containing the 0.0% NaCl sample labeled "C" (Control), the 1.5% NaCl sample labeled "E" (Experimental), an empty 50-ml clear glass beaker and a spoon for mixing.

At UMN, soupd were first heated to 75 ± 2°C, then poured into 150-ml styrofoam "squat" cups. Cups were covered with coded, plastic lids and served within 10 minutes. Pre-heating to this temperature allowed for a loss of approximately 1.5°C/min. between pouring and serving, such that samples were served at 60 ± 2°C.

Subjects rated the "C" and "E" samples on a 10-cm unstructured, graphic line scale (Appendix V) anchored at the mid-point with "Neither like nor dislike", and at the ends with "Dislike extremely" and "Like extremely". Next, subjects mixed portions of "C" and "E" into the empty beaker or cup until a mixture to their liking was achieved, then rated their "MIX" using the same hedonic scale. Subjects were provided with water for oral rinsing between samples and a plastic cuspidor for

expectoration.

At UCD, an aliquot of each subject's "MIX" was poured into a 60-ml polyethylene bottle (Nalgene, Inc., Rochester, NY) and frozen at 0 ± 1°C. Sodium analysis of the mix was performed within two weeks.

At UMN, aliquots were poured into 10-ml polyethylene vials and stored at -20 ± 2°C until all subjects had completed the session, usually within a 5-day period. Frozen vials were then packed in a styrofoam container with newspaper and a blue ice-pack and sent to UCD by express mail for sodium analysis. Samples were received within 48 hours. This shipping procedure was pre-tested and found to maintain the samples sufficiently cold (10± 2°C) to avoid spoilage. The UMN samples were kept at 5 ± 2°C and analyzed within four days of receipt.

ii) Hedonic and Saltiness Intensity Scaling: Seven concentrations were used for the hedonic and saltiness-intensity scaling tests: 0.0, 0.1, 0.2, 0.35, 0.55, 0.8 and 1.1% added NaCl. Soups were heated according to the procedures described for the ad libitum mixing test. Samples of 30 ml were poured into 80-ml blue glasses (UCD) or 150-ml styrofoam cups (UMN), covered, coded with random three-digit numbers and served in randomized order at 60 ± 2°C. At UCD, participants received the set of seven samples in a specially-designed styrofoam block. At UMN, the samples were presented in aluminum muffin trays.

For the hedonic test, samples were rated using the 10-cm scale described previously (Appendix VI). Upon completion of the test, participants signaled the experimenter, the hedonic ballot was removed and the subject received the saltiness-intensity ballot (Appendix VI). The

same set of samples was then rated on a 10-cm unstructured graphic line scale, anchored at the ends with "extremely salty" and "no saltiness".

5. Sodium analysis

Sodium content of the ad libitum mixes was analyzed using a sodium ion-selective electrode (Model IS-46, Lazar Research Lab., Los Angeles, CA) in conjunction with a reference electrode (Model 90-01, Orion Research Inc., Cambridge, MA) and an Orion 601A pH/millivolt meter. Operating conditions for the electrode and meter are listed in Appendix VII. The method of analysis used was adapted from procedures recommended by the Association of Official Analytical Chemists (AOAC, 1975) and operating instructions provided with the sodium electrode.

A separate standard curve was prepared for each analysis. Standards consisted of aliquots of the NaCl concentration series reserved from each session. The UMN standards were mailed to UCD, along with the ad libitum mixes, according to the protocol described previously.

All samples required dilution with a total ionic strength adjuster buffer (TISA). The TISA was prepared by dissolving 66.37 $\pm$ 2 ml (0.5M) triethanolamine (Aldrich Chem. Co., Inc., Milwaukee, WI) in 900 ml deionized distilled water, adjusting the pH to 10.2 with concentrated KOH (J.T. Baker Chem. Co., Phillipsburg, NJ) and completing to 1000 ml with deionized distilled water. Standards were brought to room temperature and diluted 1:10 (w/w) with the TISA buffer in 50-ml pyrex beakers. Electrodes were immersed in each standard, and a millivolt (mV) reading recorded after 60 seconds. A stirring bar and plate (Mag-Mix, Chicago, IL) were used to agitate samples at a standard rate during the recordings. Electrodes were rinsed liberally with the TISA buffer and blotted

dry between samples. Each standard was tested twice, and the mean of the readings (± 1 mV) used to construct a standard curve (mV vs % added NaCl). Polynomial and power function regressions were applied to the data coordinates using a Hewlett Packard 9815A programmable calculator. The curve of best fit, based on the coefficient of correlation, was used to determine the concentration of the unknown samples.

Ad libitum mix samples were diluted 1:10 (w/w) with the TISA buffer in 50-ml pyrex beakers. Two mV readings, several minutes apart, were recorded under the conditions described above. If the two readings differed by more than 2 mV, a third reading was taken. Sodium content of the mix, expressed as percent added NaCl, was determined by entering the mean mV reading of each sample into the appropriate regression equation.

6. Data Analysis

Data analyses were performed on campus facility Burroughs 6800 and Vax/Vms computers, using BMDP Biomedical Computer Programs (BMDP Statistical Software Inc., Los Angeles CA) and SAS Statistical Analyses System (SAS Institute Inc., Cary NY) software packages. Due to a limited number of absences at the test sessions and to missing food records and/or urine samples, the SAS General Linear Model (GLM) program for unbalanced designs, was used to perform all analyses of variance (ANOVA). Table 4 outlines test session attendance by UCD and UMN participants, by diet group. Twenty subjects missed one, while two subjects missed four of the eight scheduled tests and eleven UCD subjects were not tested at session 7 (week 14) due to schedueling conflicts.

Hedonic and saltiness-intensity ratings were obtained by recording the distance in centimeters from the bottom anchor of the vertical 10 cm

TABLE 4. Test session attendance subdivided by diet group[1] and study site[2].

DIET GROUP	STUDY SITE	TEST SESSION (WEEK)							
		1(0)	2(1)	3(3)	4(6)	5(8)	6(10)	7(13)	8(24)
NA	UCD	5	9	8	9	9	8	9	7
	UMN	6	6	6	6	6	6	6	6
	TOTAL	11	15	14	15	15	14	15	13
NK	UCD	12	11	11	10	10	11	6	12
	UMN	3	3	3	3	3	3	3	3
	TOTAL	15	14	14	13	13	14	9	15
NW	UCD	9	8	9	8	9	9	4	8
	UMN	4	4	4	4	4	4	3	4
	TOTAL	13	12	13	12	13	13	7	12
WT	UCD	8	8	8	7	7	8	7	8
	UMN	5	5	5	4	5	5	5	5
	TOTAL	13	13	13	11	12	13	12	13
CN	UCD	12	12	12	12	10	12	11	12
	UMN	8	8	8	8	8	6	8	8
	TOTAL	20	20	20	20	18	18	19	20
All[3]	TOTAL	72	74	74	71	71	72	62	73

[1]NA, NK, NW, WT, CN refer to low sodium, low sodium-high potassium, low sodium-weight loss, weight loss and control groups, respectively.

[2]UCD, UMN refer to University of California, Davis and University of Minnesota, Minneapolis.

[3]Maximum number of subjects = 76.

scales. The resultant scores were used as dependent variables in analyses of variance models. Three ANOVA models were used to examine variation both within and among treatment groups during the course of the eight-session, 24-week study. The first, a repeated measures, nested ANOVA model, was applied to each of the five treatment groups to compare the two study sites, UCD and UMN, across weeks. Subjects were nested within sites and the test source for the site main effect was the mean square term for subjects. The appropriate test source for other main effects and interactions were also specified. Non-significant site main effects and site by weeks interactions were used as criteria for pooling the data across sites for all further analyses.

A second repeated measures ANOVA model was applied to test for differential responses among the three sodium-restricted treatment groups, NA, NK and NW across weeks. Subjects were nested within diets and the test source for the diet main effect was the mean square term for subjects. Data for the three low-sodium groups were pooled, wherever possible, based on non-significant diet by week interactions. A third ANOVA model, a standard one factor, completely randomized design, was applied to compare treatment groups at each test week. Means were compared *a posteriori* using the Bonferroni multiple comparison procedure.

RESULTS

A. Characteristics of Participants

A summary of pertinent demographic information, collected on all participants at baseline, is presented in Table 5, by diet group assignment. Mean age and Quetelet Indices (weight/height^2) did not differ across treatment groups. The ratio of women to men was lower in both weight loss groups, NW and WT, than in the other diet groups. The percentage of individuals who responded correctly to five multiple choice questions (Appendix III) concerning sodium content of commonly eaten foods, was similar across groups.

B. Dietary Intake

1. Homogeneity between UCD and UMN

Dietary intake of sodium, potassium, energy and sodium per 1000 Kcal, derived from the 24-hour food records collected at baseline (week 0) and at approximately 12 and 24 weeks of the study, did not differ across the two test sites, UCD and UMN, as shown by the nested analyses of variance for the NA, NK, NW (Table 6), WT and CN (Table 7) groups. Similarly, no significant site differences were found within diet groups, for urinary sodium excretion measures (expressed as mEq Na+/g creatinine) based on overnight urine collections. Pooling of the non-significant interactions did not change the level of significance of main effects. Therefore these data will be presented pooled across sites, for comparisons over time and among diet groups.

2. Energy Intake

Figure 1 illustrates mean energy (Kcal) intakes at baseline, week

TABLE 5. Characteristics of participants at baseline, subdivided by diet group[1] (UCD and UMN[2] participants).

DIET GROUP	n	AGE $\bar{x}$±S.D.	SEX		QUETELET INDEX[3]		SODIUM KNOWLEDGE[4] % CORRECT RESPONSES
			%MALE	%FEMALE	MALE	FEMALE	
NA	15	37.3±7.4	60	40	0.038	0.035	40.0
NK	15	39.1±5.1	67	33	0.041	0.037	46.6
NW	13	40.3±6.8	85	15	0.041	0.042	44.6
WT	13	39.8±6.0	85	15	0.041	0.035	44.6
CN	20	35.7±7.0	65	35	0.037	0.031	49.0

[1]NA, NK, NW, WT, CN refer to low sodium, low sodium-high potassium, low sodium-weight loss, weight loss and control groups, respectively.

[2]UCD and UMN refer to University of California, Davis and University of Minnesota, Minneapolis.

[3]Weight (lb)/height (in)^2.

[4]Refers to percent correct responses to five multiple choice questions concerning sodium content of commonly eaten foods (Appendix III).

TABLE 6. Degrees of freedom (df) and calculated F-ratios for the nested analyses of variance of intake and excretion data[1] of UCD and UMN[2] low sodium (NA), low sodium-high potassium (NK) and low sodium-weight loss (NW) diet groups at weeks 0, 12 and 24.

SOURCE	df	TEST[3] SOURCE	Na^+/day F-RATIO	Na^+/ 1000Kcal F-RATIO	K^+/day F-RATIO	Kcal F-RATIO	Na^+/g creat F-RATIO
			NA				
Site	1	Subjects	0.08	0.007	0.45	0.29	0.39
Subjects[4]	13	Residual	1.67	2.79*	4.00**	2.43*	4.05***
Weeks	2	Residual	3.22	5.07*	0.83	0.79	4.02*
SiteXweeks	2	Residual	2.03	1.64	2.58	0.62	0.86
Residual[5]	24						
			NK				
Site	1	Subjects	0.34	0.02	0.66	0.31	0.21
Subjects[6]	13	Residual	0.60	0.56	1.75	2.42*	2.13
Weeks	2	Residual	4.45*	2.88	0.61	0.44	0.90
SiteXweeks	2	Residual	0.23	0.41	0.17	1.05	0.56
Residual	24						
			NW				
Site	1	Subjects	0.66	2.12	0.99	1.26	0.27
Subjects[7]	11	Residual	1.00	1.10	2.23*	1.22	2.16
Weeks	2	Residual	8.99**	6.49**	1.21	5.32*	13.32***
SiteXweeks	2	Residual	1.54	0.22	0.50	0.91	1.88
Residual[8]	21						

[1] Na^+, Na^+/1000Kcal, K^+, Kcal, Na^+/g creat refer to sodium intake per day, sodium intake per 1000 Kcal, potassium intake per day, energy intake per day and urinary sodium excretion per g creatinine per night, respectively.

[2] UCD and UMN refer to University of California, Davis and University of Minnesota, Minneapolis.

[3] Mean square error source used to calculate F-ratios.

[4] Excludes subject #48 at weeks 0 and 12 due to missing food records.

[5] Residual df for Na^+/g creat = 26.

[6] Excludes subject #54 at week 24 and subject #66 at week 12 due to missing food records; excludes subjects #11 and 13 at week 24 due to missing urine samples.

[7] Excludes subject #81 at week 24 and subjects #84 and 85 at week 12 due to missing food records.

[8] Residual df for Na^+/g creat = 22.

*,**,***Significant at $p < 0.05$, 0.01 and 0.001, respectively.

TABLE 7. Degrees of freedom (df) and calculated F-ratios for the nested analyses of variance of intake and excretion data[1] for UCD and UMN[2] weight loss (WT) and control (CN) diet groups at weeks 0, 12 and 24.

SOURCE	df	TEST[3] SOURCE	Na^+/day F-RATIO	Na^+/ 1000Kcal F-RATIO	K^+/day F-RATIO	Kcal F-RATIO	Na^+/g creat F-RATIO
			WT				
Site	1	Subjects	0.003	0.002	0.41	0.58	1.58
Subjects[4]	11	Residual	1.33	1.25	4.04**	1.06	1.96
Weeks	2	Residual	2.11	0.13	0.42	2.25	1.77
SiteXweeks	2	Residual	1.37	1.12	0.39	0.28	0.84
Residual[5]	19						
			CN				
Site	1	Subjects	0.12	1.68	0.40	3.78	0.08
Subjects	18	Residual	1.94*	1.30	4.15***	3.72***	2.22*
Weeks	2	Residual	1.40	0.44	1.00	1.41	0.47
SiteXweeks	2	Residual	1.68	1.94	1.03	0.07	0.27
Residual	36						

[1] Na^+, Na^+/1000Kcal, K^+, Kcal, Na^+/g creat refer to sodium intake per day, sodium intake per 1000 Kcal, potassium intake per day, energy intake per day and urinary sodium excretion per g creatinine per night, respectively.

[2] UCD and UMN refer to University of California, Davis and University of Minnesota, Minneapolis.

[3] Mean square error source used to calculate F-ratios.

[4] Excludes subject #81 at week 24 and subjects #84 and 85 at week 12 due to missing food records.

[5] df for Na^+/g creat = 22.

*,**,***Significant at $p < 0.05$, 0.01 and 0.001, respectively.

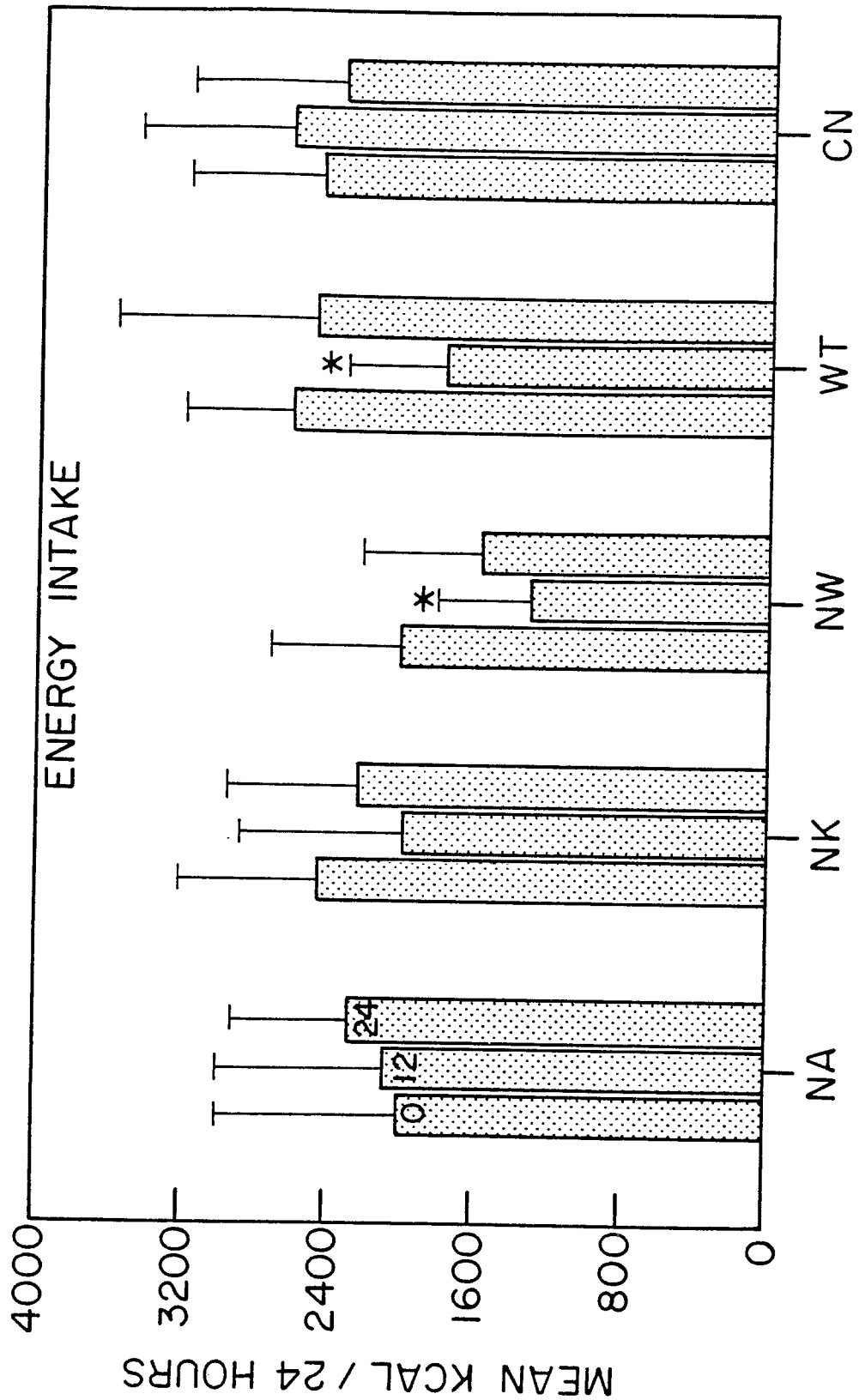


FIGURE 1. Mean energy intake of low sodium (NA), low sodium-high potassium (NK), low sodium - weight loss (NW), weight loss (WT) and control (CN) diet groups at baseline (week 0), week 12 and week 24 of study.

* Significantly different from baseline at $p<0.05$ (Bonferroni).

12 and week 24, of the five diet groups. Little variation in energy intake was observed in the NA, NK or CN groups over time. In contrast, in both weight-loss groups (NW, WT), energy intake decreased at week 12 and rose toward baseline at week 24. These changes were not unexpected as it was necessary for NW and WT diet subjects to reduce their energy intake in order to achieve the HPT weight reduction goal. Following weight loss, however, energy intake could be expected to increase to an appropriate maintenance level. Mean energy intakes by individuals in the WT and NW group were significantly lower ($p<0.05$) than baseline after 12, but not after 24 weeks of dietary intervention. Analyses of variance applied separately to the NA, NK and CN groups (Tables 6 and 7) showed that energy intake differed significantly among participants, but not over time, indicating that sodium restriction in the NA and NK groups, or participation in the study per se (CN group), did not affect calorie consumption.

3. Potassium Intake

Average potassium intake for all diet groups was 3373 mg/day at baseline, 3261 mg at week 12 and 3469 mg at week 24, intakes well above the 3200 mg/day HPT study goal specified for the NK group. Mean potassium intake varied little within or among treatment groups during the study (Table 8). Those on the low sodium-high potassium (NK) diet had slightly higher mean potassium intakes than other treatment groups at weeks 12 and 24. However, one-way analyses of variance applied separately to each time period indicated that potassium intakes did not differ across diet groups at week 0 ($F_{4,70}=0.35$), week 12 ($F_{4,67}=1.63$) or week 24 ($F_{4,70}=0.84$). Similarly, analyses of variance applied separately to each diet group (Tables 6 and 7) showed that potassium

TABLE 8. Mean (± S.D.) dietary potassium intakes subdivided by diet group at baseline (week 0), weeks 12 and 24. (Number of subjects in parenthesis).

DIET GROUP[1]	WEEKS ON DIET[2]			F[3] RATIO
	0	12	24	
NA	3429±1729 (14)	3069±1736 (14)	3559±1623 (15)	0.61
NK	3487±1555 (15)	3877±1665 (14)	4469±1922 (14)	0.48
NW	3043±1367 (13)	2715± 911 (13)	3137±1279 (12)	0.91
WT	3628±1310 (13)	3153± 907 (11)	3349±1527 (12)	0.25
CN	3279± 924 (20)	3489± 953 (20)	3336±1197 (20)	0.69

[1]NA, NK, NW, WT, CN refer to low sodium, low sodium-high potassium, low sodium-weight loss, weight loss, and control groups, respectively, from the University of California, Davis, and the University of Minnesota, Minneapolis.

[2]Means within a column do not differ significantly at weeks 0 ($F_{4,70}$ = 0.35), 12 ($F_{4,67}$ = 1.63) or 24 ($F_{4,68}$ = 0.84).

[3]F-ratio, for one-way analysis of variance, applies to means within a row.

intake also did not differ over time, as shown by the non-significant F-ratios for weeks. Variability among participants was high, as demonstrated by significant F-ratios for subjects in the NA (Table 6), WT and CN groups (Table 7), and by the relative size of the standard deviations shown in Table 8.

4. Sodium Intake

Mean daily sodium intake at baseline, as determined by the 24-hour food records, was 3490±1817 and 2375±1580 mg/day for men and women, respectively, with a range of 377-9355 mg/day. Figure 2 illustrates mean sodium intake per day and mean overnight urinary sodium excretion per g creatinine, at baseline (week 0), week 12 and week 24, by diet group. Figure 2 also presents dietary sodium as a function of energy intake (mg Na^+/1000 Kcal) to correct for the changes in caloric intake sustained in both the NW and WT intervention groups. Across time, no significant variation in sodium intake or excretion occurred within the WT or CN groups, while all three sodium measures decreased at week 12, then generally increased slightly at week 24, within the three sodium restricted groups, NA, NK and NW. Data on individual participants showed that at weeks 12 and 24 respectively, 71.4% and 61.6% of subjects on sodium-restricted diets were at or below the 1600mg/day HPT study goal.

Nested analyses of variance applied to these data for participants on a sodium-restricted diet (Table 9) confirmed that the pattern of change in sodium intake and excretion over time was consistent among the three low-sodium groups, NA, NK and NW, as indicated by the non-significant interactions of diet by weeks. Variation among individuals

was highly significant for overnight urinary sodium excretion, but not for either measure of dietary sodium intake. Pooling of these data across the sodium-restricted groups resulted in significant differences over time with sodium intake per day, sodium intake per 1000 Kcal and urinary sodium excretion significantly lower during the dietary intervention period (weeks 12 and 24) than at baseline.

As shown in Figure 2, sodium intake/day and overnight excretion of sodium/g creatinine also appeared to decrease slightly from baseline in the WT group. However, sodium intake/1000 Kcal was similar over time, indicating that the changes in sodium intake and excretion resulted from a decrease in total food intake. Analyses of variance applied separately to the sodium measures for this group (Table 7) showed no significant differences over time in sodium intake per day, sodium intake per 1000 Kcal or urinary sodium excretion.

Table 10 shows that all diet groups had similar sodium intake and excretion measures at the onset of the study, prior to dietary intervention. By weeks 12 and 24, however, one-way analyses of variance showed that participants on sodium-restricted diets (NA-NK-NW) had significantly lower sodium intakes than either WT or CN groups. Although mean urinary sodium/g creatinine excretion was also lower in sodium restricted than in WT or CN groups, the intergroup differences failed to reach significance at $p<0.05$.

Table 11 shows that dietary sodium intake, pooled over the three low-sodium groups NA, NK and NW, was significantly correlated with overnight excretion of sodium/g creatinine and that both of these measures were negatively correlated with weeks on the diet. Correlation

FIGURE 2. Mean dietary sodium intake per day and per 1000 kcal, and mean overnight urinary sodium excretion per g creatinine by low sodium (NA), low sodium-high potassium (NK), low sodium-weight loss (NW), weight loss (WT) and control (CN) diet groups at baseline (week 0), week 12 and week 24 of study.

[a]Means sharing same superscript within a diet group do not differ at $p<0.05$ (Bonferroni).

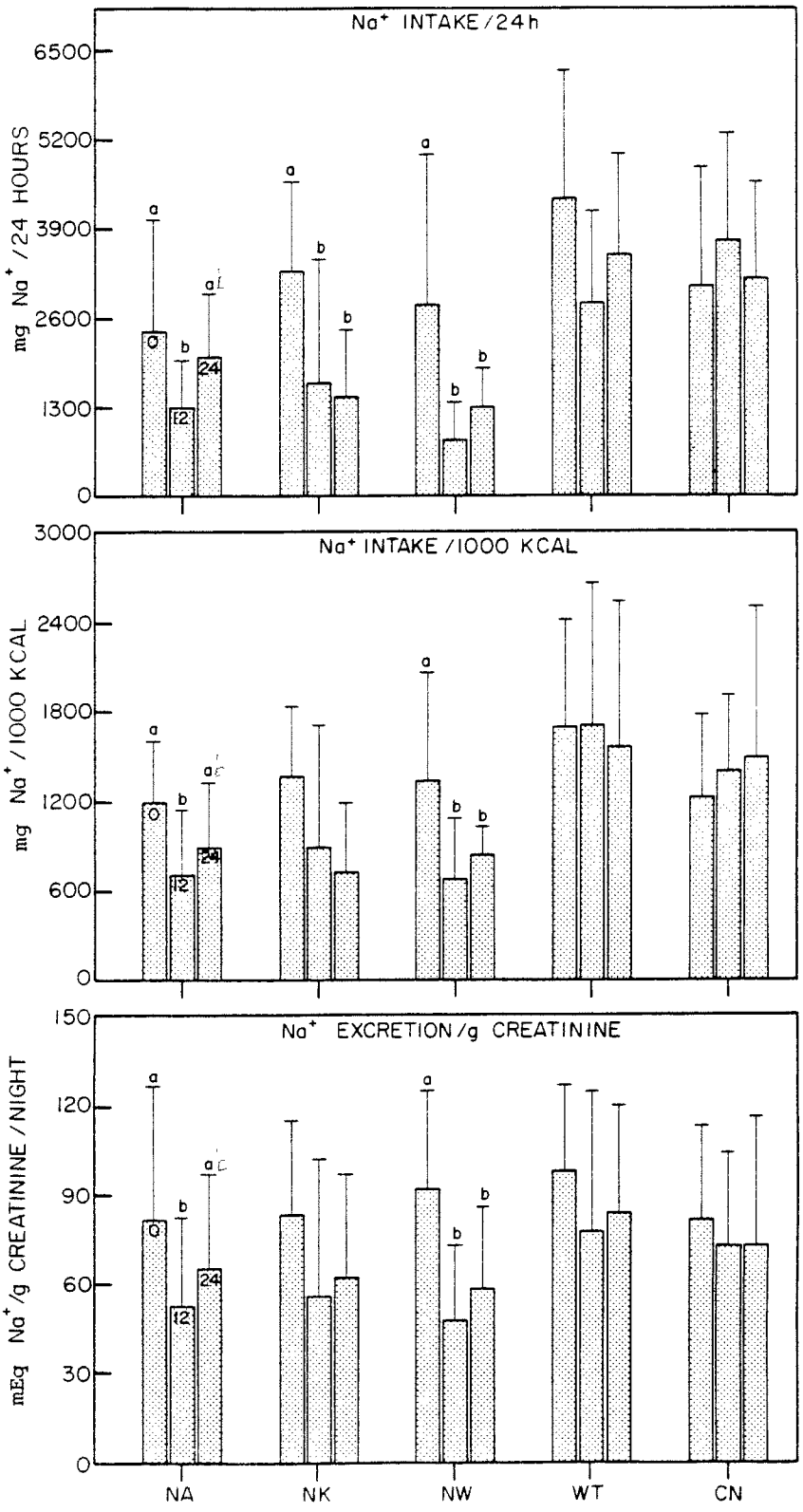


TABLE 9. Degrees of freedom (df) and calculated F-ratios for the nested analyses of variance of sodium intake and excretion data for pooled sodium-restricted diet groups (NA, NK, NW)[1], at weeks 0, 12 and 24.

SOURCE	df	TEST[2] SOURCE	Na^+/day F-RATIO	mg Na^+/ 1000 kcals F-RATIO	mEq Na^+/ g creat F-RATIO
Total	123				
Diet	2	Subjects	1.74	0.22	0.001
Subjects	40	Residual	0.89	0.98	2.59***
Weeks	2	Residual	15.64***	12.20***	16.11***
Diet X Weeks	4	Residual	1.24	0.63	0.54
Residual[3]	75				

[1]NA, NK, NW refer to low sodium, low sodium-high potassium and low sodium-weight loss diet groups, respectively.

[2]Mean square error source used to calculate F-ratios.

[3]Residual df for mEq Na^+/g creat = 78.

***Significant at $p < 0.001$.

TABLE 10. Mean (± S.D.) dietary sodium intake per day and per 1000 kcals, and mean overnight urinary sodium excretion per g creatinine by diet groups at baseline (week 0), week 12 and week 24.

VARIABLE	DIET GROUP[1]	WEEKS ON DIET[2]		
		0	12	24
Total Na^+ (mg/24 h)	NA-NK-NW	2849±1720[a]	1288±1179[a]	1636± 887[a]
	WT	4371±1852[b]	2843±1325[b]	3545±1461[b]
	CN	3094±1750[a]	3757±1465[b]	3207±1407[b]
Prob F[3]		0.03	0.0001	0.0001
mg Na^+/ 1000 kcal	NA-NK-NW	1304± 533	766± 655[a]	822± 391[a]
	WT	1707± 716	1719± 950[b]	1578± 967[b]
	CN	1238± 555	1419± 499[b]	1504±1010[b]
Prob F[3]		0.08	0.0001	0.0004
Na^+/Creatinine (mEq/g)	NA-NK-NW	85.6±36.3	52.9±34.9	62.3±31.1
	WT	98.6±28.3	78.2±46.9	84.7±32.9
	CN	82.1±31.5	73.5±31.1	73.8±42.9
Prob F[3]		0.37	0.03*	0.11

[1]NA-NK-NW, WT, CN refer to sodium-restricted, weight loss and control groups, respectively.

[2]Means sharing or having no superscripts within a column do not differ significantly at $p < 0.05$ (Bonferroni).

[3]Probability of $F_{2,72}$ by one-way analysis of variance.

*F-ratio for diets significant, however, means were not differentiated by the Bonferroni multiple comparison procedure.

TABLE 11. Correlation matrices of sodium intake and excretion measures, weeks, and concentration of ad libitum mixes[1], subdivided by diet group[2].

	WEEK	$mgNa^+$ DAY	$mgNa^+$ 1000Kcal	$mEqNa^+$ g CREAT	ad lib NaCl
NA-NK-NW (43 Ss X weeks 1, 12 & 24)					
Week	1.0				
mg/Na^+/day	-0.342***	1.0			
$mgNa^+$/1000Kcal	-0.340***	0.793***	1.0		
mEq Na^+/g creat	-0.263***	0.264**	0.226*	1.0	
ad lib NaCl	-0.358***	0.247**	0.185*	0.190*	1.0
WT (13 Ss X weeks 1, 12 & 24)					
Week	1.0				
$mgNa^+$/day	-0.217	1.0			
$mgNa^+$/1000Kcal	-0.062	0.615***	1.0		
mEq Na^+/g creat	-0.156	-0.067	-0.147	1.0	
ad lib NaCl	-0.210	0.394*	0.106	0.310*	1.0
CN (20 Ss X weeks 1, 12 & 24)					
Week	1.0				
mg/Na^+/day	0.030	1.0			
$mgNa^+$/1000Kcal	0.152	0.689***	1.0		
mEq Na^+/g creat	-0.097	0.138	0.157	1.0	
ad lib NaCl	-0.280*	0.081	0.028	0.063	1.0

[1]Only ad libitum data collected at approximately same time period as food records were used in correlations.

[2]NA-NK-NW, WT, CN refer to sodium-restricted, weight loss and control groups, respectively.

*,**,***Significant at $p < 0.05$, 0.01 and 0.001, respectively.

matrices for the WT and CN groups showed that sodium intake per day was highly correlated with sodium intake per 1000 Kcal and not with sodium excretion. Lack of correlation between dietary sodium intake and overnight urinary sodium excretion for the WT and CN groups groups is puzzling; it may be related to the small sample sizes and the high amount of variability and possibility of error in the overnight urine collections. The correlation between dietary sodium intake and NaCl concentration of the ad libitum test mixes presented in Table 11 will be discussed in a subsequent section.

C. Sensory Responses

1. Hedonic Scaling

Figures 3 and 4 illustrate the mean hedonic responses to the concentration series of NaCl in soup by each of the diet groups NA, NK, NW, WT and CN, pooled over the two study sites UCD and UMN, at five time periods from baseline to the 24th week of study. Data for weeks 0 and 1, weeks 3 and 6, and weeks 8 and 10 of the study were averaged to facilitate comparison of responses over time.

At baseline (week 0-1, bold-face solid line), hedonic response curves for the NA, NK, NW (Figure 3) and CN (Figure 4) groups approximated an inverted U-shape. Hedonic maxima or "peaks" for these groups occurred at the 0.55% NaCl concentration, with mean scores of 3.8, 4.7, 5.5 and 4.9 respectively, on the 10-cm hedonic scale. In the WT group (Figure 4), hedonic scores increased progressively with NaCl concentration, with the 0.8% NaCl sample receiving a mean rating of 4.2. One-way analyses of variance applied separately to hedonic scores for each concentration showed that hedonic responses did not differ significantly

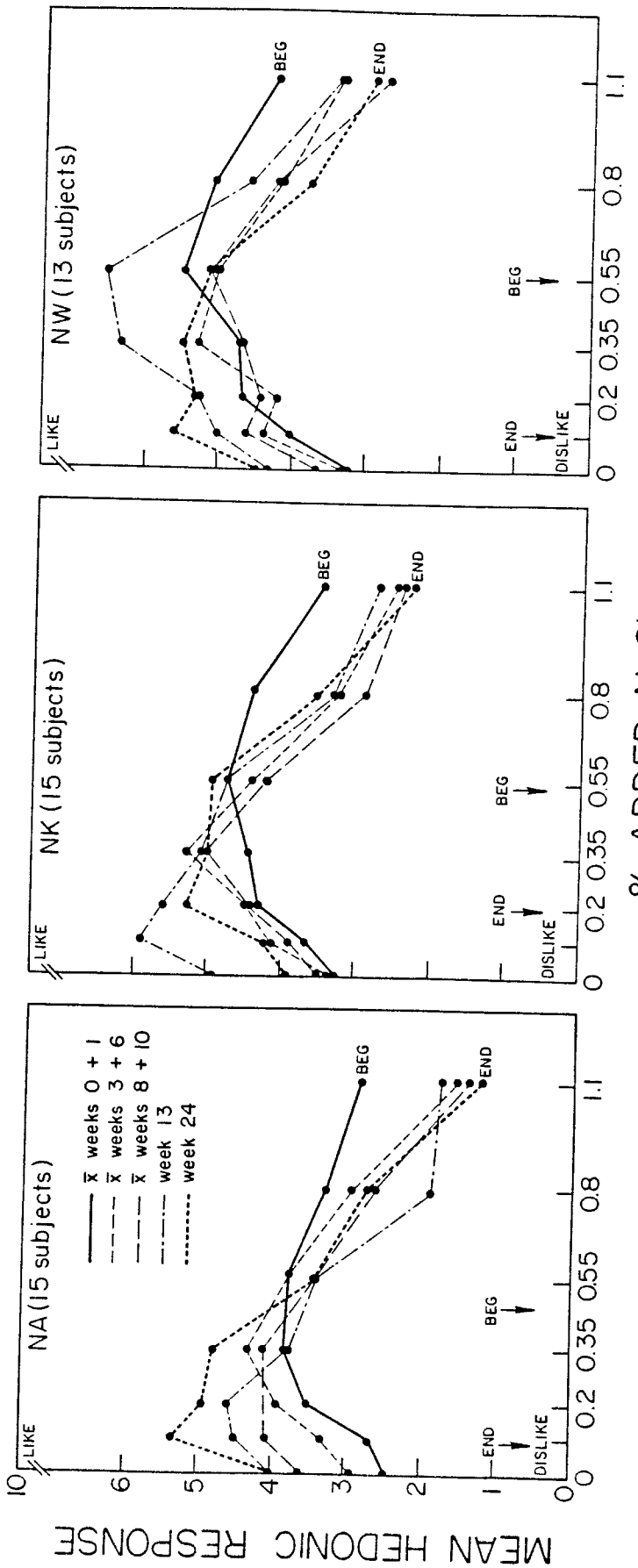
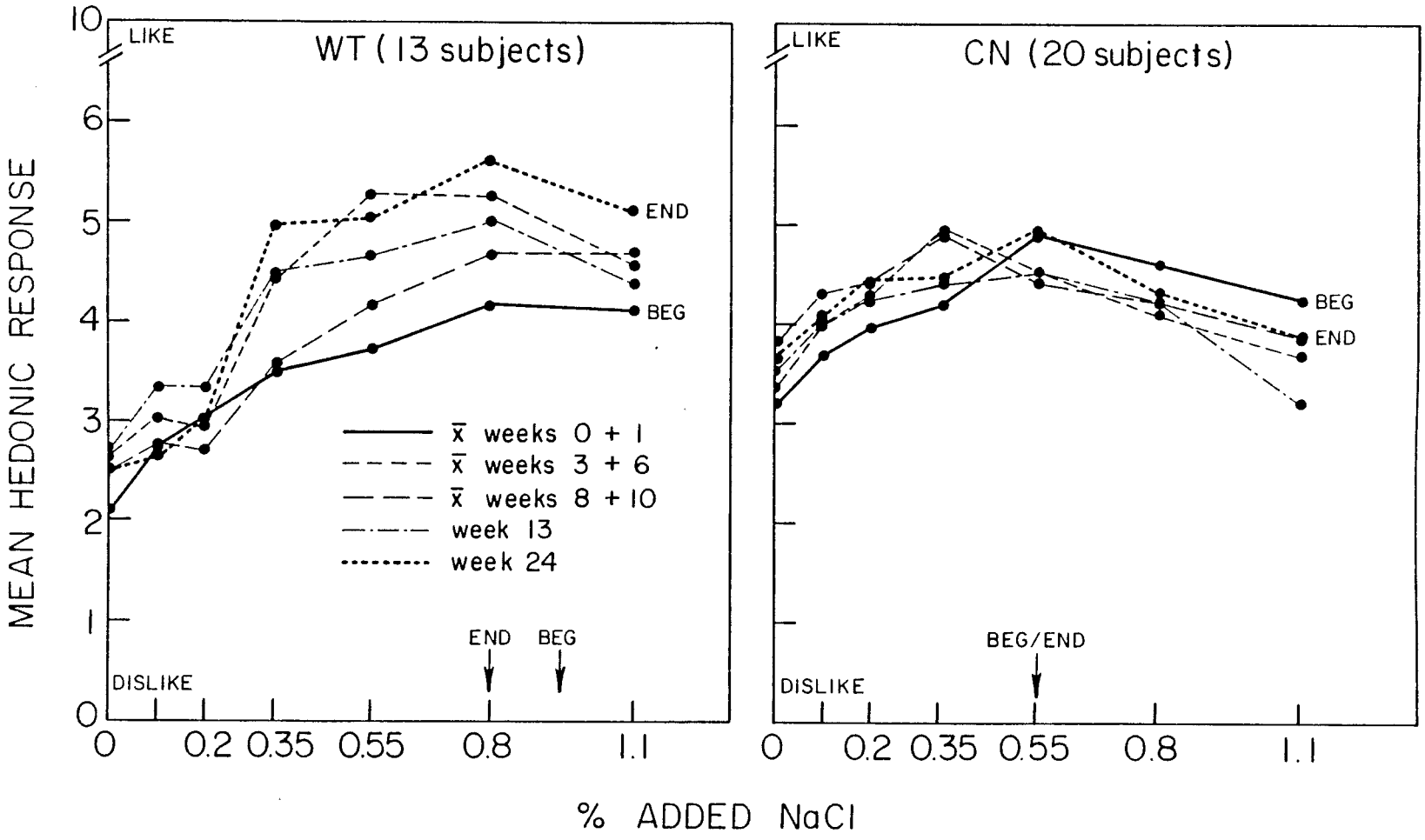


FIGURE 3. Mean hedonic responses to increasing concentrations of NaCl in soup by low sodium (NA), low sodium-high potassium (NK) and low sodium-weight loss (NW) diet groups, at intervals from the begining (BEG) to the 24th week (END) of study. Hedonic peaks shown by arrows.

FIGURE 4. Mean hedonic responses to increasing concentrations of NaCl in soup, by weight loss (WT) and control (CN) diet groups, at intervals from the begining (BEG) to the 24th week (END) of study. Hedonic peaks shown by arrows.



among the five diet groups at baseline, prior to dietary intervention.

Following initiation of the diets, similar changes in the pattern of hedonic responses to the seven NaCl concentrations were observed within the three sodium-restricted treatment groups NA, NK and NW (Figure 3). Higher NaCl concentrations received progressively lower hedonic scores, lower NaCl concentrations received progressively higher hedonic scores and the hedonic maxima occurred at lower NaCl concentrations. By the end of the experimental period (week 24, bold-face dotted line), hedonic maxima for the NA, NK and NW groups had shifted from 0.55% at baseline to 0.1, 0.2 and 0.1% NaCl respectively. In contrast, hedonic response curves for the CN group changed little across time, while in the WT group, scores attributed to all the samples tended to increase over time, especially for the higher NaCl concentrations (Figure 4).

The shift in hedonic responses observed within the sodium-restricted and WT groups, were substantiated by paired Student's t-tests applied to the difference between hedonic scores ascribed to each NaCl concentration, at the onset and at the end (week 24) of the experimental period (Figure 5). Participants on sodium-restricted diets gave significantly higher scores to the three least salty NaCl concentrations, and significantly lower scores to the most concentrated 1.1% NaCl sample at week 24 than at baseline. In the WT group, scores were significantly higher for mid-range 0.35, 0.55 and 0.8% NaCl samples, while no significant shifts were found in Controls. Furthermore, one-way analyses of variance confirmed that by week 24, hedonic scores differed significantly among the sodium-restricted, WT and CN groups, especially at the lower and higher NaCl concentrations (Table 12). Data for the three

FIGURE 5. Mean difference in hedonic response to NaCl in soup, by sodium-restricted (NA-NK-NW), weight loss (WT) and control (CN) diet groups from baseline (mean of weeks 0 and 1) to week 24.

*,*** Week 24 differs significantly from baseline, at $p<0.05$ and $p<0.001$, respectively.

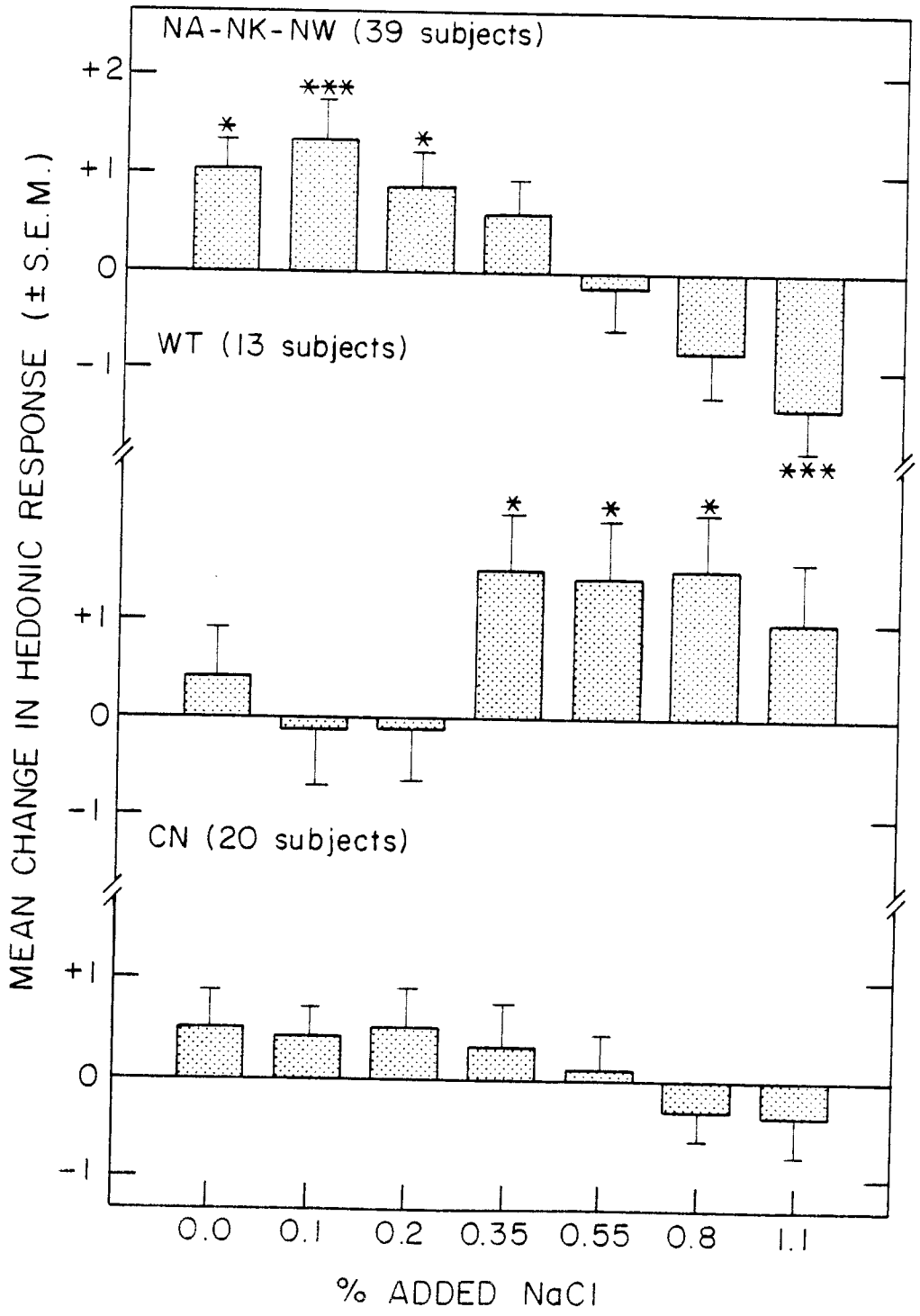


TABLE 12. Mean hedonic responses[1] (± S.D.) to NaCl in soup by diet groups[2] at the end of the study (week 24).

DIET GROUP	(n)	% ADDED NaCl 0.0%	0.1%	0.2%	0.35%	0.55%	0.8%	1.1%
NA-NK-NW	(39)	4.1 ±2.3	4.9[a] ±2.3	5.2[a] ±2.1	5.0 ±1.8	4.5 ±2.2	3.3[a] ±2.3	2.1[a] ±1.9
WT	(13)	2.5 ±1.7	2.6[b] ±2.3	3.0[b] ±1.5	5.0 ±1.5	5.1 ±1.7	5.6[b] ±1.8	5.1[b] ±2.0
CN	(20)	3.7 ±2.6	4.1[a,b] ±2.2	4.5[a,b] ±2.0	4.5 ±2.0	5.0 ±1.5	4.3[a,b] ±2.3	4.0[b] ±2.6
Prob F[3]		0.12	0.008	0.005	0.51	0.53	0.007	0.0001

[1]Means sharing or having no superscripts within a column do not differ significantly at $p < 0.05$ (Bonferroni).

[2]NA-NK-NW, WT, CN refer to sodium-restricted, weight loss and control, respectively.

[3]Probability of $F_{2,70}$ by one-way analysis of variance.

sodium-restricted groups, NA, NK and NW, were pooled for Figure 5 and Table 12, to increase the sample size and facilitate intergroup comparisons.

Nested analyses of variance were applied separately to each diet group, NA, NK, NW (Table 13), WT and CN (Table 14), to examine variation in individual hedonic scores due to subjects, concentrations and test site (UCD and UMN). Hedonic responses to NaCl in soup did not differ across sites, within any of the diet groups, as indicated by non-significant F-ratios for site and for the interactions of site by week and site by week by concentration. The interaction of site by concentrations also was non-significant, except in the NK group (Table 13). The latter may be due to the small UMN NK group sample size (n=3). For all diet groups, there was a significant interaction between subjects and concentrations, indicating that within treatments, individual participants varied in the way each rated the soups.

Examination of the variation due to weeks on the diet and to the interaction of weeks by concentration in the nested analyses of variance tables (Tables 13-14) is another means of assessing whether NaCl concentrations were rated differentially over time. All diet groups, except WT, had non-significant F-ratios for weeks, indicating that hedonic responses, averaged over the seven NaCl concentrations, did not vary across weeks. A significant interaction of weeks and concentrations was observed only in the NA (Table 13) and WT (Table 14) groups, confirming changes, previously discussed, in the pattern of hedonic responses to NaCl across weeks. The interaction of week by concentration did not reach statistical significance in the NK and NW groups, despite the

TABLE 13. Degrees of freedom (df) and calculated F-ratios for the nested analyses of variance of hedonic scores for NaCl in soup by low sodium (NA) low sodium-high potassium (NK) and low sodium-weight loss (NW) diet groups, at UCD and UMN[1] study sites.

SOURCE	TEST[2] SOURCE	NA			NK			NW		
		df	F	p<	df	F	p<	df	F	p<
Total		780			737			656		
(1) Site	(2)	1	0.28	NS	1	0.61	NS	1	0.35	NS
(2) Subjects	Residual	13	22.72	0.001	13	32.64	0.001	11	47.95	0.001
(3) Weeks[3]	(2)X(3)	7	0.96	NS	7	0.98	NS	7	0.71	NS
(4) Concentration	(2)X(4)	6	10.85	0.001	6	8.38	0.001	6	3.13	0.01
Site X Weeks	(2)X(3)	7	1.35	NS	7	1.34	NS	7	0.27	NS
Site X Conc	(2)X(4)	6	0.37	NS	6	4.98	0.001	6	0.18	NS
Subjects X Weeks	Residual	83	2.17	0.001	77	2.57	0.001	67	3.77	0.001
Subjects X Conc	Residual	78	3.04	0.001	78	5.17	0.001	66	7.05	0.001
Weeks X Conc	Residual	42	2.00	0.001	42	0.97	NS	42	1.17	NS
(1) X (3) X (4)	Residual	42	0.66	NS	42	0.80	NS	42	0.74	NS
Residual		495			458			401		

[1]UCD, UMN refer to University of California, Davis and University of Minnesota, Minneapolis.

[2]Mean square error source used to calculate F-ratios.

[3]Weeks refer to 8 test sessions conducted at approximately weeks 0, 1, 3, 6, 8, 10, 13 and 24 of the study.

TABLE 14. Degrees of freedom (df) and calculated F-ratios for the nested analysis of variance of hedonic scores for NaCl in soup by weight loss (WT) and control (CN) diet groups at UCD and UMN[1] study sites.

SOURCE	TEST[2] SOURCE	WT			CN		
		df	F	p<	df	F	p<
Total		687			1082		
(1) Site	(2)	1	2.73	NS	1	0.19	NS
(2) Subjects	Residual	11	26.94	0.001	18	53.44	0.001
(3) Weeks[3]	(2) X (3)	7	2.62	0.05	7	0.72	NS
(4) Concentration	(2) X (4)	6	11.63	0.001	6	1.53	NS
Site X Weeks	(2) X (3)	7	0.66	NS	7	1.48	NS
Site X Conc	(2) X (4)	6	0.42	NS	6	0.27	NS
Subjects X Weeks	Residual	72	3.79	0.001	121	2.08	0.001
Subjects X Conc	Residual	66	6.35	0.001	108	14.01	0.001
Weeks X Conc	Residual	42	1.43	0.05	42	1.27	NS
(1) X (3) X (4)	Residual	42	0.68	NS	42	0.92	NS
Residual		427			724		

[1]UCD, UMN refer to University of California, Davis and University of Minnesota, Minneapolis.

[2]Mean square error source used to calculate F-ratios.

[3]Weeks refer to 8 test sessions conducted at approximately weeks 0, 1, 3, 6, 8, 10, 13 and 24 of the study.

observed shifts in hedonic maxima and in hedonic responses to lower and higher NaCl concentrations over time. This may be due to greater inter-subject variability observed within these treatments (Table 13).

Although the t-tests and nested analyses of variance provide an indication of overall change in hedonic responses to NaCl concentrations, they fail to indicate whether or not these changes occurred randomly or systematically over time. To answer this question, hedonic scores for each NaCl concentration were plotted separately against weeks on the diet, and the slope of the resulting line calculated for each individual participant. Figures 6, 7 and 8 illustrate the time plots for each NaCl concentration, for the sodium-restricted (NA-NK-NW), WT and CN groups, respectively, and show the mean hedonic slope values. The significance of the "hedonic slope", tested by dividing the mean slope for each concentration by its standard error, provides an indication of the linearity and rate of increase or decrease in hedonic ratings over time.

As seen in Figure 6 for the sodium-restricted groups, hedonic scores for single NaCl concentrations generally changed linearly over time. Hedonic slopes were significantly positive, or increasing, for the two least salty 0.0 and 0.1% NaCl concentrations, and significantly negative, or decreasing, for the two most concentrated, 0.8 and 1.1%, NaCl samples. These shifts in response occurred mostly between baseline and week 13, after which time there was little or no apparent variation, signifying perhaps the establishment of a new baseline preference level. In the WT group (Figure 7), hedonic slopes for the 0.35, 0.55, and 0.8% NaCl concentrations were significantly positive, substantiating the

FIGURE 6. Mean hedonic responses to NaCl in soup as a function of weeks on diet, and calculated slopes "b" for sodium-restricted diet groups (NA-NK-NW). Significance of slope = b ÷ S.E.M.> critical t_{40}, two-tailed.

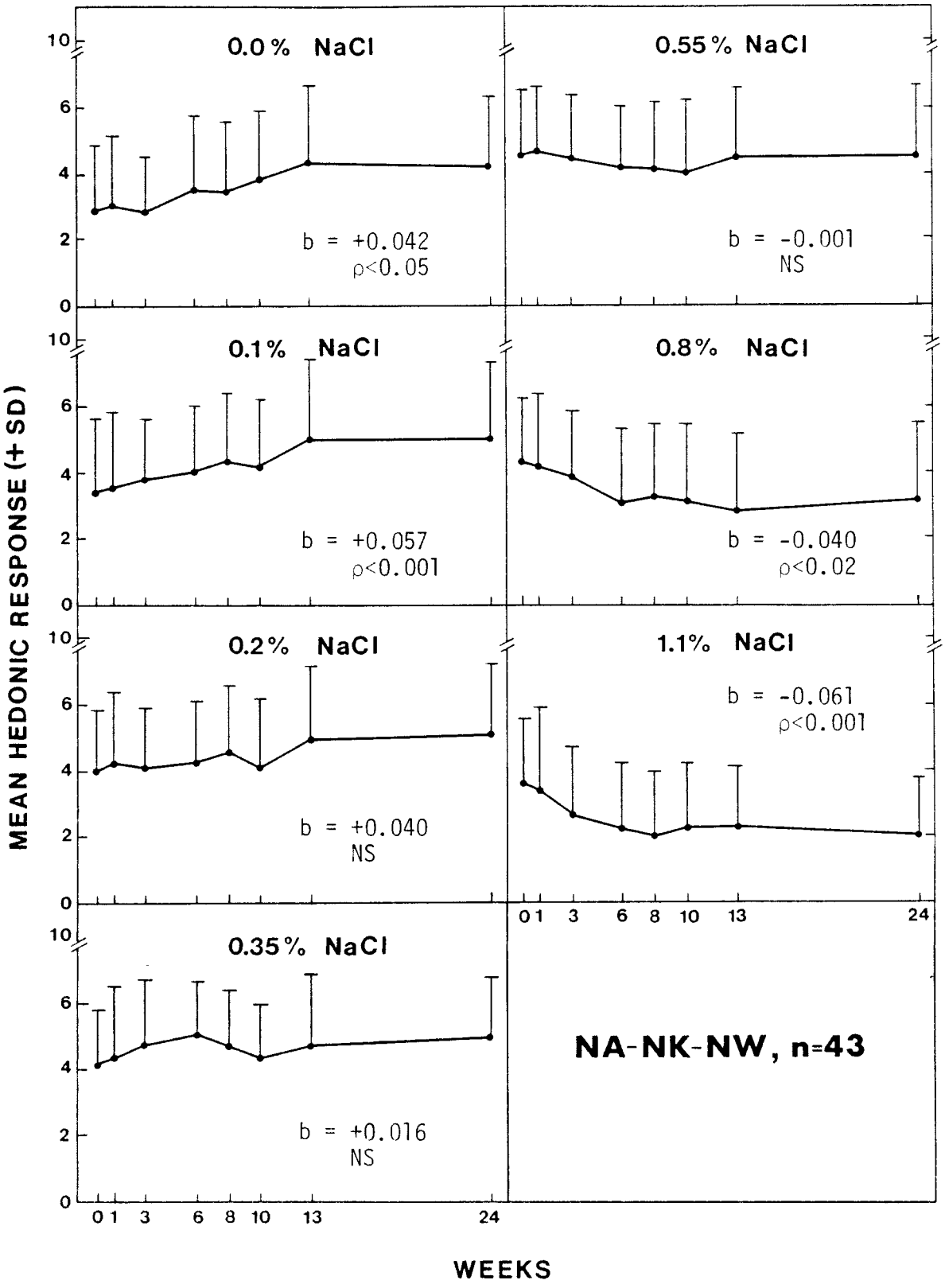


FIGURE 7. Mean hedonic response to NaCl in soup as a function of weeks on diet, and calculated slopes "b" for weight loss diet group (WT). Significance of slope = b ÷ S.E.M. > critical t_{11}, two-tailed.

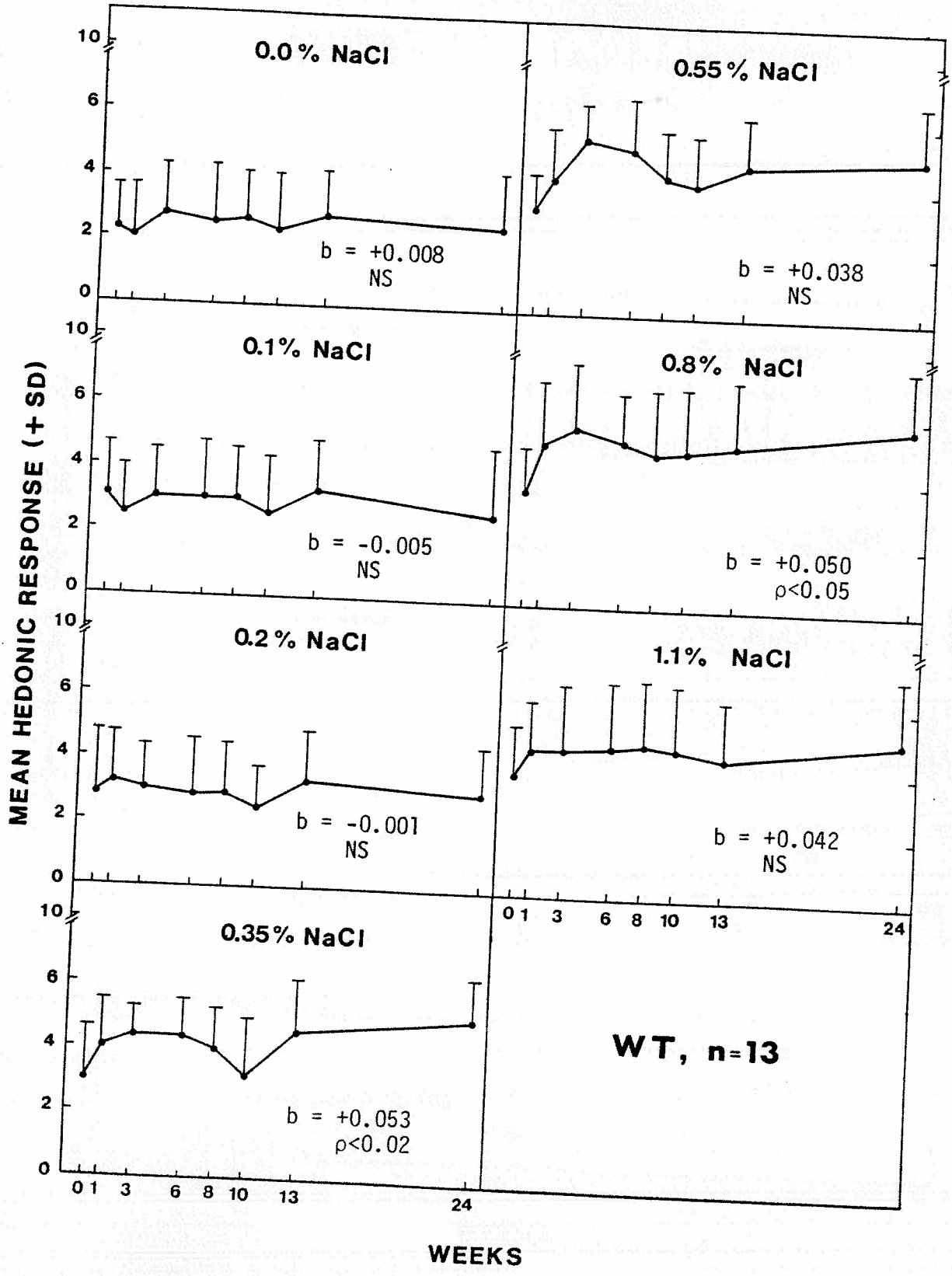
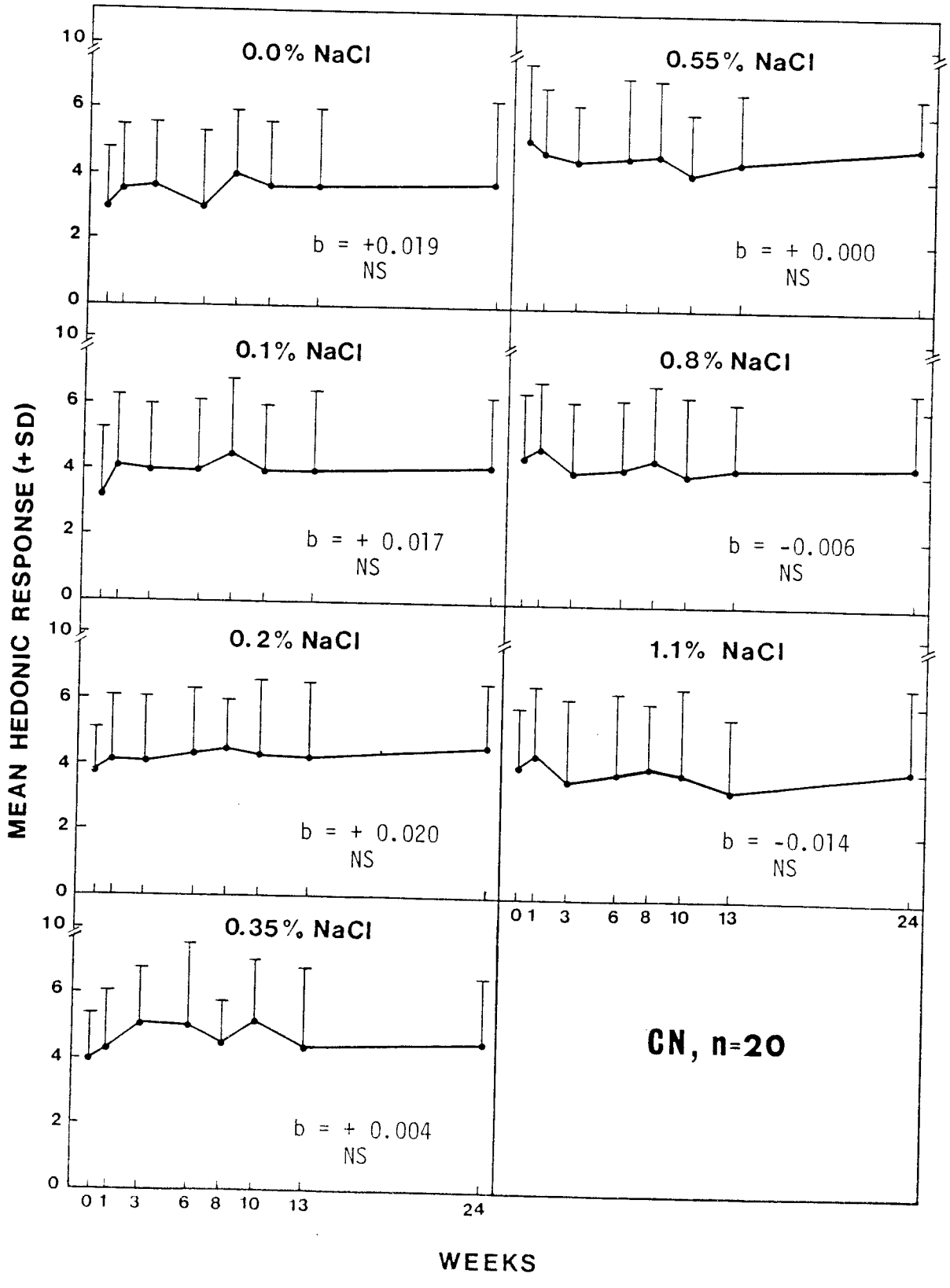


FIGURE 8. Mean hedonic response to NaCl in soup as a function of weeks on diet, and calculated slopes "b" for control diet group (CN). Significance of slope = b ÷ S.E.M. > critical t_{18}, two-tailed.



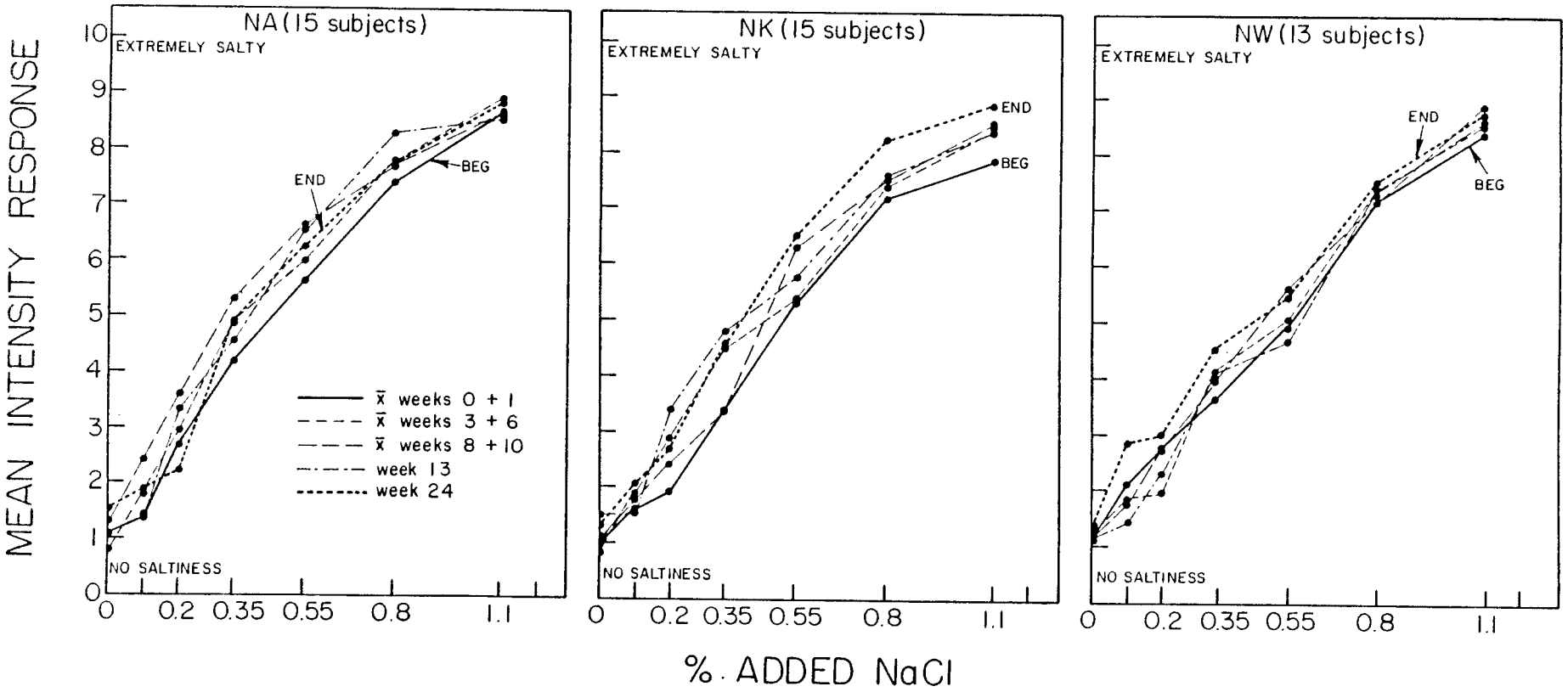
results of the t-tests previously shown in Figure 5. However, the time plots in Figure 7 also show a puzzling, systematic drop in liking for these concentrations, occuring at approximately week 10, which cannot readily be explained. By comparison, time plots for the CN group (Figure 8) were relatively flat, and hedonic slopes were not significantly different from zero, again indicating little or no fluctuation in responses from week to week.

2. Saltiness Intensity Scaling

Figures 9 and 10 illustrate the mean saltiness intensity responses to NaCl in soup, by the NA, NK, NW and WT and CN groups, respectively, pooled across the two study sites, at five time periods. Data for weeks 0 and 1, weeks 3 and 6 and weeks 8 and 10 were averaged, based on non-significant differences in slopes, to facilitate comparisons over time. Saltiness intensity scores increased linearly as a function of NaCl concentraion for all diet groups, with only slight variation in slope of the lines for each time period, within and among treatments. A small upward shift in intensity ratings was apparent in all groups, from "BEG" (baseline) to "END" (week 24), especially in the NA and NK treatments (Figure 9).

The similarity of saltiness intensity responses across time, within diet groups, was confirmed by analyses of variance of the slopes of individual regression lines. Intensity slopes did not differ significantly across the five time periods (Table 15). Mean intensity slopes varied from 6.6 to 7.2, 6.7 to 7.5, 6.6 to 7.2, 6.3 to 7.0 and 6.3 to 6.7 within the NA, NK, NW, WT and CN groups, respectively. Mean intensity slopes were slightly, but consistently lower in the WT group, rela-

FIGURE 9. Mean saltiness-intensity responses to increasing concentrations of NaCl in soup, by low sodium (NA), low sodium-high potassium (NK) and low sodium-weight loss (NW) diet groups, at intervals from the begining (BEG) to the 24th week (END) of study.



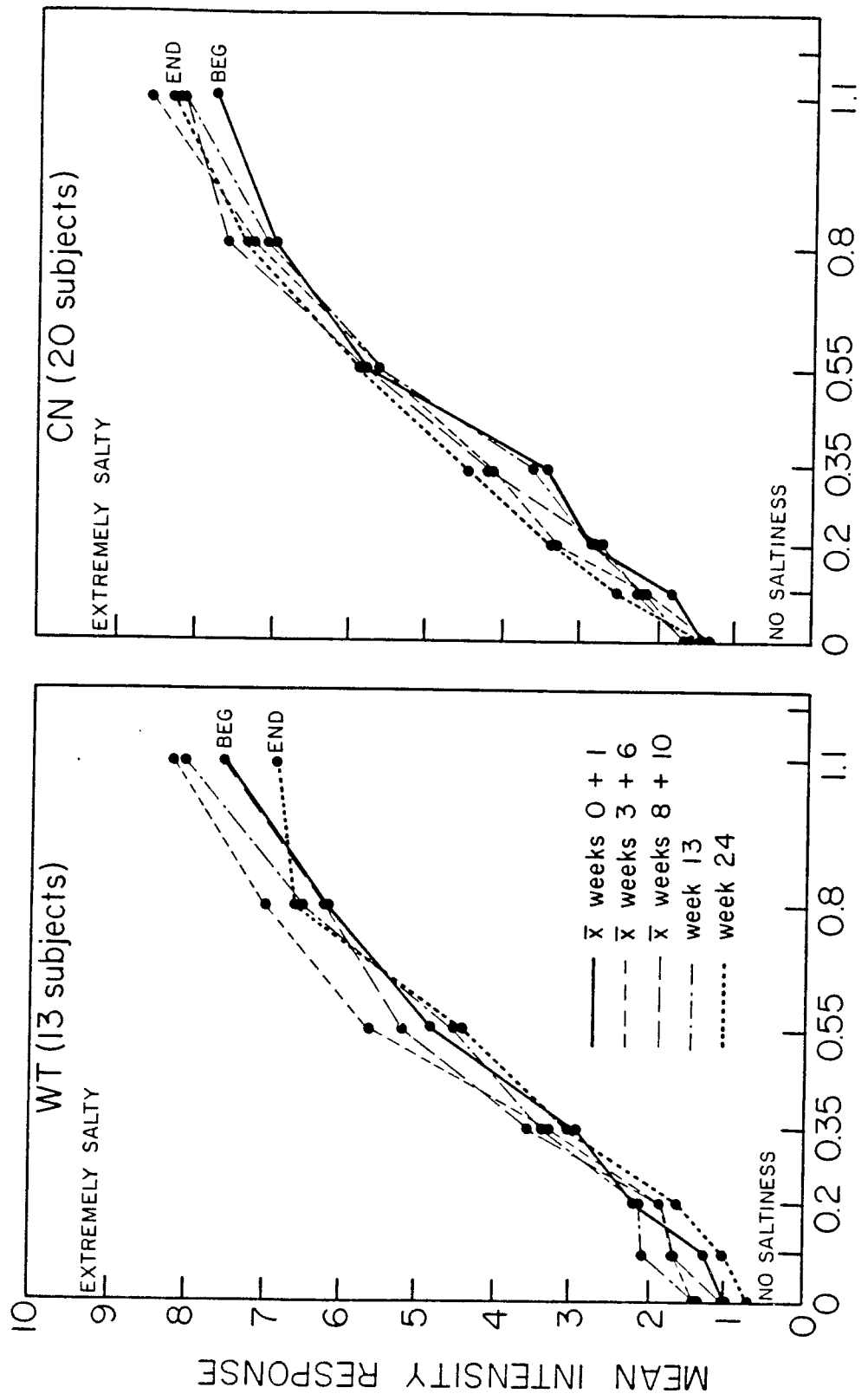


FIGURE 10. Mean saltiness-intensity responses to increasing concentrations of NaCl in soup, by weight loss (WT) and control (CN) diet groups, at intervals from the begining (BEG) to the 24th week (END) of study.

TABLE 15. Mean slopes (± S.D.) of intensity responses to increasing NaCl concentrations, at intervals[1] from baseline (week 0-1) to 24 weeks of study, subdivided by diet group[2]. (Number of subjects in parenthesis).

DIET GROUP	WEEK 0-1	WEEK 3-6	WEEK 8-10	WEEK 14	WEEK 24	F-RATIO[3]
NA	7.2±0.9 (11)	7.4±1.7 (14)	6.6±1.3 (14)	7.5±1.7 (15)	7.3±2.0 (13)	1.47
NK	6.8±1.5 (14)	7.0±2.1 (12)	7.3±2.3 (11)	6.7±2.1 (9)	7.5±1.3 (15)	0.73
NW	6.7±1.4 (12)	7.1±2.2 (12)	7.2±1.9 (13)	7.2±1.9 (7)	6.6±2.6 (11)	0.35
WT	6.3±1.3 (13)	7.0±1.2 (11)	6.3±1.4 (11)	6.3±1.3 (12)	6.3±1.5 (13)	0.38
CN	6.3±1.8 (20)	6.7±1.9 (20)	6.4±2.3 (16)	6.4±2.2 (19)	6.4±2.2 (20)	0.36

[1]Week 0-1, week 3-6 and week 8-10 refer to the mean of individual intensity slopes pooled over weeks 0 and 1, weeks 3 and 6 and weeks 8 and 10, respectively.

[2]NA, NK, NW, WT, CN refer to low sodium, low sodium-high potassium, low sodium-weight loss, weight loss and control groups, respectively.

[3]F ratios apply to means within a row.

TABLE 16. Nested analysis of variance for the saltiness intensity slopes of the five diet groups[1].

SOURCE	df	TEST SOURCE[2]	SUM OF SQUARES	F-RATIO
Total	337			
Subjects	71	Residual	801.02	8.93***
Diet	4	Subjects	46.53	1.03
Weeks[3]	4	Residual	3.05	0.60
Diet X Weeks	16	Residual	13.52	0.67
Residual	242		305.79	

[1]Diet groups refer to low sodium (NA), low sodium-high potassium (NK), low sodium-weight loss (NW), weight loss (WT) and control (CN).

[2]Mean square error used to calculate F-ratio.

[3]Weeks refer to five intervals: weeks 0-1, weeks 3-6, weeks 8-10, week 14 and week 24.

***Significant at $p < 0.001$.

tive to the NA, NK and NW groups. However, a nested analysis of variance of these data showed that intensity slopes also did not differ among any of the diet groups (Table 16).

Since it is possible that a shift in rated saltiness intensity might occur without a concomitant change in slope, analyses of variance were applied to individual intensity scores for each diet group (Table 17-18). These results generally support the findings of the intensity slope analyses. Saltiness intensity scores, averaged across the seven NaCl concentrations, did not differ over time. In addition, the non-significant F-ratios for the interaction of weeks by concentration, demonstrated in the NA, NW, WT and CN groups indicate that the pattern of saltiness intensity scores ascribed to the seven NaCl concentrations was consistent from week to week. A slight, but significant interaction of weeks and concentrations occurred in the NK group (Table 17).

These analyses of variance were also used to examine homogeneity in response between the two test sites, UCD and UMN. As in the case of hedonic responses, saltiness intensity scores were consistent across sites within the NA, NW, WT and CN groups. This is indicated by non-significant F-ratios for site and for the interactions of site by week, site by concentration and site by week by concentration for these treatments (Tables 17-18). The NK group exhibited a significant site effect, but no site interactions, probably due to the small UMN NK group sample size (n=3). All diet groups demonstrated significant variation due to subjects and to concentrations, as expected, as well as significant interactions of subjects by weeks and subject by concentrations.

TABLE 17. Degrees of freedom (df) and calculated F-ratios for the nested analyses of variance of intensity responses to NaCl in soup by low sodium (NA), low sodium-high potassium (NK) and low sodium-weight loss (NW) diet groups at UCD and UMN[1] study sites.

SOURCE	TEST[2] SOURCE	NA			NK			NW		
		df	F	p<	df	F	p<	df	F	p<
Total		778			737			656		
(1) Site	(2)	1	6.60	0.05	1	0.69	NS	1	0.27	NS
(2) Subjects	Residual	13	11.22	0.001	13	25.12	0.001	11	15.07	0.001
(3) Weeks[3]	(2)X(3)	7	0.93	NS	7	2.02	NS	7	0.95	NS
(4) Concentration	(2)X(4)	6	181.09	0.001	6	110.20	0.001	6	116.92	0.001
Site X Week	(2)X(3)	7	1.52	NS	7	2.72	0.05	7	0.71	NS
Site X Conc	(2)X(4)	6	1.23	NS	6	0.49	NS	6	0.81	NS
Subject X Week	Residual	83	3.47	0.001	77	3.94	0.001	67	3.97	0.001
Subject X Conc	Residual	78	3.05	0.001	78	4.40	0.001	66	3.69	0.001
Week X Conc	Residual	42	1.24	NS	42	1.42	0.05	42	0.85	NS
(1) X (3) X (4)	Residual	42	1.28	NS	42	1.02	NS	42	0.80	NS
Residual		493			458			401		

[1]UCD, UMN refer to University of California, Davis and University of Minnesota, Minneapolis.

[2]Mean square error source used to calculate F-ratios.

[3]Weeks refer to 8 test sessions conducted at approximately weeks 0, 1, 3, 6, 8, 10, 13 and 24 of the study.

TABLE 18. Degrees of freedom (df) and calculated F-ratios for the nested analyses of variance of intensity responses to NaCl in soup, by weight loss (WT) and control (CN) diet groups, at UCD and UMN[1] study sites.

SOURCE	TEST SOURCE[2]	WT			CN		
		df	F	p<	df	F	p<
Total		686			1079		
(1) Site	(2)	1	0.35	NS	1	0.09	NS
(2) Subjects	Residual	11	21.17	0.001	18	45.33	0.001
(3) Weeks[3]	(2)X(3)	7	1.33	NS	7	1.84	NS
(4) Concentration	(2)X(4)	6	240.90	0.001	6	156.88	0.001
Site X Weeks	(2)X(3)	7	2.02	NS	7	1.17	NS
Site X Conc	(2)X(4)	6	0.71	NS	6	0.50	NS
Subjects X Weeks	Residual	72	4.34	0.001	121	2.91	0.001
Subjects X Conc	Residual	66	2.17	0.001	108	4.72	0.001
Weeks X Conc	Residual	42	1.22	NS	42	1.11	NS
(1) X (3) X (4)	Residual	42	1.06	NS	42	0.92	NS
Residual		426			721		

[1]UCD, UMN refer to University of California, Davis and University of Minnesota, Minneapolis.

[2]Mean square error source used to calculate F-ratios.

[3]Weeks refer to 8 test sesssions conducted at approximately weeks 0, 1, 3, 6, 8, 10, 13 and 24 of the study.

3. Ad Libitum Mixing

(0.0% added NaCl) and "E" (1.5% added NaCl) and to the subjects' "MIX" of C and E in the ad libitum test procedure are illustrated in Figure 11, for the sodium-restricted (NA-NK-NW), WT, and CN groups, pooled across the two study sites, UCD and UMN, from baseline to the 24th week of study. All groups rated their ad libitum mixtures higher than either test samples, with little or no variation across weeks, except in the WT group. Participants on sodium-restricted diets ascribed progressively higher ($p<0.001$) hedonic scores to "C" and progressively lower ($p<0.001$) scores to "E" over time, until approximately week 13. Little change in response occurred between week 13 and week 24. In contrast, scores attributed to "C" and "E" by the WT group fluctuated, but did not vary significantly over time. In the CN group, no change in response to the 0.0% NaCl sample was observed, while a slight, but significant ($p<0.01$) decrease in liking for the 1.5% NaCl sample occurred at week 13.

Mean NaCl concentration of the participants' ad libitum mixes, as determined by sodium ion-selective electrode, is illustrated in Figure 12 for the sodium-restricted (NA-NK-NW), WT and CN groups, pooled across sites. At baseline, mean ad libitum mix NaCl concentrations for the sodium-restricted, WT and CN groups were 0.72, 0.90 and 0.76% added NaCl, respectively, or slightly less than the concentration of salt found in commercial cream soups (0.8-1.15% NaCl). The average amount of NaCl mixed into soup by participants on sodium-restricted diets decreased progressively ($p<0.001$) throughout the study period, from 0.72 $\pm$ 0.29% at the onset, to 0.33 $\pm$ 0.23% added NaCl at both weeks 13 and 24. In contrast, participants in the WT group generally maintained

FIGURE 11. Mean hedonic responses to test sample "C" (0.0% added NaCl), "E" (1.5% added NaCl) and to the ad libitum "MIX" of C and E, by sodium-restricted (NA-NK-NW), weight loss (WT) and control (CN) diet groups from baseline (week 0) to the 24th week of study.

* Significantly different from baseline at $\rho<0.05$ (Bonferroni).

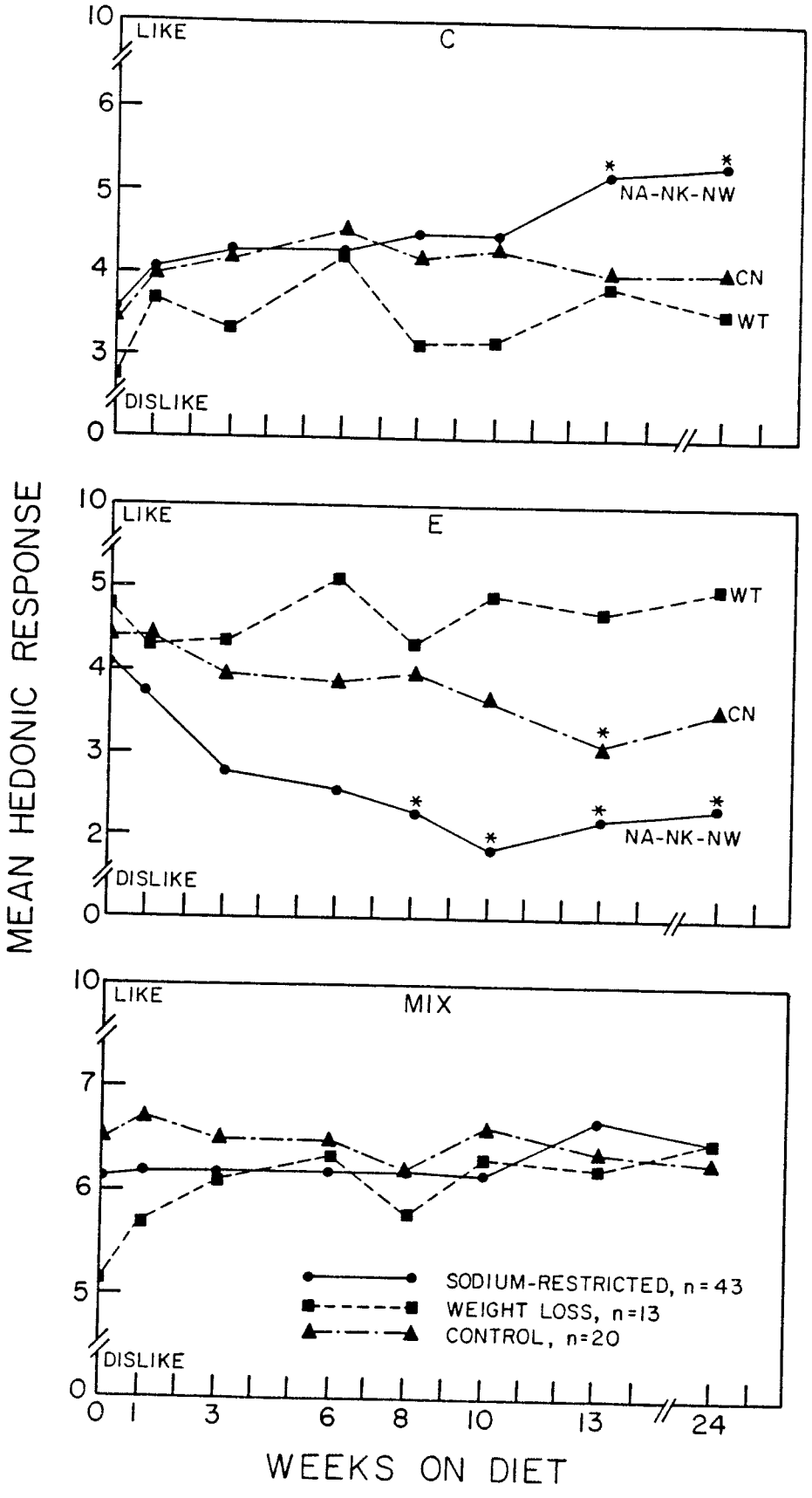
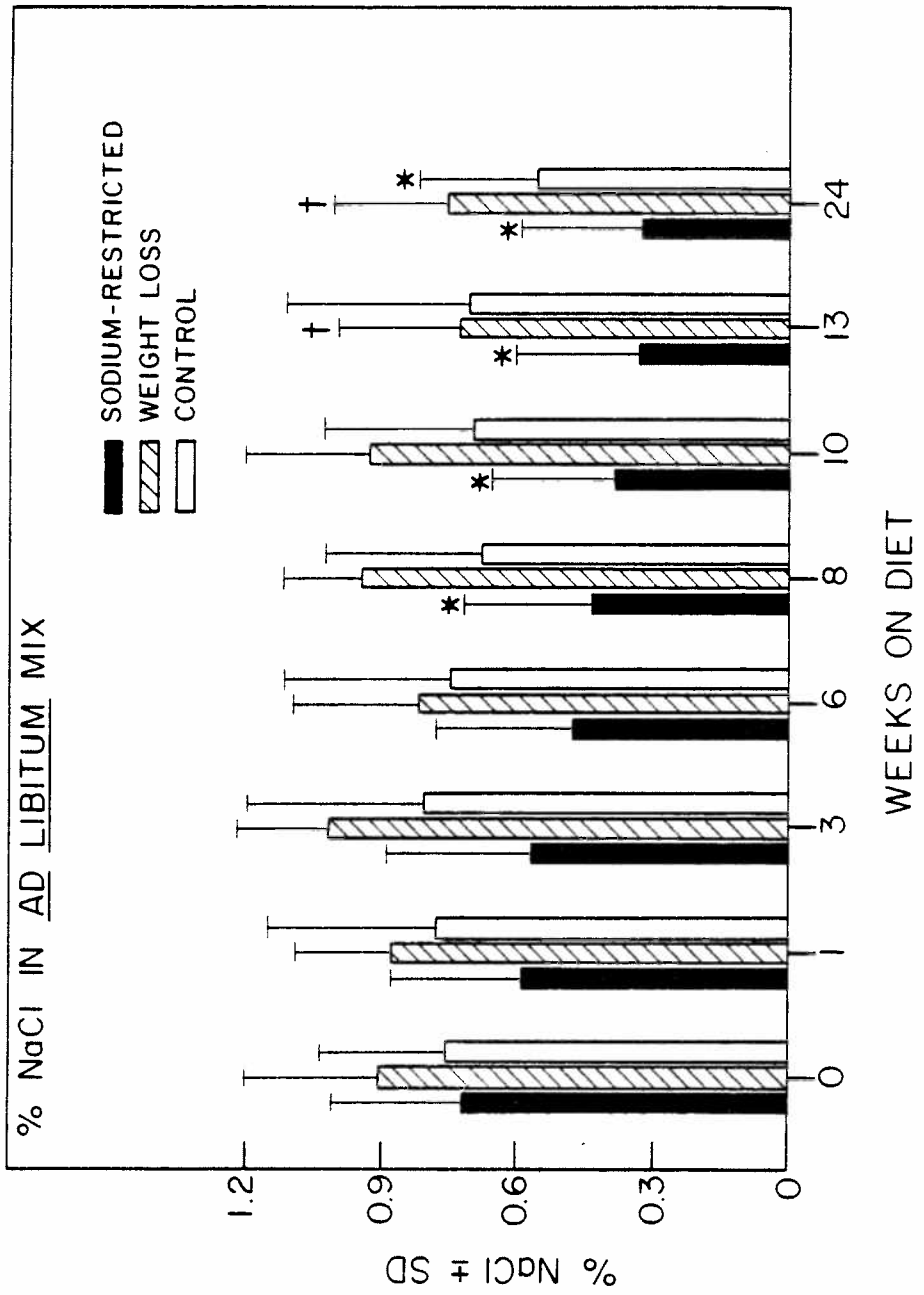

MEAN HEDONIC RESPONSE
C
LIKE
DISLIKE
NA-NK-NW
CN
WT
E
MIX
SODIUM-RESTRICTED, n=43
WEIGHT LOSS, n=13
CONTROL, n=20
WEEKS ON DIET

FIGURE 12. Mean NaCl concentration of ad libitum mixes for sodium-restricted (NA-NK-NW), weight loss (WT) and control (CN) diet groups from baseline (week 0) to the 24th week of study.

* Significantly different from week 0, 1 and 3 at $\rho<0.05$ (Bonferroni).

† Significantly different from weeks 3 and 5 at $\rho<0.05$ (Bonferroni).


% NaCl IN AD LIBITUM MIX
SODIUM-RESTRICTED
WEIGHT LOSS
CONTROL
% NaCl ± SD
1.2
0.9
0.6
0.3
0
0
1
3
6
8
10
13
24
WEEKS ON DIET
*
†

their baseline salting level, and any differences appeared to be random, rather than systematic. For example, significantly less ($p<0.003$) NaCl was added to soup at weeks 13 (0.73% NaCl) and 24 (0.76% NaCl) compared to weeks 3 (1.02% NaCl) and 8 (0.95% NaCl). The CN group subjects also generally maintained their salting level across weeks, except for a significant decrease ($p<0.03$) in NaCl concentration at week 24 (0.56% NaCl) compared with weeks 0, 1, and 3 (0.76, 0.78 and 0.81% NaCl, respectively).

As shown in Figures 11 and 12, all treatment groups had similar responses at baseline, but responded differentially across weeks, following initiation of their diets. This was confirmed by one-way analyses of variance applied to both baseline and end-point ad libitum test responses (Table 19). No significant differences were found among diet treatments at the onset, while at week 24, sodium-restricted subjects had significantly higher hedonic scores for "C", lower hedonic scores for "E", and were mixing significantly less NaCl into soup than either the WT or CN subjects.

The data for the two test sites, UCD and UMN, were pooled for Figures 11 and 12, based on results of nested analyses of variance applied separately to each diet group (Tables 20 and 21). The ad libitum test responses were consistent across sites, except in two cases. In the NA group (Table 20), mean hedonic responses to the ad libitum mixes were significantly higher ($p<0.001$) at UCD. More importantly, however, there was no interaction of site by week. In the WT group (Table 21), the interaction of site by week for NaCl concentration of the ad libitum mixes was significant, while the F-ratio for sites was not. The ad

TABLE 19. Mean (± S.D.)[1] hedonic responses to ad libitum test samples "C", "E" and mean NaCl concentrations of the subjects' ad libitum mixes by diet group[2] at baseline (week 0) and at the end (week 24) of the study.

	DIET GROUP	(n)	"C" (0.0% NaCl)	"E" (1.5% NaCl)	%NaCl in MIX
Week 0	NA-NK-NW	(42)	3.5 ± 1.8	4.1 ± 2.4	0.72 ± 0.30
	WT	(13)	2.7 ± 1.0	4.8 ± 1.7	0.91 ± 0.29
	CN	(20)	3.4 ± 2.2	4.4 ± 2.1	0.76 ± 0.28
Prob F[3]			0.38	0.59	0.14
Week 24	NA-NK-NW	(40)	5.3 ± 1.9[a]	2.4 ± 1.8[a]	0.33 ± 0.25[a]
	WT	(13)	3.5 ± 2.1[b]	5.0 ± 1.6[b]	0.76 ± 0.25[c]
	CN	(20)	4.0 ± 2.4[a,b]	3.5 ± 2.1[b]	0.56 ± 0.26[b]
Prob F[3]			0.01	0.0001	0.0001

[1]Means sharing or having no superscript within a column do not differ significantly at $p < 0.05$ (Bonferroni).

[2]NA-NK-NW, WT, CN refer to sodium-restricted, weight loss and control groups, respectively.

[3]Probability of $F_{2,70}$ by one-way analysis of variance.

TABLE 20. Degrees of freedom (df) and calculated F-ratios for the nested analyses of variance of ad libitum test responses[1] by low sodium (NA), low sodium-high potassium (NK) and low sodium-weight loss (NW) diet groups at UCD and UMN[2].

SOURCE	df	TEST SOURCE	"C" (0.0%NaCl) F-RATIO	"E" (1.5%NaCl) F-RATIO	"MIX" F-RATIO	%NaCl in MIX F-RATIO
			NA			
Site	1	Subjects	1.20	1.44	15.90***	2.42
Subjects	13	Residual	2.59**	3.87***	7.23***	15.19***
Weeks	7	Residual	4.10***	5.71***	1.54	13.19***
SiteXweeks	7	Residual	1.34	1.22	0.89	1.26
Residual	86					
			NK			
Site	1	Subjects	3.39	1.04	0.15	4.24
Subjects	13	Residual	4.39**	5.93**	8.83***	8.15***
Weeks	7	Residual	0.90	0.58	0.40	4.93***
SiteXweeks	7	Residual	0.43	1.12	0.37	0.89
Residual	78					
			NW			
Site	1	Subjects	0.44	0.11	0.26	0.02
Subjects	11	Residual	7.03***	7.14***	16.42***	11.90***
Weeks	7	Residual	1.65	3.18**	0.78	4.98***
SiteXweeks	7	Residual	0.61	0.28	1.41	1.18
Residual	68					

[1]Responses refer to hedonic scores for test soups "C", "E" and for subjects' "MIX" of "C" and "E", as well as NaCl concentration of the ad libitum MIX.

[2]UCD and UMN refer to University of California, Davis and University of of Minnesota, Minneapolis.

[3]Mean square error source used to calculate F-ratio.

[4]Weeks refer to 8 test sessions conducted at approximately 0, 1, 3, 6, 8, 10, 13 and 24 weeks of the study.

**, ***Significant at $p < 0.01$ and 0.001, respectively.

TABLE 21. Degrees of freedom (df) and calculated F-ratios for the nested analyses of variance of ad libitum test responses[1] by weight loss (WT) and control (CN) groups at UCD and UMN[2].

SOURCE	df	TEST[3] SOURCE	"C" (0.0%NaCl) F-RATIO	"E" (1.5%NaCl) F-RATIO	"MIX" F-RATIO	%NaCl in MIX F-RATIO
			WT			
Site	1	Subjects	2.44	0.42	0.05	0.79
Subjects	11	Residual	4.16***	7.73***	10.75	9.52***
Weeks[4]	7	Residual	1.34	1.15	2.86**	3.84**
SiteXweeks	7	Residual	0.78	2.10	0.95	4.27**
Residual	73					
			CN			
Site	1	Subjects	0.02	0.35	0.47	0.00
Subjects	18	Residual	21.16***	27.72***	38.30***	18.43***
Weeks[4]	7	Residual	1.55	2.59*	0.89	2.90**
SiteXweeks	7	Residual	0.44	0.91	1.51	1.89
Residual	120					

[1]Responses refer to hedonic scores for test soups "C", "E" and for subjects' "MIX" of "C" and "E" as well as NaCl concentration of the ad libitum MIX.

[2]UCD and UMN refer to University of California, Davis and University of Minnesota, Minneapolis.

[3]Mean square error source used to calculate F-ratios.

[4]Weeks refer to 8 test sessions conducted at approximately 0, 1, 3, 6, 8, 10, 13 and 24 weeks of the study.

*,**,***Significant at $p < 0.05$, 0.01 and 0.001, respectively.

TABLE 22. Degrees of freedom (df) and calculated F-ratios for the nested analyses of variance of ad libitum test responses[1] by pooled sodium-restricted diet groups (NA, NK, NW)[2].

SOURCE	df	TEST[3] SOURCE	"C" (0.0%NaCl) F-RATIO	"E" (1.5%NaCl) F-RATIO	"MIX" F-RATIO	%NaCl in MIX F-RATIO
Diet	2	Subjects	0.10	3.27*	0.21	1.30
Subjects	40	Residual	5.13***	5.73***	12.59***	12.34***
Weeks	7	Residual	4.98***	9.31***	1.01	23.12***
DietXweeks	14	Residual	0.75	1.10	0.62	1.28
Residual	252					

[1]Responses refer to hedonic scores for test soups "C", "E" and for subjects' "MIX" of "C" and "E", as well as NaCl concentration of the ad libitum MIX.

[2]NA, NK, NW refer to low sodium, low sodium-high potassium and low sodium-weight loss, respectively.

[3]Mean square error source used to calculate F-ratios.

*,***Significant at $p < 0.05$ and 0.001, respectively.

libitum test data also were pooled across the three sodium-restricted diet groups NA, NK and NW, based on consistency in response (Table 22). Appendix VIII, IX, X and XI show mean hedonic scores for "C", "E" as well as the ad libitum mix, and mean NaCl concentrations of the ad libitum mixes, subdivided by treatment group and site.

As shown previously in the correlation matrices in Table 11, the amount of salt mixed into soup by sodium-restricted subjects at baseline, week 13 and week 24, correlated significantly with total dietary sodium intake ($r=0.247$, $p<0.01$), sodium intake per 1000 Kcal ($r=0.185$, $p<0.05$) and overnight urinary sodium/g creatinine excretion ($r=0.190$, $p<0.05$), and correlated negatively with number of weeks on the diet ($r=-0.358$, $p<0.001$). In the WT group, NaCl concentration of the ad libitum mixes correlated significantly with sodium intake per day ($r=0.394$, $p<0.05$) and sodium excretion/g creatinine ($r=0.310$, $p<0.05$), but not with sodium intake per 1000 Kcal ($r=0.106$, $p=0.54$) which corrects for the changes in food and energy intake sustained in this group. In the CN group, none of the measures of sodium intake correlated with concentration of their ad libitum mixes, however, a slight, but significant negative relationship was found between NaCl in the ad libitum mixes and number of weeks in the study. This latter correlation may reflect the slight decrease in the amount of NaCl mixed into soup during the last weeks of the study, as shown previously in Figure 12.

Baseline sodium intake per day and per 1000 Kcal for all subjects combined correlated significantly with ad libitum salt preferences ($r=0.3$, $p<0.01$ and $r=0.80$, $p<0.0001$, respectively) indicating a positive relationship between dietary sodium intake and salt taste preference prior to initiation of dietary treatments.

DISCUSSION

Data presented herein support anecdotal as well as clinical reports that following restriction of sodium intake, patients adapt to the taste of foods containing less salt (Dahl, 1960; Gillum et al., 1981; Bertino et al., 1982; Thaler et al., 1982; Teow et al., 1984). Specifically, it was observed that participants on low sodium (NA), low sodium-high potassium (NK) and low sodium-weight loss (NW) diets, preferred significantly lower concentrations of salt in soup after six months of reduced sodium intake than individuals on weight loss (WT) and control (CN) diets. These changes occurred gradually over the 24-week intervention period, independent of variation in energy or potassium intakes and were demonstrated in two separate population groups- Davis, California and Minneapolis, Minnesota.

Because responses were obtained using a specific food item as the test medium, precautions must be exercised in extrapolating the results to other, more complex foods. Mean hedonic scores rarely exceeded 5, the "neither like nor dislike" point on the 10-cm scale. The fact that the cream of green bean soup was not well-liked by some participants, regardless of NaCl concentration, may have biased their responses to saltiness per se. Many participants disliked the puree-like texture and bean flavor of the soup, and complained of an unpleasant odor, released from the samples when lids were first removed from the serving cups. Initially, the cream soup was selected over other available test media, such as chicken or beef broth, because of previous negative reports concerning these products (Braddock, 1982; Stone, 1984). Other unsalted cream soups were pretested (green pea, spinach, corn), but were judged

inappropriate due to excessive sweetness, bitterness or sediment imparted by the vegetable. Clearly, there is a need to develop a simple, yet palatable medium for clinical testing of saltiness.

A. Taste responses in low-sodium diet groups

1. Hedonic scaling

Changes in hedonic response pattern over time observed in the sodium-restricted diet groups were consistent with results of two previous investigations. Gillum et al. (1981) noted that peak preference ratings for broth and tomato juice samples shifted from a concentration of 98.3 to 64.4 mmol, in 15 patients with hypertension after five months of reduced sodium intake. This change was not, however, statistically significant. In another study, Bertino et al. (1982) reported that the concentration of NaCl rated most pleasant in strained vegetable soup, decreased significantly (0.06M or 0.35% NaCl) in a group of nine healthy individuals following self-maintained low-sodium diets for five months. A reduction of comparable magnitude was noted in the present study. Hedonic maxima shifted from 0.55% NaCl at the onset to 0.1% in the NA and NW groups and to 0.2% NaCl in the NK group after six months, a mean concentration change of 0.40% added NaCl.

A major shortcoming of the studies by Bertino et al, (1982) and Gillum et al, (1981), was that hedonic responses were not measured until two to five months after initiation of the diets. In the present study, recording of taste responses at regular intervals from the onset to the end of the experimental period allowed assessment of the direction, linearity and time course of the taste changes. The time plots of hedonic responses showed that degree of liking for the most

concentrated, pre-salted NaCl test samples (0.8 and 1.1% NaCl) decreased from baseline, as early as the third week of intervention and continued to decline progressively until approximately week 13. During the same time period, scores for test samples with the least NaCl (0.0 and 0.1%) increased in a systematic fashion. Little or no change in response was apparent between week 13 and week 24. Contrary to an hypothesis postulated by Bertino et al. (1982), there was no evidence to support a proposed attraction or craving for salt during the initial stages of the diet. A steady, progressive change in preference was observed over the 6-month study period. Bertino et al. (1981) hypothesized that low-sodium diet has an acute initial effect on taste, leading to increased liking for foods high in salt, analogous to responses seen in sodium-deficient animals (Contreras, 1978) and humans (McCance, 1936). After this, a new baseline would be established with liking shifting towards low-sodium foods. This conclusion was based on results of a short-term study in which three individuals showed increased liking for salty soups after three weeks of dietary sodium restriction. Bertino et al. (1982) speculated that abruptness of the reduction in sodium intake may be the underlying cause of initial attraction to higher concentrations of salt. Since the significant reduction in sodium intake and excretion observed in the present study was not documented until approximately week 12, it is difficult to verify how quickly subjects attained the 1600 mg Na^+/day HPT goal. However, participants were encouraged to reduce their sodium intake slowly during the course of the first few weeks of intervention. This gradual lowering of sodium in the diet may have been responsible for the progressive changes observed in salt taste preferences.

2. Ad libitum mixing

Results of the ad libitum test further support the concept of gradual change in preference for the taste of salt. As in the hedonic scaling tests, NA, NK and NW groups ascribed progressively higher scores to the test sample containing no added salt and progressively lower scores to the highly pre-salted test sample containing 1.5% added NaCl, across the study period. These responses paralleled those for soups containing 0.0 and 1.1% added NaCl presented within the NaCl concentration series for hedonic scaling. Again, no evidence was found for salt cravings during initial stages of the diet. The amount of salt mixed into soup by subjects on sodium-restricted diets to achieve a concentration of preference, declined progressively from a mean of 0.72% at the onset to 0.33% added NaCl at the end of the study, a difference of 0.39% NaCl. This would translate to approximately 380 mg less sodium per 250 ml serving of soup. This reduction is surprisingly similar to the mean concentration change of 0.40% NaCl observed between hedonic maxima at the beginning (0.55% NaCl) and the end (0.1-0.2% NaCl) of the study. Similarity of results for the hedonic scaling and ad libitum mixing procedures provides an internal check for consistency of the participants and validates that they were indeed mixing to their preferred level of NaCl.

Despite the 11-week span between tests conducted at week 13 and week 24 of the study period, the sodium-restricted diet groups maintained surprisingly similar mean ad libitum salting levels of .335 and .330% added NaCl, respectively. The relative stability of ad libitum salt concentrations during this time period had a parallel in the hedonic scaling, where degree of liking for pre-salted high and low NaCl

concentrations was maintained between weeks 13 and 24. These results suggest that study participants had attained a new "baseline" preference for salt, in line with their reduced level of sodium intake. This conclusion is strengthened by two additional observations. First, sodium intake and excretion measures correlated significantly with ad libitum salting levels and second, mean dietary sodium intakes, like sodium preference measures, also were not significantly different after 12 weeks (1283 mg Na^+) and 24 (1636 mg Na^+) weeks of intervention.

These findings indicate that it may take up to three months for individuals to adapt to the taste of a reduced sodium diet. This could be of relevance to clinicians and dietitians planning low-sodium intervention programs. Frequent counseling during the first three months of diet, followed by a less intensive schedule when patients' salt preferences have adjusted downward, may be the most effective intervention approach. However, the success of long-term compliance may be contingent upon maintenance of the lowered baseline preference level. A test of this hypothesis would be to continue recording taste responses and dietary sodium intake at regular intervals beyond 24 weeks, and examine whether the proposed "baseline" is maintained. In light of the relationship between sodium in the diet and preferred level of salt shown in the present study, one would predict that ad libitum salting levels would vary as a function of changes in sodium intake. Thus, maintenance of low sodium diets might result in little or no change in sodium preference while recidivism might effect a reversion of salt preferences towards pre-diet levels.

3. Saltiness intensity scaling

Changes in preference for the taste of NaCl observed in the sodium-restricted groups was independent of shifts in rated saltiness-intensity of the samples. A slight, upward shift in intensity scores occurred during the latter stages of the diet, especially in the NK group, however, saltiness intensity slopes, or scores did not increase significantly over time in any of the diet groups. Bertino et al. (1982) also reported conflicting results in their study on dietary sodium restriction and salt taste. These investigators found that while preference ratings for salt in soup and crackers decreased, an increase in rated saltiness-intensity occurred only for crackers.

In other studies, where diets were not experimentally manipulated, intensity judgements also varied considerably less than did ratings of preference. Sontag (1978) and Witherly (1978) studied preference for sweetness in lemonade in students and in normal and overweight adults. While participants exhibited distinct differences in hedonic functions, preferring either high, mid-range or low sucrose concentrations, much less variability was noted in individual sweetness intensity functions. Similarly, Drenowski et al. (1983) tested preference for sucrose and fat in milkshakes by obese, reduced-obese and normal weight individuals and found that despite significant differences in preference, the three groups displayed similar "sweetness" and "creaminess" intensity functions.

In the present study, independence of the hedonic and saltiness intensity ratings is at odds with comments by HPT participants that foods which, prior to dietary intervention tasted "O.K.", were "too

salty" after several weeks of reduced sodium intake. If true, one would expect ratings for some, if not all of the NaCl concentrations to increase. However, changes in perceived saltiness intensity may not have been revealed because of scaling behavior inherent to intensity rating tasks. Parducci (1974) has written extensively on "stimulus-range" or "centering-bias" effects associated with intensity scales. Generally, it has been shown that people tend to adjust intensity scales to fit the range of stimulus concentrations presented to them. As a result, the slope of intensity functions vary inversely with the range of concentrations in the stimulus, i.e., the rated intensity of a small range of concentrations increase faster than that of a larger range. In this case, since neither range of the NaCl concentrations (0.0-1.1% added NaCl), nor length of the rating scale (10 cm) were varied during the study, the least salty soup might consistently be judged as having "no saltiness" or near zero on the the scale, while the most concentrated soup might consistently be judged as "extremely salty" or near the endpoint of the scale. Once the extreme concentrations are matched to the scale endpoints, remaining concentrations are spaced somewhere in between. Because participants would tend to use the same criteria for rating the samples from week to week, saltiness ratings might vary little, despite possible changes in actual perceived saltiness intensity of the soups over time.

McBride (1982) proposed a rating method designed to minimize the concentration-range bias, in which judges sample only one stimulus per session. Because of the required interval between sessions (i.e., 24 hours), such a procedure would not be feasible in the context of the present study, due to time restrictions. Further investigation of

intensity responses and their measurement is required before definite conclusions can be drawn regarding the relationship between shifts in hedonic response to salt and perceived saltiness intensity.

4. Mechanisms for change in preference

The mechanisms underlying the changes in hedonic response and ad libitum salt preference in the NA, Nk and NW groups are not clear. A lowering of salivary sodium content should be considered because of its' influence on the perception of salty taste (McBurney and Pfaffmann, 1963; O'Mahony, 1979; Bartoshuk et al., 1964). However, shifts in taste perception of saltiness due to a process of sensory adaptation of the receptors to a lower level of salivary sodium, seems unlikely in the present study for several reasons. First, because participants were required to rinse their mouths with water between test samples, their receptors were probably adapted to the taste of the rinse water, and not to their saliva, throughout the study. Second, a role for salivary sodium assumes that reduced sodium intake in NA, NK and NW participants affected their salivary sodium concentration. However, the available evidence for a relation between dietary sodium intake and salivary sodium content is inconclusive. Neidermeirer et al. (1956) reported that supplements of 5900 mg NaCl/day, given for up to six days did not affect salivary sodium. Horowitz et al. (1982) noted reduced salivary sodium only when individuals were placed on a severly restricted sodium diet (i.e., 200 mg Na^+/day). Salivary sodium levels were 20 ± 2, 25 ± 2 and 26 ± 2 mEq/l on diets containing 200, 2500 and 5900 mg Na^+/day, respectively. Braddock (1982) observed that subjects categorized as having low-salt intakes had significantly lower salivary sodium than a high-salt intake group. In contrast, Pangborn and Pecore (1982) found a

nonsignificant trend for lower salivary sodium with higher salt intake. Finally, and perhaps most importantly, at least two studies have failed to demonstrate any relationship between salivary sodium levels and preference for salty taste (Pangborn and Pecore, 1982; Braddock, 1982).

Although evidence is lacking in humans, sodium deprivation may alter electrophysiological response to NaCl. Contreras and Frank (1979) have shown that chorda tympani, sodium-best fiber responsivity, to higher, suprathreshold NaCl concentrations, was significantly reduced in sodium-deprived compared to sodium-replete rats. Receptor change may account for the reduction in neural taste sensitivity in two ways: after sodium deprivation, either the effectiveness of the interaction between NaCl and its taste membrane components may be reduced, or the number of such components may be reduced. According to Contreras et al. (1984), altered taste sensitivity may have evolved as an adaptive mechanism to increase salt consumption. Indeed, in a 10 min. NaCl solution intake test, sodium-deprived animals were found to consume more of all concentrations presented than controls. The relationship between these electrophysiological and behavioral findings in sodium-deprived animals, versus the results of the present study, in which subjects were sodium-replete, but consuming less salt than usual, is unclear and warrants further investigation.

A more probable explanation for the reduction in preference for the taste of salt is mere adjustment by participants to the context of a diet composed of foods containing less sodium. Psychophysical experiments performed in the sensory laboratory lend support to this proposed mechanism. The context in which a given stimulus is judged has been

shown to affect sensory responses (Parducci, 1974; Riskey et al., 1979; Riskey, 1980). Defining context as the frequency with which a stimulus concentration occurs in a series, Riskey (1980) showed that low NaCl concentrations were judged "more pleasant" when tasted within the context of many other varying, but low NaCl samples. Riskey speculated that, outside the laboratory, diet may constitute a "context" relevant to taste where an individuals' preferences would tend to shift in the direction of frequently experienced flavors. In this case, frequent exposure to the taste of lower sodium-containing foods would produce a context in which foods one had previously been accustomed to, would taste more salty and less acceptable. This is supported by the observation that prior to initiation of the diets, sodium-restricted diet groups added approximately the same amount of NaCl to their ad libitum mixes (0.75%) as the level normally found in commercial, salted cream soups (0.8-1.15% added NaCl), products with which they would presumably be familiar. However, by the end of the study, this level of NaCl was less liked, and the diet groups had cut their mean ad libitum salting level by half.

Although not documented, informal comments made by NA, NK, and NW HPT participants, including those not taking part in the taste tests, support the "diet context" hypothesis. During the course of the dietary intervention progam, participants were asked to not salt food at the table, reduce or eliminate salt in cooking, and experiment with commercial low-sodium products (i.e., butter, cheese, bread, crackers, condiments, canned soups and vegetables etc.), thus creating the necessary low sodium "diet context". Initially, many participants found the low-sodium products tasteless or bland. This is consistent with other

reports regarding the acceptability of low-sodium diets (Thaler et al., 1982; Kris-Etherton et al., 1982). However, by the latter stages of the study, participants commented that some, but not all of these sodium-reduced foods tasted "O.K", while salted food items (i.e., cured meats, canned soups, pizza, home prepared foods to which the "usual" amount of salt had been added etc.), tasted "too salty".

Behavioral factors also may have played a role in changing preference for high- and low-sodium containing foods. Booth (1981) has emphasized that acceptance of a food is a dynamic process, involving at least four determinants: sensory qualities of the food, physiological states of the consumer, sociopsychological contexts and the effect of learning on all of these categories. According to Booth, processes most likely to effect a change in acceptability of a food, are sensory adaptation, familiarization, conditioning due to positive sensory and physiological consequences of ingestion, the influence of others as well as the media and finally, a sense of personal benefit, or well-being from eating the food. Applying these processes to the present study, familiarization with, and adaptation to the taste of low-sodium foods, increased acceptability induced by perceived physiological benefits (i.e., lower blood pressure, less water retention), heightened awareness of possible detrimental effects of excess dietary sodium and personal reinforcement from the sense that "less salt is better for me" may all have contributed to change in attitude and behavior towards salt.

B. Taste responses in weight loss and control groups

Although individuals in the NA, NK and NW diet groups served as their own controls over time, two comparison groups were also used in

this study. Individuals in the HPT weight loss group (WT) served to control for participation in the HPT intervention program *per se* while a no-diet-change group served as taste test only controls (CN). The differential responses between the sodium-restricted and comparison groups during the intervention period further substantiates the changes in salt preference observed in the NA, NK and NW groups.

An unexpected shift in hedonic response to NaCl also occurred in the WT group. Scores for mid-range (0.35, 0.55 and 0.8% NaCl) concentrations increased significantly over time. In addition, the WT group was the only diet treatment in which mean hedonic scores to their own *ad libitum* mixes, increased slightly, but significantly over time. Interestingly, however, the concentration of salt in the *ad libitum* mixes did not increase, but rather fluctuated randomly around the WT group's baseline salting level (0.90% added NaCl), with a slight tendency to decrease towards the end of the study. One explanation for these findings may be that after initial exposure to the test soups, the WT group's subjective opinion of their taste improved. Indeed, many WT participants strongly disliked the soup initially, but commented that it was less unpleasant with time. This is consistent with reports in the literature on the effects of exposure (experience with a stimuli) upon hedonic responses to unfamiliar foods. Harrison and Zazonc (1970) found that while repetition of an already familiar stimulus had a negligible effect on affective responses, novel stimuli were liked better with exposure. Murphy (1982) reported that solutions of salt in water, a product not normally consumed, were judged more pleasant with repeated exposure. This finding is in disagreement with the report by Bertino et al. (1982) that preference ratings for saline solutions by a group of *ad*

libitum diet controls tended to decrease over a five month period, while ratings for salt in more familiar food systems, soup and crackers, did not. Similarly, in the present study, no changes in hedonic ratings by controls were observed over time. Assuming that the test soup used in this study was initially unfamiliar to the participants, and an exposure effect was operating in the WT group, one would expect analogous trends in controls. However, this was not the case. One explanation for the differential responses between WT and CN groups may involve the salutary effects of participation in the HPT per se. The intervention and monitoring activities of the HPT provided many tangible and intangible benefits to WT participants (i.e., group involvement, health education, loss of weight, possible lowering of blood pressure, positive feedback from goal achievement, etc.), whereas controls may have felt little or no personal betterment from participation in the taste tests alone. Thus, a sense of well-being may, on a conscious or subconscious level, have influenced WT participants' attitude toward the test soups. Alternatively, it is possible that weight loss, or low calorie diets per se may have affected hedonic responses to NaCl, but few studies have tested this hypothesis. For example, Rodin et al. (1976) found no change in "pleasantness" ratings for increasing concentrations of salt in water following jejuno-ileostomy and weight loss in 11 overweight women. However, hedonic evaluation of saline solutions are not necessarily relevant to the taste of salt in real foods. A current investigation, assessing the effect of weight loss on hedonic response to salt in an actual food system should help clarify this issue (A. Kaye, personal communication, 1985).

Few changes in salt preference were observed in controls over time. Hedonic responses to the NaCl concentration series were similar from week to week, however a slight drop in ratings for the highly pre-salted 1.5% NaCl sample did occur in the ad libitum mixing test. Also, significantly less NaCl was added to soup at week 24 than during the first three weeks of the study. The latter changes did not correlate with variation in sodium intake or excretion measures, which were similar at baseline, week 12 and week 24 of study.

C. Sodium intake and excretion

Sodium intake in the present study was assessed via random, single 24-hour food records and analysis of corresponding overnight urine specimens for sodium excretion. Baseline dietary sodium intakes, as determined by the 24-hour records, was in line with sodium estimates from previous investigations involving longer documentation periods. Using four series of seven-day food records, Holbrook et al. (1984) found mean sodium intakes of 2300 and 3300 mg Na^+/day for 16 women and 12 men, respectively, compared to mean intakes of 2375 and 3490 mg Na^+/day for 22 women and 54 men in the present study. Similarly, Bertino et al. (1982) observed a mean daily sodium intake of 3175 mg Na^+ in eight individuals on ad libitum salt diets, as determined by seven-day food records. The results of the present study confirm the widely-held opinion that although a 24-hour food record may not be representative of an individual's usual intake, it is a practical, and statistically acceptable alternative to more lengthy documentation methods, given an adequate sample size (Garn et al., 1978; Block, 1982; Todd et al., 1983).

The overnight urinary sodium/creatinine excretion ratios used in this study, served to validate results of the 24-hour food records and establish relationships among the five diet groups, rather than to estimate sodium intake. Urinary sodium/creatinine excretion ratios correlated well with dietary sodium intake in the pooled low-sodium (NA, NK, NW) but not in WT or CN groups. Many factors may have contributed to lack of correlation in the latter two diet groups. First, the sample size of the WT (n=13) and CN (n=20) groups may have been too small to show a relationship. For example, sodium intake and excretion were not correlated in the NA (n=15) or NK (n=15) groups alone. However, pooling of the three sodium-restricted diet modalities increased the sample size to 43 and resulted in a significant sodium intake/excretion relationship. A second confounding factor, involves mechanisms of sodium homeostasis. Because of variability in the delay required for equilibrium to occur following changes in sodium intake, the amount of sodium excreted overnight may not accurately reflect the previous days' consumption. Several factors influencing urinary sodium output include: sodium intake *per se*, potassium intake, degree of hydration and level of physical activity (Schacter et al., 1979; Watson and Langford, 1970). In addition to these factors, the time of day that sodium is consumed particularly affects validity of overnight urine specimens (Watson and Langford, 1970). For example, salted foods (i.e., pizza, cheese and crackers) consumed late at night or at bedtime would results in higher nocturnal excretion of sodium than if the same foods were eaten earlier in the day. In spite of these numerous sources of variability, and of the lack of correlation between sodium intake and excretion in the WT and CN groups, the same relationship was observed among the five diet

treatments with respect to sodium intake and overnight sodium/g creatinine excretion, following initiation of the diets (i.e., NA-NK-NW < WT or CN).

D. Validity of ad libitum mixing

Although this study was not originally intended to test the validity of sensory methods, the finding that dietary sodium intake and excretion correlated significantly with salt preferences quantified in the ad libitum mixing procedure, corroborates and extends previous research. Unlike the present study, previous investigations on the relationship between dietary sodium intake and ad libitum salt preferences have relied on food frequency questionnaires to categorize subjects into low-, medium- and high-intake groups, and were not designed to examine changes with diet. Stone (1984) found that subjects in a high-salt group mixed significantly saltier broths than either low- or medium-intake groups. Other studies using ad libitum salting of tomato juice (Pangborn and Pecore, 1982) or chicken broth (Braddock, 1982) however, were inconclusive, owing primarily to difficulties in classifying participants according to salt intake. In the present study, actual estimates of sodium intake were used. In addition, ad libitum salt preferences were tested under two experimental conditions: at baseline and during the dietary intervention period. The preferred concentration of salt in ad libitum mixes at baseline correlated significantly with 24-hour dietary sodium intakes ($r=0.29$, $p=0.01$, $n=74$) and sodium/creatinine excretion ($r=0.28$, $p=0.02$, $n=75$). Interestingly, baseline ad libitum mix concentrations also correlated with number of meals consumed away from home ($r=0.25$, $p=0.03$, $n=75$), where consumers

presumably have less control over sodium intake and foods are likely to contain more salt. Furthermore, it was demonstrated that ad libitum NaCl preferences decreased with sodium in the diet, and that magnitude of the concentration change was equivalent to that observed between pre- and post-diet hedonic maxima in the hedonic scaling test. These results confirm and extend the report by Stone (1984), that the ad libitum mixing method is a simple, reliable alternative to traditional hedonic scaling for quantifying salt taste preference.

CONCLUSIONS

This study examined the nature and direction of changes in salt taste, during a six month period, in invididuals following moderately-reduced sodium diets.

Reduction in sodium intake and overnight urinary sodium excretion was accompanied by a steady, progressive decline in amount of salt added to soup to achieve a concentration of preference. In hedonic scaling tests, liking for concentrations of salt in soup equivalent to that of commercial products decreased, while liking for low-sodium soup increased gradually over time. Change in preference occured independently of alterations in energy or potassium intake, and were not associated with changes in perceived saltiness intensity.

These results confirm anecdotal reports that patients on low-sodium diets gradually prefer less salt in food (Dahl, 1960; Thaler et al., 1982). However, there was no evidence to support an increased attraction or craving for salt during the initial stages of the diet, as previously shown by Bertino et al. (1981).

Approximately three months were required for preferences to stabilize at a lower salt level. This may be of relevance in clinical settings where low-sodium diets are used for the treatment or prevention of hypertension. Efficacy of intervention might be improved if frequent counseling is provided until individuals have adjusted to the taste of foods containing less salt. Further study is needed to examine the importance of salt taste and long-term compliance.

Results of this study support and confirm the usefulness and validity of the ad libitum mixing procedure as a means of assessing salt preference. Change in the concentration of ad libitum mixes related well to shifts in hedonic responses for an NaCl concentration series. In addition, concentration of ad libitum mixes correlated with measures of sodium intake and excretion, before and after modification of salt intake.

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APPENDIX

Ancillary Study
The Hypertension Prevention Trial
University of California, Davis

Title of Study

Relation Between Dietary Changes And Sensory Responses To A Food.

Investigators

Nemat O. Borhani, M.D., Department of Community Health, School of Medicine. University of California, Davis, 95616, 752-1352, and Christina Blais, Department of Nutrition.

Purpose:

You are invited to participate in an ancillary study concerned with how changes in food habits over time might alter your sensory responses to food.

Procedures:

If you decide to volunteer, you will be asked to partake in nine, simple 15-minute taste experiments, in room TB 167B of the Dept. of Community Health, immediately following your regularly scheduled HPT group intervention meetings. These will be meetings on weeks 2, 4, 6, 8, 10, 12, 18, and 24. An introductory taste session will be organized prior to the first HPT intervention group meeting. These taste experiments will require that you taste various cream soups to measure your degree of liking.

Risks:

There are no known risks or discomforts involved in participation in this ancillary study. The soups will consist of commercial products purchased at local supermarkets and handled under careful supervision. You are not required to swallow the samples.

Participation:

Participation in this study is entirely voluntary. Declining will in no way compromise your future relations with the Hypertension Prevention Trial or any members of the staff.

Benefits:

We forsee no immediate benefits of this study to the participants.

Confidentiality:

All information will be coded so that it cannot be identified with you personally, and will remain confidential.

Cost:

There will be no cost to you for participation in this study.

Right to withdraw:

If you decide to participate, you are free to withdraw at any time.

Questions:

If you have any questions please ask us. Nemat O. Borhani, M.D. or Christina Blais will be happy to answer them at the Department of Community Health, TB 168, University of California, Davis, CA 95616. (916) 752-1352. We would greatly appreciate your participation as the data will form an important part of the research being initiated by Christina Blais.

YOUR SIGNATURE BELOW WILL INDICATE THAT YOU HAVE DECIDED TO VOLUNTEER FOR THIS ANCILLARY STUDY ON THE RELATION BETWEEN DIETARY CHANGES AND SENSORY RESPONSES TO FOOD.

_____ _____

Date Signature of Participant

_____ _____

Date Signature of Witness

Informed Consent Form
Ancillary Study
The Hypertension Prevention Trial
University of California, Davis

Title of Study

Relation Between Dietary Intake and Sensory Responses to a Food.

Investigators

Nemat O. Borhani, M.D., Department of Community Health, School of Medicine, University of California, Davis, 95616, 752-1352, and Christina Blais, Department of Nutrition.

Purpose

You are invited to participate in an Ancillary Study of the Hypertension Prevention Trial, concerned with the possible relationship between food habits and taste responses to food. We also hope to learn whether sensory responses ro a food change over time.

Procedures

If you decide to participate, you will be asked to partake in nine simple 15-minute taste experiments in TB 167A or TB 167B of the Department of Community Health. These tests will take place in the evening, either Tuesday, Wednesday or Thursday, between 7:30 and 8:00 from October through April. The exact schedule will be announced in September.

In addition, you will be asked to complete three detailed 24-hour dietary food records and collect three overnight urine samples at regular intervals. A questionnaire to establish age, height, weight, current medication, demographic data and dietary patterns will be taken.

Risks

There are no known risks or discomforts involved in participation in this study. The soups will consist of commercial products purchased at local supermarkets and handled under careful supervision. You are not required to swallow the samples.

Participation

Participation is entirely voluntary.

Benefits

You will receive a detailed nutrient analysis of your food intake based on the 24-hour food records.

Confidentiality

All information will be coded so that it cannot be identified with you personally, and will remain confidential.

Cost

There will be no cost to you for participation in this study.

Right to withdraw

If you decide to participate, you are free to withdraw at any time.

Questions:

If you have any questions, please ask us. Nemat O. Borhani, M.D. or Christina Blais will be happy to answer them at the Department of Community Health, TB 168, University of California, Davis, CA 95616, (916) 752-1352. We would greatly appreciate your participation as the data will form an important part of the research being initiated by Christina Blais.

YOUR SIGNATURE BELOW WILL INDICATE YOU HAVE DECIDED TO VOLUNTEER FOR THIS STUDY ON THE RELATION BETWEEN DIETARY INTAKE AND SENSORY RESPONSES TO A FOOD.

_____ _____

Date Signature of Participant

_____ _____

Date Signature of Witness

C/08/83

ANCILLARY STUDY
HYPERTENSION PREVENTION TRIAL
RELATION BETWEEN DIETARY INTAKE AND TASTE RESPONSES

QUESTIONNAIRE

1) Date of HPT BL1 visit: _____

2) Name: _____

3) Height: _____feet _____inches

4) Weight: _____lbs

5) Sex ( ) M ( ) F

Please answer the following questions:

6) How would you characterize your ethnic group? Check:
( ) White
( ) Black
( ) Hispanic
( ) Asian
( ) Other (Specify) _____.

7) What is the highest grade you completed in school? Check one:
( ) No formal education
( ) Grade 6 or less
( ) Grades 7, 8, 9
( ) Grades 10 or 11
( ) Grade 12 (H.S. graduate)
( ) 1 yr college
( ) 2,3,or 4 yrs college (without degree)
( ) Degree from 4 yr college
( ) Some graduate education
( ) Graduate degree

8) What is your current job? _____

9) Which category best describes your job? Check one:
( ) Professional, technical
( ) Managers, Administrators,
( ) Sales workers
( ) Clerical
( ) Craftsman
( ) Operatives and transport workers
( ) Laborer, except farm
( ) Farmers, farm managers
( ) Farm laborers & foremen
( ) Service workers

10) How many meals do you eat away from home per week, not counting lunches brought from home?
_____ per week

11) Are you currently taking any prescription or non-prescription drugs?
( ) yes
Name of drug(s) _____
_____
( ) no

12) Which foods do you think are highest in sodium content. Check one in each category:

a. Meat
( ) Hamburger with bun
( ) Bologna sandwich
( ) Turkey sandwich
( ) Don't know

b. Snack
( ) Two cookies with cream filling
( ) Cherry snack pie
( ) Small package of potato chips
( ) Don't know

c. Vegetables
( ) Fresh peas
( ) Canned peas
( ) Frozen peas
( ) Don't know

d. Bread
( ) Two slices of bread
( ) English muffin
( ) One medium pancake
( ) Don't know

e. Beverage
( ) Orange juice
( ) Vegetable juice
( ) Diet soda
( ) Don't know

13) Do you salt food when cooking?
( ) Yes
( ) No
( ) Don't cook

14) Do you salt your food at the table?
( ) Yes
( ) No

If yes, do you salt:
( ) Before tasting
( ) After tasting
( ) Both

15) Do you use a salt substitute such as No Salt, Low Salt, or Lite Salt?
( ) Yes
( ) No

ANCILLARY STUDY
HYPERTENSION PREVENTION TRIAL
RELATION BETWEEN DIETARY INTAKE AND TASTE RESPONSES

OVERNIGHT URINE COLLECTION AND FOOD RECORD FORM

The information on this form provides instructions for your food record and urine collection. Please fill in the boxed dates and times as directed. The urine collection follows the day you begin to complete your food record.

Name: _____

Day of week and date on which you are to begin your food record:
_____, _____.

STEP 1

- Record the time you arise on the day assigned above for your food record

TIME:

- Please enter all items you eat or drink throughout the day and night, beginning at the time you recorded above and ending at the time you arise the next day.

STEP 2

- Empty your bladder before going to bed the evening of:
_____, _____
DO NOT COLLECT THIS URINE.

- Record the time of this evening voiding:

TIME:

STEP 3

- Collect all urine voided throughout the night and the first urine upon arising from bed, the morning of _____, _____.

  Use the bottle provided, leaving the tablets in the bottle for preservation. The urine DOES NOT need to be refrigerated.

- Record the date, day and time of this morning voiding:

DAY:
DATE:
TIME:

STEP 4

- Bring this form, the food record and urine bottle to your next clinic visit, scheduled for:

DAY:_____
DATE:_____
TIME:_____

THANK YOU!!!

Christina Blais

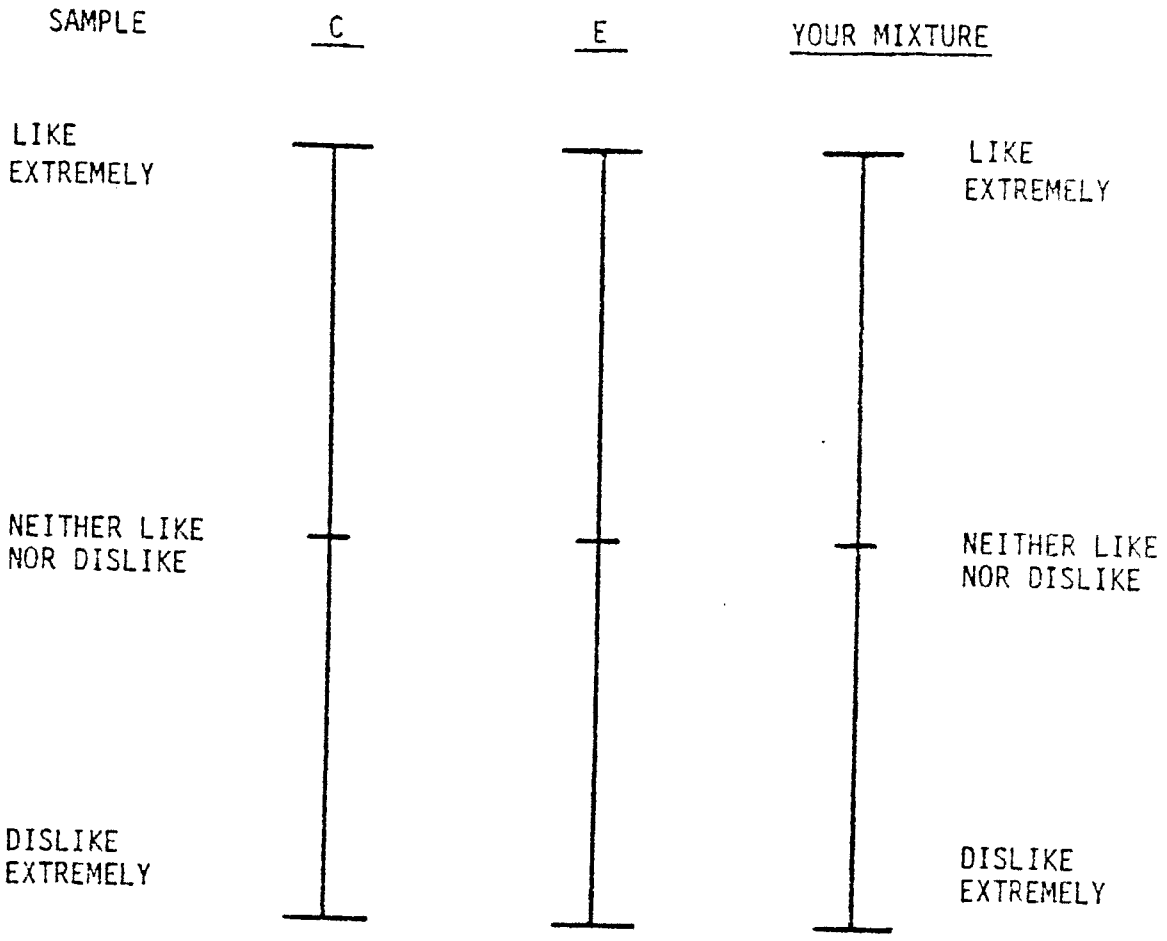
If you have any questions or problems concerning these directions or the completion of the collections, please call me at 752-1352.

AD LIBITUM MIXING: CREAM SOUPS SET NO._____

JUDGE NO. _____ SESSION NO. _____ DATE_____

INSTRUCTIONS:

YOU WILL RECEIVE TWO SAMPLES OF SOUP AND AN EMPTY CUP.
FIRST TASTE "C" (CONTROL), THEN TASTE "E" (EXPERIMENTAL). DO NOT SWALLOW.
RECORD YOUR DEGREE OF LIKING FOR EACH BELOW, BY PLACING A MARK ON THE LINE.
THEN, MIX PORTIONS OF C AND E INTO THE EMPTY CUP UNTIL YOU OBTAIN A MIXTURE YOU PREFER.
FINALLY, TASTE THE MIXTURE AND RECORD YOUR DEGREE OF LIKING BELOW. DO NOT SWALLOW.
RINSE YOUR MOUTH WITH WATER BETWEEN SAMPLES. DO NOT SWALLOW.



COMMENTS:

APPENDIX VI. Scoresheets for hedonic and saltiness intensity scaling of concentration series if NaCl in soup.

DEGREE OF LIKING FOR CREAM SOUPS

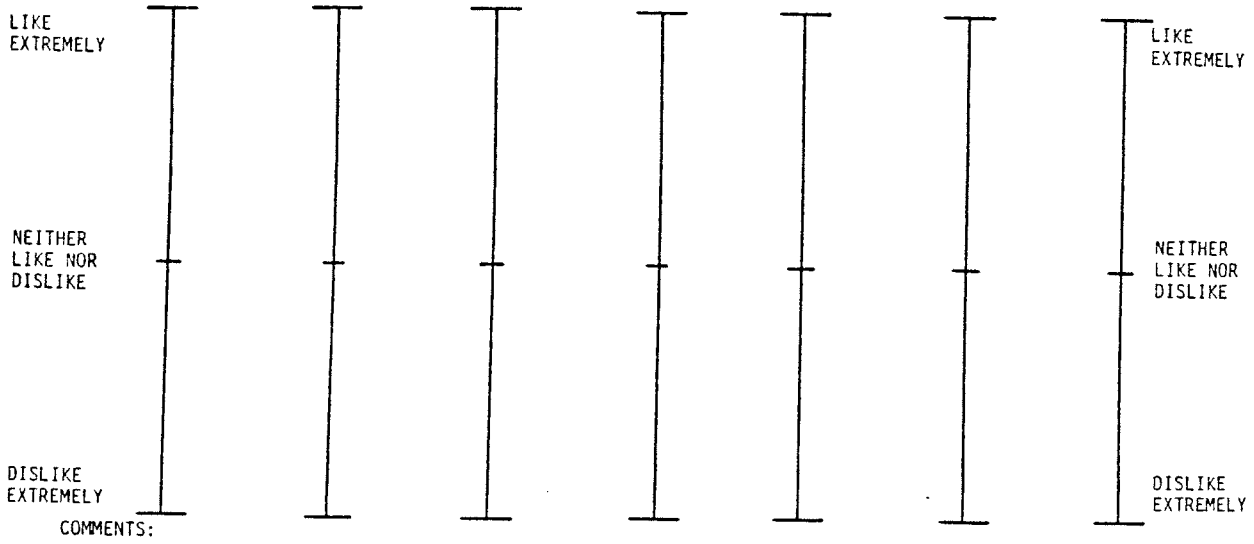
SET NO._____

JUDGE NO._____ SESSION NO._____ DATE_____

INSTRUCTIONS:

TASTE SAMPLES IN ORDER PRESENTED. PLACE ABOUT 1 teaspoon IN MOUTH, MOVE IT AROUND WITH TONGUE AND EXPECTORATE INTO CUSPIDOR. DO NOT SWALLOW.
RECORD YOUR DEGREE OF LIKING FOR EACH, BY PLACING A MARK ON THE LINES BELOW. RETASTING O.K.
BETWEEN SAMPLES, RINSE YOUR MOUTH WITH WATER. DO NOT SWALLOW.

SAMPLE NUMBER _____ _____ _____ _____ _____ _____ _____



COMMENTS:

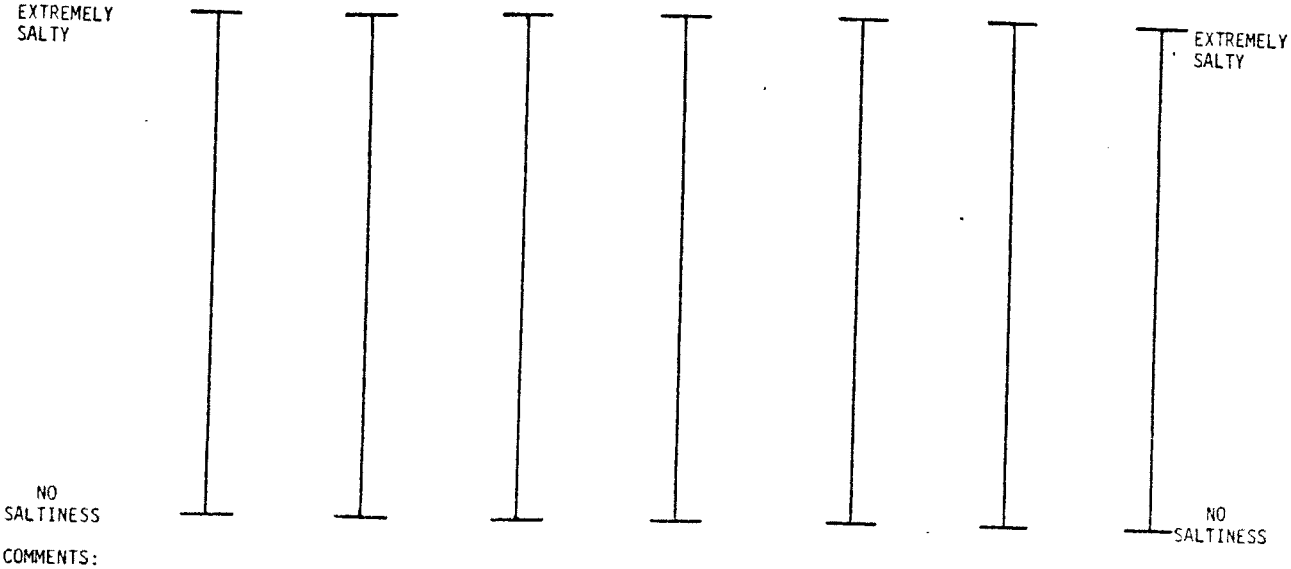
SALTINESS INTENSITY OF CREAM SOUPS

JUDGE NO._____ SESSION NO._____ DATE_____ SET NO._____

INSTRUCTIONS:

TASTE SAMPLES IN ORDER PRESENTED. PLACE ABOUT 1 teaspoon IN MOUTH, MOVE IT AROUND WITH TONGUE AND EXPECTORATE INTO CUSPIDOR. DO NOT SWALLOW.
RECORD YOUR PERCEPTION OF SALTINESS INTENSITY FOR EACH, BY PLACING A MARK ON THE LINES BELOW. RETASTING O.K.
BETWEEN SAMPLES, RINSE YOUR MOUTH WITH WATER. DO NOT SWALLOW.

SAMPLE NUMBER _____ _____ _____ _____ _____ _____ _____



COMMENTS:

APPENDIX VII: Operating condition for sodium electrode.

1. pH Meter

- Calibrate to pH 7, 000 mV, using pH electrode immersed in stock pH 7 buffer.
- Disconnect pH electrode; connect sodium and reference electrodes.
- Allow standards and samples to reach room temperature.
- Stir solutions with magnetic stirrer, while taking mV measurement.
- Leave meter in "stand-by" mode when not in use.

2. Electrodes

The following conditions apply only to Lazar (Los Angeles, CA) sodium electrode model no. IS-46.

- Store sodium electrode in 0.001M NaCl in 0.5M triethanolamine (TEA) at pH 10.2 when not in use.
- If sodium electrode becomes sluggish, precondition in a solution of 5.0M NaCl in 0.5M TEA, overnight, prior to use.
- Rinse both sodium and reference electrode with 0.5M TEA, pH 10.2, between all samples; blot dry.
- Check that reference electrode contains an adequate amount of filling solution (up to fill hole).

APPENDIX VIII. Mean[1] hedonic response to test sample "C" (0.0% added NaCl), subdivided by diet group, site and weeks on diet. (Number of subjects in parenthesis)

DIET[2]	SITE[3]	WEEKS ON DIET 0	1	3	6	8	10	13	24	F-RATIO[4] SIG p=
NA	UCD	3.9^{ab} (8)	3.1^{a} (9)	4.6^{ab} (8)	4.2^{ab} (9)	4.6^{ab} (9)	5.1^{ab} (8)	5.4^{ab} (9)	6.4^{b} (7)	0.02
	UMN	2.2^{a} (6)	4.2^{ab} (6)	3.8^{ab} (6)	4.4^{b} (6)	4.4^{b} (6)	4.5^{b} (6)	4.5^{b} (6)	5.1^{b} (6)	0.005
	pooled	3.2^{a} (14)	3.6^{a} (15)	4.2^{ab} (14)	4.3^{ab} (15)	4.5^{ab} (15)	4.8^{ab} (14)	5.0^{b} (15)	5.8^{b} (13)	0.0005
NK	UCD	3.7 (12)	4.0 (11)	4.1 (11)	4.3 (10)	3.4 (10)	3.8 (11)	5.0 (6)	4.5 (12)	0.7
	UMN	4.3 (3)	4.8 (3)	5.5 (3)	5.2 (3)	5.7 (3)	5.6 (3)	6.0 (3)	6.5 (3)	0.16
	pooled	3.8 (15)	4.2 (14)	4.4 (14)	4.5 (13)	3.9 (13)	4.2 (13)	5.3 (9)	4.9 (15)	0.45
NW	UCD	3.8 (9)	5.2 (8)	4.4 (9)	4.3 (8)	4.8 (9)	4.9 (9)	5.4 (4)	5.5 (8)	0.6
	UMN	3.2 (4)	3.4 (4)	3.8 (4)	3.3 (4)	5.3 (4)	3.3 (4)	5.6 (3)	5.2 (4)	0.2
	pooled	3.6 (13)	4.6 (12)	4.2 (13)	4.0 (12)	5.0 (13)	4.4 (13)	5.5 (7)	5.4 (12)	0.15
NA-NK-NW	pooled	3.5^{a} (42)	4.1^{a} (41)	4.3^{ab} (41)	4.3^{ab} (40)	4.5^{abc} (41)	4.5^{abc} (41)	5.2^{bc} (31)	5.3^{c} (40)	0.0001
WT	UCD	2.5 (8)	3.4 (8)	2.4 (8)	4.0 (7)	2.9 (7)	2.9 (8)	3.4 (7)	3.5 (8)	0.38
	UMN	3.1 (5)	4.2 (5)	4.7 (5)	4.6 (4)	3.4 (5)	3.6 (5)	4.6 (5)	3.6 (5)	0.33
	pooled	2.7 (13)	3.7 (13)	3.3 (13)	4.2 (11)	3.2 (12)	3.2 (13)	3.9 (12)	3.5 (13)	0.20
CN	UCD	3.3 (12)	4.0 (12)	4.2 (12)	4.4 (12)	4.0 (10)	4.2 (12)	4.0 (11)	3.5 (12)	0.35
	UMN	3.5 (8)	4.2 (8)	4.1 (8)	4.7 (8)	4.5 (8)	4.5 (6)	4.1 (8)	4.3 (8)	0.52
	pooled	3.4 (20)	4.1 (20)	4.2 (20)	4.5 (20)	4.2 (18)	4.3 (18)	4.0 (19)	4.1 (20)	0.13

[1]Means sharing or having no superscript within a diet group do not differ significantly at $p < 0.05$ (Bonferrani).

[2]NA, NK, NW, WT, CN refer to low sodium, low sodium-high potassium, low sodium-weight loss, weight loss and control, respectively.

[3]UCD, UMN refer to University of California, Davis and University of Minnesota, Minneapolis.

[4]Probability of F-ratio for "weeks", by one-way analysis of variance.

APPENDIX IX. Mean[1] hedonic response to test sample "E" (1.57% added NaCl), subdivided by diet group group, site and weeks on diet. (Number of subjects in parenthesis)

DIET[2]	SITE[3]	WEEKS ON DIET 0	1	3	6	8	10	13	24	F-RATIO[4] SIG p=
NA	UCD	3.8^{ab} (8)	4.0^{a} (9)	3.3^{abc} (8)	1.7^{abc} (9)	1.5^{abc} (9)	1.2^{bc} (8)	0.96^{bc} (9)	1.4^{c} (7)	0.0003
	UMN	2.7 (6)	2.3 (6)	1.6 (6)	1.1 (6)	1.2 (6)	0.98 (6)	1.53 (6)	1.62 (6)	0.04
	pooled	3.3^{a} (14)	3.4^{a} (15)	2.6^{ab} (14)	1.5^{b} (15)	1.4^{b} (15)	1.1^{b} (14)	1.2^{b} (15)	1.5^{b} (13)	0.0001
NK	UCD	4.5 (12)	4.3 (11)	2.1 (11)	4.3 (9)	2.7 (10)	2.0 (11)	3.3 (6)	2.6 (12)	0.015
	UMN	1.4 (3)	2.2 (3)	2.8 (3)	1.6 (3)	2.4 (3)	1.6 (3)	2.4 (3)	2.1 (3)	0.04
	pooled	3.9 (15)	3.8 (14)	2.3 (14)	3.6 (13)	2.6 (13)	1.9 (13)	3.0 (9)	2.5 (15)	0.04
NW	UCD	5.1 (9)	4.1 (8)	3.6 (9)	2.8 (8)	3.0 (9)	2.5 (9)	3.0 (4)	2.9 (8)	0.02
	UMN	5.3 (4)	3.7 (4)	3.4 (4)	2.9 (4)	3.2 (4)	2.8 (4)	3.8 (3)	3.5 (4)	0.2
	pooled	5.2^{a} (13)	4.0^{ab} (12)	3.5^{ab} (13)	2.9^{b} (12)	3.1^{b} (13)	2.6^{b} (13)	3.4^{ab} (7)	3.1^{b} (12)	0.0006
NA-NK-NW	pooled	4.1^{a} (42)	3.7^{ab} (41)	2.8^{bc} (41)	2.6^{bc} (39)	2.3^{c} (41)	1.8^{c} (41)	2.2^{c} (31)	2.4^{c} (40)	0.0001
WT	UCD	5.6 (8)	4.8 (8)	4.7 (8)	5.3 (7)	4.8 (7)	4.4 (8)	4.4 (7)	5.1 (8)	0.60
	UMN	3.6 (5)	3.5 (5)	3.8 (5)	4.8 (4)	3.6 (5)	5.7 (5)	5.1 (5)	4.9 (5)	0.14
	pooled	4.8 (13)	4.3 (13)	4.4 (13)	5.1 (11)	4.3 (12)	4.9 (13)	4.7 (12)	5.0 (13)	0.64
CN	UCD	4.6^{a} (12)	4.0^{ab} (12)	3.8^{ab} (12)	3.6^{ab} (12)	3.7^{ab} (10)	3.5^{ab} (12)	2.6^{b} (11)	3.0^{ab} (12)	0.05
	UMN	4.2 (8)	5.1 (8)	4.3 (8)	4.3 (8)	4.4 (8)	4.1 (6)	3.8 (8)	3.8 (8)	0.12
	pooled	4.4^{a} (20)	4.4^{a} (20)	4.0^{ab} (20)	3.9^{ab} (20)	4.0^{ab} (18)	3.7^{ab} (18)	3.1^{b} (19)	3.5^{ab} (20)	0.01

[1]Means sharing or having no superscript within a diet group do not differ significantly at $p < 0.05$ (Bonferrani).

[2]NA, NK, NW, WT, CN refer to low sodium, low sodium-high potassium, low sodium-weight loss, weight loss and control, respectively.

[3]UCD, UMN refer to University of California, Davis and University of Minnesota, Minneapolis.

[4]Probability of F-ratio for "weeks", by one-way analysis of variance.

APPENDIX X. Mean[1] hedonic response ad libitum "MIX", subdivided by diet group, site and weeks on diet. (Number of subjects in parenthesis).

DIET[2]	SITE[3]	WEEKS ON DIET 0	1	3	6	8	10	13	24	F-RATIO[4] SIG p=
NA	UCD	6.9 (8)	7.1 (9)	6.6 (8)	7.1 (9)	6.8 (9)	6.9 (8)	7.4 (9)	7.3 (7)	0.91
	UMN	4.7^{ab} (6)	4.3^{a} (6)	4.7^{ab} (6)	5.3^{ab} (6)	5.4^{ab} (6)	5.3^{ab} (6)	5.2^{ab} (6)	6.0^{b} (6)	0.01
	pooled	6.0 (14)	6.0 (15)	5.8 (14)	6.3 (15)	6.2 (15)	6.2 (14)	6.5 (15)	6.7 (13)	0.21
NK	UCD	5.8 (12)	6.3 (11)	6.4 (11)	5.9 (10)	5.7 (10)	5.7 (11)	5.9 (6)	6.4 (12)	0.82
	UMN	5.9 (3)	5.8 (3)	6.4 (3)	6.6 (3)	6.4 (3)	6.4 (3)	6.8 (3)	6.7 (3)	0.50
	pooled	5.8 (15)	6.2 (14)	6.4 (14)	6.0 (13)	5.9 (13)	5.9 (14)	6.2 (9)	6.5 (15)	0.76
NW	UCD	6.5 (9)	6.9 (8)	6.8 (9)	6.6 (7)	6.5 (9)	6.8 (9)	8.1 (4)	6.5 (8)	0.90
	UMN	7.0 (4)	5.4 (4)	5.7 (4)	5.6 (4)	6.3 (4)	5.8 (4)	7.1 (3)	6.7 (4)	0.32
	pooled	6.7 (13)	6.4 (12)	6.5 (13)	6.2 (11)	6.4 (13)	6.5 (13)	7.7 (7)	6.6 (12)	0.90
WT	UCD	5.4 (8)	5.7 (8)	6.1 (8)	6.5 (7)	6.2 (7)	6.3 (8)	5.9 (7)	6.5 (8)	0.29
	UMN	4.8 (5)	5.7 (5)	6.1 (5)	6.1 (4)	5.1 (5)	6.3 (5)	6.7 (5)	6.5 (5)	0.07
	pooled	5.1^{a} (13)	5.7^{ab} (13)	6.1^{ab} (13)	6.3^{ab} (11)	5.8^{ab} (12)	6.3^{ab} (13)	6.2^{ab} (12)	6.5^{b} (13)	0.02
CN	UCD	6.1 (12)	6.2 (12)	6.4 (12)	6.3 (12)	5.9 (10)	6.5 (12)	5.9 (11)	6.3 (12)	0.77
	UMN	7.0 (8)	7.4 (8)	6.5 (8)	6.9 (8)	6.6 (8)	7.0 (6)	7.1 (8)	6.4 (8)	0.31
	pooled	6.5 (20)	6.7 (20)	6.5 (20)	6.5 (20)	6.2 (18)	6.6 (18)	6.4 (19)	6.3 (20)	0.75

[1]Means sharing or having no superscript within a diet group do not differ significantly at $p < 0.05$ (Bonferrani).

[2]NA, NK, NW, WT, CN refer to low sodium, low sodium-high potassium, low sodium-weight loss, weight loss and control, respectively.

[3]UCD, UMN refer to University of California, Davis and University of Minnesota, Minneapolis.

[4]Probability of F-ratio for "weeks", by one-way analysis of variance.

APPENDIX XI. Mean[1] NaCl concentration (% added NaCl) of ad libitum mixes, subdivided by diet group, site and weeks on diet. (Number of subjects in parenthesis).

DIET[2]	SITE[3]	WEEKS ON DIET 0	1	3	6	8	10	13	24	F-RATIO[4] SIG p=
NA	UCD	0.77^{a} (8)	0.59^{ab} (9)	0.59^{ab} (8)	0.50^{abc} (9)	0.32^{bc} (9)	0.42^{bc} (8)	0.37^{bc} (9)	0.27^{c} (7)	0.0001
	UMN	0.66^{a} (6)	0.41^{b} (6)	0.25^{b} (6)	0.21^{b} (6)	0.23^{b} (6)	0.22^{b} (6)	0.24^{b} (6)	0.25^{b} (6)	0.0001
	pooled	0.72^{a} (14)	0.52^{b} (15)	0.44^{bc} (14)	0.38^{bc} (15)	0.28^{c} (15)	0.33^{bc} (14)	0.32^{c} (15)	0.26^{c} (13)	0.0001
NK	UCD	0.75^{a} (12)	0.71^{ab} (11)	0.66^{ab} (11)	0.61^{abc} (10)	0.58^{abc} (10)	0.45^{bc} (11)	0.38^{c} (6)	0.36^{c} (12)	0.0001
	UMN	0.54 (3)	0.30 (3)	0.29 (3)	0.24 (3)	0.23 (3)	0.25 (3)	0.22 (3)	0.11 (3)	0.22
	pooled	0.71^{a} (15)	0.62^{ab} (14)	0.58^{abc} (14)	0.53^{abcd} (13)	0.50^{abcd} (13)	0.40^{bcd} (14)	0.32^{cd} (9)	0.31^{d} (15)	0.0001
NW	UCD	0.70^{ab} (9)	0.66^{abc} (8)	0.75^{a} (9)	0.56^{abc} (8)	0.54^{abc} (9)	0.41^{bc} (9)	0.37^{c} (4)	0.46^{abc} (8)	0.001
	UMN	0.85^{a} (4)	0.65^{ab} (4)	0.52^{ab} (4)	0.57^{ab} (4)	0.61^{ab} (4)	0.50^{ab} (4)	0.40^{b} (3)	0.38^{b} (4)	0.04
	pooled	0.75^{a} (13)	0.66^{ab} (12)	0.68^{a} (13)	0.56^{ab} (12)	0.56^{ab} (13)	0.44^{b} (13)	0.38^{b} (7)	0.43^{b} (12)	0.90
NA-NK-NW	pooled	0.72^{a} (42)	0.59^{b} (41)	0.57^{b} (41)	0.48^{bc} (40)	0.44^{cd} (41)	0.39^{cd} (41)	0.35^{d} (31)	0.33^{d} (40)	0.0001
WT	UCD	1.02^{a} (8)	0.95^{ab} (8)	1.06^{a} (8)	0.96^{ab} (7)	1.01^{a} (7)	0.89^{ab} (8)	0.70^{b} (7)	0.69^{b} (8)	0.0001
	UMN	0.73^{ab} (5)	0.77^{ab} (5)	0.96^{a} (5)	0.58^{b} (4)	0.85^{ab} (5)	0.99^{a} (5)	0.77^{ab} (5)	0.88^{ab} (5)	0.02
	pooled	0.91^{abc} (13)	0.88^{abc} (13)	1.02^{c} (13)	0.82^{abc} (11)	0.95^{bc} (12)	0.93^{abc} (13)	0.73^{a} (12)	0.76^{ab} (13)	0.003
CN	UCD	0.80 (12)	0.73 (12)	0.76 (12)	0.74 (12)	0.65 (10)	0.81 (12)	0.73 (11)	0.56 (12)	0.03
	UMN	0.71^{ab} (8)	0.86^{a} (8)	0.89^{a} (8)	0.76^{ab} (8)	0.71^{ab} (8)	0.48^{b} (6)	0.69^{ab} (8)	0.56^{ab} (8)	0.05
	pooled	0.76^{a} (20)	0.78^{a} (20)	0.81^{a} (20)	0.75^{ab} (20)	0.68^{ab} (18)	0.70^{ab} (18)	0.71^{ab} (19)	0.56^{b} (20)	0.03

[1]Means sharing or having no superscript within a diet group do not differ significantly at $p < 0.05$ (Bonferrani).

[2]NA, NK, NW, WT, CN refer to low sodium, low sodium-high potassium, low sodium-weight loss, weight loss and control, respectively.

[3]UCD, UMN refer to University of California, Davis and University of Minnesota, Minneapolis.

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