Dietary Sodium Reduction for Hypertension
Prevention and Treatment
Patricia J. Elmer, Richard H. Grimm Jr., John Flack, and Brian Laing

Nutritional–nonpharmacological approaches for the treatment and prevention of hypertension are of great interest. Sodium reduction is one of the primary methods recommended for these purposes. The general public is interested in the reduction of dietary sodium intake and has responded with a decrease in table salt use, the purchase of lowered sodium food products, and the use of food labels to help guide food purchases. Countervailing trends in the use of convenience foods and dining out increase the difficulty for individuals to lower sodium intake. Clinical trials that have used sodium reduction alone or in combination with other lifestyle therapies have demonstrated the feasibility of reducing dietary sodium intake from 30% to 50% for up to 4 years, in a variety of populations. Trials that used lifestyle and weight loss interventions have also achieved significant reductions in body weight and alcohol consumption and increases in physical activity. A variety of studies indicate that long-term sodium reduction is feasible and that it is acceptable to patients. No negative consequences of these interventions have been observed, and in some cases improvement in the intake of other nutrients has occurred. Nonpharmacological interventions have resulted in hypertension control in significant proportions of the trial populations. These studies demonstrate that the foregoing types of interventions can significantly contribute to hypertension treatment and prevention. (Hypertension 1991;17[suppl I]:I-182-I-189)

There is considerable interest in the use of nonpharmacological approaches for the treatment and prevention of hypertension in the United States. One of the primary nonpharmacological approaches is the reduction of dietary sodium intake. Interest in sodium stems from a variety of sources. Epidemiological studies have identified broadly different levels of sodium intake and excretion among populations and markedly different prevalence rates for hypertension. Early therapy for hypertension before the advent of antihypertensive medications relied on severe dietary modifications for blood pressure control. To varying degrees, clinical trials have demonstrated the lowering of blood pressure or prevention of rises in blood pressure in both adults and children. Recent results of clinical trials of drug treatment for hypertension have raised questions about possible adverse effects of antihypertensive agents. National medical guidelines recommend the use of nonpharmacological therapy, including sodium reduction, for the treatment of borderline high blood pressure, for the initial therapy of mild hypertension, and for therapy in combination with antihypertensive drugs in hypertensive patients. National dietary guidelines and health objectives recommend sodium reduction or the avoidance of excessive sodium intake. Finally, there is tremendous public interest in nutritional approaches for the prevention and treatment of hypertension, heart disease, and chronic disease in general.

Because of the medical and public interest in dietary sodium, a variety of questions emerge that concern dietary sodium reduction. In addition to questions about the blood pressure-lowering effects of sodium reduction, the practicality of sodium reduction is of interest. What levels of sodium reduction can hypertensive persons achieve, through what kinds of educational efforts, and can these changes be sustained over long periods of time? Is a lowered sodium diet acceptable in terms of taste, cost, and convenience? Are there other positive benefits that result from a reduced-sodium eating pattern? Does sodium reduction pose any risks? What are the implications of current lifestyle and demographic trends for sodium intake?

Clinical Trials of Sodium Reduction
For the past 20 years, numerous clinical trials have been conducted to evaluate the effect on blood pressure of sodium reduction alone or combined with
other nonpharmacological and pharmacological interventions.4-12 In several early studies by Parijs,11 Morgan,12 Carney,21 and Richards,22 hypertensive patients achieved 40-50% reductions in sodium intake. However, these studies included relatively small numbers of patients (10-40) and had treatment periods of only 1-2 months. Studies that use sodium supplements in double-blind, randomized trials23-25 have been reviewed in previous papers in this supplement (Grimm,26 Cutler27). Patients in these trials lowered dietary sodium intake to 70-80 meq/day before the initiation of the capsule-taking (sodium supplement or placebo) phase. These sodium levels also reflect a 40-50% reduction in dietary sodium intake. As with the above, the studies were of short duration (1-2 months) and excluded individuals who were unable to complete the requirements of the study, particularly the reduction in sodium intake.

After completion of the Hypertension Detection and Follow-up Program (HDFP) trial,28 several studies were begun to evaluate the effects of various nonpharmacological interventions on long-term hypertension control in patients on antihypertensive drug therapy or in untreated mild hypertensive individuals. Because these studies were longer and included larger sample sizes, they provide more information about the magnitude and maintenance of sodium reduction in hypertensive patients. These studies include the Dietary Intervention Study in Hypertension (DISH),9 Hypertension Control Program (HCP),7 Mount Sinai Hypertension Trial (MSHT),8 Treatment of Mild Hypertension Study (TOMHS),9,46 and the Hypertension Intervention Trial (HIT).5 (Table 1). The dietary intervention in all these trials focused on reduction of sodium intake to 70-80 meq/day, or a 30-50% reduction in total intake. These studies used randomized, controlled designs and similar dietary intervention methods. The intervention programs typically included an initial phase of intensive education, which lasted 2-6 months. Information on the sodium content of foods, behavioral approaches toward dietary changes, food purchasing and preparation skills, and motivational activities were provided through group sessions, individual counseling, or a combination of these methods. A maintenance period was then established; follow-up visits were scheduled at intervals of 1-3 months, depending on the trial. These sessions focused on helping patients achieve and maintain their sodium reduction and were tailored to the special needs of the individual patients. Patients received extensive written material, kept self-monitoring records, completed food records or 24-hour diet recalls to provide esti-

<table>
<thead>
<tr>
<th>Trial/treatment</th>
<th>n*</th>
<th>Mean age (yr)</th>
<th>Length of follow-up (months)</th>
<th>Format</th>
<th>Number of initial sessions</th>
<th>Follow-up frequency (months)</th>
<th>Baseline (meq/24 hr)</th>
<th>% Change (12 months)</th>
<th>% Change through follow-up</th>
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<td>48</td>
<td>I</td>
<td>5</td>
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<td>170</td>
<td>34</td>
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<td>G/I</td>
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<td>167</td>
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<td>G</td>
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<td>2</td>
<td>43</td>
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<td>PPHP (Stamler, 1989)</td>
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*Urine sodium excretion in meq/8 hr.
†Sodium excretion at 3 years; 12-month data not published.
mates of dietary intake, and provided urine specimens for measurement of sodium excretion.

**Sodium Reduction Trials for Blood Pressure Therapy**

Only two of these trials, MSHT and that of Rissanen, included treatment groups that used sodium reduction as the sole intervention. The Rissanen trial also included a treatment group that combined sodium and weight reduction and one that used weight loss only. The DISH trial evaluated sodium reduction combined with increased dietary potassium in overweight and nonoverweight patients and weight reduction alone in overweight patients, while the HCP and TOMHS interventions included sodium reduction combined with weight loss and hygienic intervention to reduce alcohol intake and increase physical activity. The educational program in trials with weight loss and hygienic components included nutritional, behavioral, and motivational content specific to these lifestyle changes. Patients in these trials were withdrawn from their blood pressure medications, usually after initiation of dietary treatment, and were then followed according to strict protocol guidelines to monitor blood pressure control; if blood pressure reached hypertensive levels, patients were returned to their medications.

Because the patient populations of these trials were primarily hypertensive patients who had been on antihypertensive medications for 4 years or more, the mean age of the groups was 45–65 years. The average urinary sodium excretion at baseline ranged from 130–189 meq/24 h. After 1 year, sodium excretions in these dietary treatment groups (calculated as percent change of treatment group--percent change of control group) showed reductions that ranged from 17% to 47%. Trials that included longer follow-up periods demonstrated that these reductions could be maintained for periods of up to 4 years. These trials report positive results, with those of sodium reduction, weight control, and hygienic interventions as replacements for drug therapy. After 4 years, 39% of the patients in the HCP diet intervention group remained normotensive and without drug therapy compared with only 5% in the control group. Randomization of the sodium reduction or weight reduction group increased the likelihood of continued cessation of drug therapy for over 1 year in the DISH. Sodium reduction and weight loss reduced by 50% the number of individuals who required medication for the control of hypertension in the HIT. Patients in the dietary treatment groups in these trials also showed significant improvements in biochemical parameters, including serum uric acid, cholesterol, triglycerides, potassium, and glucose, as compared with the control groups.

**Sodium Reduction Trials for Hypertension Prevention**

Two controlled clinical trials that used sodium reduction or sodium reduction combined with weight loss and other hygienic approaches focused on the primary prevention of hypertension, have also been reported (Table 1). The Hypertension Prevention Trial (HPT) included individuals with diastolic blood pressure between 78 and 89 mm Hg and evaluated several different dietary treatments for a 3-year period: sodium reduction alone, sodium reduction and increased dietary potassium, sodium reduction plus weight loss, and weight loss alone. The Primary Prevention of Hypertension Program (PPHP), a 5-year program, included patients with diastolic blood pressure of 80–89 mm Hg; sodium reduction plus weight loss and hygienic intervention was the treatment studied. Both studies were conducted in populations younger than those in the hypertension treatment trials cited above. Sodium excretion was reduced by 30% in the PPHP and 15–20% in the HPT. In the PPHP, the incidence of hypertension was significantly reduced in patients who were randomly assigned to the sodium, weight, and hygienic intervention; 8.8% became hypertensive during the 5-year follow-up period compared with 19.2% in the control group. The relative risk for hypertension developing in the control group was 2.4%. These results indicate that even moderate reductions in risk factors for hypertension among borderline hypertensive men and women contribute to the primary prevention of hypertension.

These trials have demonstrated significant reductions in sodium intake, 30–50% of subjects, achieved an excretion rate of 70–80 meq/day at follow-up. Although most subjects were unable to reach this level, the 70-meq goal does not consider differences in body size, calorie intake, energy expenditure, or gender. Consequently, considerable individual and trial variation around this goal level is to be expected. Participants in these trials reported that eliminating use of the salt shaker was the easiest change to accomplish and eating less sodium in restaurants posed the most difficulty. A reduction in the use of high sodium cured meats and convenience foods was also difficult to accomplish; cooking with less salt, using herbs and spices as flavorings, and reducing the sodium intake from salad dressings and other condiments were generally much easier to accomplish. In some studies, participants reported very high use of low sodium food products. For example, in the MSHT, 80% of the participants reported the regular use of low sodium food products; those individuals also had lower sodium excretions at follow-up. Other studies may not have emphasized the use of low sodium products, for these products may not have been widely available when the trial was conducted. The HPT found that at baseline, two thirds of the total sodium intake was accounted for by salt, meats, and grain items; after the sodium reduction program, participants reported significantly less sodium from most food groups except for dairy and dessert items. The HPT also found that men were less successful in meeting the overall sodium goal compared with women. This finding may be partially due to the...
TABLE 2. Weight Loss After 1 Year in Randomized Clinical Trials of Hypertension Prevention and Treatment

<table>
<thead>
<tr>
<th>DISH*</th>
<th>Rissanen10</th>
<th>HCP†</th>
<th>TOMHS^1</th>
<th>HIT3</th>
<th>PPHP*^†</th>
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<tr>
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<td>Wt</td>
<td>Wt+Na</td>
<td>Wt+Na+Hyg</td>
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<td>57</td>
<td>7.8</td>
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<td>48</td>
<td>13.6</td>
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<td>(24)</td>
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<td>57</td>
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<td>8.6</td>
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<td></td>
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<td>55</td>
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<td>10.4</td>
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<td>(234.0)</td>
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<td>49</td>
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<td>6.0</td>
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<td>(49.0)</td>
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<td>39</td>
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<td></td>
<td></td>
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<td>(92.0)</td>
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Range (7.8-13.6) (7.0-11.0) (6.0-10.4)

Wt, weight loss only; Wt+Na, weight loss plus sodium reduction; Wt+Na+Hyg, weight loss+sodium reduction+exercise and alcohol advice. Weight loss values are calculated as (weight loss in the treatment group—weight loss in the control group). Sample size appears in parentheses below the weight loss.

*Means this treatment group was not included in this trial.
†Weight loss group includes patients over 100% of ideal weight; some patients may have less than 5 lbs to lose to reach ideal weight; other trials' weight loss group minimum inclusion criteria ranged from more than 110-120% of ideal weight.

higher caloric intake of men as well as their reliance on others to purchase and prepare foods.

**Combined Interventions: Sodium Reduction and Weight Loss**

Although sodium reduction is the discussion topic, weight loss remains a major focus of hypertension treatment and prevention. Educational programs that combine the two are of interest because of the potential for greater blood pressure reduction and the lowering of lipid levels. Lipids are an important consideration because 40% of hypertensives also have serum cholesterols greater than 240 mg/dl. However, there is concern about possible interactions between the weight loss and sodium intervention strategies, which might result in smaller changes in one or both of these factors. Two studies provide direct comparisons of these two treatment modalities (Table 1). In the HPT,^31 a 20% reduction in sodium excretion was observed for the sodium and weight-combined group, and the sodium-only group achieved just a 13% reduction. Rissanen^10 observed the opposite; a 17% reduction in sodium excretion was shown in the sodium and weight loss group, and the sodium-only group had a 33% reduction. There are plausible explanations for both findings. The weight loss component requires reduction in total food intake, which could result in a greater sodium reduction. Conversely, when the two modalities are combined, more extensive dietary changes are needed and educational messages are more complex. Thus, it may be more difficult for patients to make changes, and lower rates of compliance may result.^36

If one examines all the trials in Table 1, negligible difference occurs among those that use sodium reduction alone (13–35% reduction) or those that combine sodium with weight loss or with broader lifestyle interventions (17–47% reduction). When we examine weight loss results in these studies (Table 2), slightly greater losses are seen in the weight loss-only conditions compared with the combined sodium and weight condition. Trials that include lifestyle treatment show similar or slightly lower weight losses when compared with the trials that had weight loss-only conditions. However, differences in study populations (age, gender, and ethnicity) and aspects of the intervention programs such as the duration of the intensive phase of intervention and number of contacts could account for these differences. Further investigations are needed before this issue can be resolved.

Researchers and health practitioners alike want to know what educational techniques are the most effective for reducing sodium intake. Unfortunately, only a few studies have directly compared different sodium reduction intervention approaches. The aforementioned multisesssion programs, which provided nutrition education, behavioral and skills training, and included follow-up visits at 1–4-month intervals, were successful in producing and maintaining reductions in sodium intake averaging 30%. Similar changes were observed whether the intervention used group sessions, individual contacts, or a combination of both. Jeffery et al^37 compared group versus individual contacts for weight loss and sodium outcomes in a 6-month study. Both methods produced a
33% sodium reduction and a 13-pound weight loss. Trials that relied on minimal information approaches, which targeted salt shaker use, a few high sodium foods, and those using single contact counseling formats, have been ineffective in producing substantial sodium reduction.40,41

Public Attitudes, Knowledge, and Practices Regarding Dietary Sodium

Health education efforts in the past decade have been very successful in developing public awareness about excess sodium consumption as a risk factor for hypertension.42-44 Public education campaigns with messages addressing dietary sodium as a risk factor for hypertension were begun as part of the National High Blood Pressure Education Program.20 Professional and patient education programs were developed and, in conjunction with the FDA, food manufacturers were encouraged to voluntarily provide sodium labeling on food packages and lower the amount of sodium in processed foods.42 The public's awareness of the relation between salt and high blood pressure increased threefold from 1979 to 1982, and awareness through the 1980s has remained high.19,20 There has been a corresponding increase in the public's desire to lower sodium intake.20,42,43 Surveys indicate three major trends: the sodium content of foods is a major health concern of grocery shoppers, parents are concerned about the sodium intake of their children, and hypertensive individuals report many efforts to lower sodium intake.19,20,44

Salt Avoidance Practices

Many consumers report that they practice sodium or salt avoidance behaviors. From 1982 to 1988, nearly 40% of the adult population said they were on some type of sodium avoidance diet43; the prevalence of self-prescribed sodium reduction diets was more than twofold that of physician-prescribed diets. Generally, younger and more highly educated individuals fall into the category of self-initiated low sodium avoidance, and older and less educated individuals and those with diagnosed hypertension fall into the doctor-prescribed category. Table salt use, an easily identified sodium intake behavior, has declined, as indicated by table salt supermarket sales. Sales fell 12% from 1979 to 1983 and have stabilized at these lower levels in the late 1980s.43 During the 1970s, it was estimated that discretionary salt use contributed an average of 30% to the total sodium intake of Americans.45 Recently, clinical and epidemiological investigators have reported that the contribution of salt to total sodium consumption has declined in the general and hypertensive populations, and few patients report salt shaker use at the table.5,46 In many reports, salt shaker use contributed as little as 2-10% to total sodium intake.

Trends in Grocery Stores and Meals Away From Home

Food manufacturers have responded to increased consumer awareness of dietary sodium and health issues by introducing a large number of sodium-reduced products. Approximately 200 new sodium-reduced food products were introduced in 1986 compared with five in 1981.47 Although sodium-reduced items are available in most food categories, those that account for over half of the new products are nuts and sweets, soups, salad dressing, snack items, condiments, and soft drinks.47 National surveys indicate 20% of consumers report that they regularly purchased some low sodium food products.42 Sodium labeling has also dramatically increased in the past 10 years.42 Consumer use of food package nutrition labels to avoid or limit sodium intake increased from 14% in 1978 to 44% in 1986.42

Changes in lifestyle, increased employment of women, smaller households, an increased number of fast food establishments, changes in food preparation technology, and increased numbers of processed foods influence food consumption patterns and, consequently, dietary sodium intake and an individual's ability to control sodium intake. For example, the percentage of total food dollars spent on away-from-home food consumption has continued to steadily increase in the last 20 years; in the mid-1980s estimates indicated that 40% of household food dollars were spent on food away from home48; this trend means that restaurant, cafeteria, fast food, and vending machine meals, all notoriously high in sodium, are being consumed in ever-increasing amounts. Table 3 shows the sodium content of some restaurant items. A single fast-food restaurant meal could contribute as much as 100 meq/sodium, or 140% of the daily sodium goal that most clinical trials have tried to achieve. Thus, individuals who consume many meals prepared away from home have less control over sodium intake; even if they prefer lower sodium items, they may not be available, pinpointing a major difficulty for individuals who try to limit sodium intake.

Food purchasing and preparation practices are also changing dramatically. High sodium convenience items such as deli foods, frozen main course meals, refrigerated salads, and microwave snacks are among the fastest growing product categories and are expected to dominate the supermarket of the 1990s.49 The trend toward greater convenience contradicts the recommendations made in the clinical trials previously discussed, which typically required partic-

<table>
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<th>Table 3. Sodium Content of Fast Foods</th>
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</tr>
<tr>
<td>French dip sandwich</td>
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<tr>
<td>Chicken dinner</td>
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<td>Taco salad</td>
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<td>Chili</td>
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<td>Pepperoni pizza</td>
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<td>Fish sandwich</td>
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Downloaded from http://hyper.ahajournals.org/ by guest on July 12, 2017
ipants to rely on simple, home-prepared foods. Although manufacturers are introducing many lower sodium items, there are still few options available in food categories that contribute the largest amount of sodium to total intake—main dishes, bread products, and fast foods. The recent introduction of entrées and dinners, which are reduced in both fat and sodium and are aimed at meeting consumer demand for “heart-healthy” products, may provide more options for those who try to lower sodium intake.

Safety and Acceptability of a Lowered Sodium Eating Pattern

With so much medical and public interest in the reduction of sodium intake, questions have arisen that concern deleterious effects that might result from the reduction of dietary sodium intake. The major issues raised relate to the nutritional adequacy of a low sodium diet, with a concern that other nutrients may be lost from the diet when high sodium foods are eliminated. Advocates of the lower sodium diet characterize it as healthy, high in potassium, and low in fat and calories. Opponents caution that the lower sodium diet may be of lower nutritional quality and may be unpalatable. The charge that the low sodium diet is unpalatable may derive from the early use of the Kempner Rice Diet and the use of therapeutic diets, which are very low in sodium (500 mg/day), in the hospital setting for congestive heart failure. In addition, during the 1970s food manufacturers produced a small number of very low sodium dietetic foods targeted for sale to patients who required severe sodium restrictions. These products often used potassium chloride to replace sodium chloride as the seasoning agent; potassium chloride is characterized by a bitter or metallic taste, and products that incorporate this compound often have an unpleasant aftertaste. Diets used in the early years of hypertension treatment and many of the early dietetic low sodium food products were probably unpalatable; also, patients who followed these diets were sick, perhaps from medications, which probably also affected taste and food acceptance. However, these diets are not the ones recommended and used today. Great advances have been made in food product formulation and food preparation techniques to lower salt content.

Studies of salt taste show that subjects adapt to lower dietary sodium levels; these lower sodium levels seem more pleasant, and subjects prefer lower concentrations of sodium chloride in foods after relatively short periods of time. Participants in several clinical trials reported some positive results: adjustment to the low sodium diet was not difficult, many high sodium foods became very unpleasant after sodium intake was reduced, many foods tasted better without salt, and perhaps most important, they believed the low sodium diet helped them achieve a healthier diet in general. In one study, 85% of participants reported that they would not return to their previous eating habits after completion of the clinical trial for sodium reduction.

Questions on the feasibility of achieving and maintaining a low sodium dietary pattern have also arisen, with the supposition that in addition to the purported unpalatable aspects of the diet, undue anxiety or other negative emotional sequelae could develop. Despite these concerns, there is presently no published data to support the assertion that dietary sodium reduction to the levels used in recent clinical trials (70–100 meq/24 hr) results in any negative consequences, such as nutrient deficiency or other physiological or psychological abnormalities.

Calcium intake has been of special concern, but none of the clinical trials have reported major changes in this mineral. Importantly, clinical trials generally provide information to participants on nutritional adequacy of the diet. This practice is one that should also be done in general clinical practice when providing therapy for hypertensive patients. Some studies have also shown improvements in other nutritional components. These include reductions in fat and cholesterol and increased in potassium; fiber; ascorbic acid; vitamins A, B6, and B12; riboflavin; folic acid; iron; and zinc. Trials that used hygienic lifestyle interventions in addition to weight loss and sodium reduction showed significant reductions in alcohol intake, increased physical activity, and reductions in fat and cholesterol intake.

In conclusion, there is extensive medical and public interest in the health effects of excessive dietary sodium intake, with concomitant efforts to reduce intake. Despite the high level of consumer interest and concern over dietary sodium, countervailing factors appear to influence intake. Individuals are consuming less sodium in the form of table salt, and more reduced-sodium products are available. Conversely, more meals are eaten away from home, fast food consumption is increasing, and more convenient and prepared meals are being used.

To accomplish significant sodium reduction in the future, more reduced sodium prepared and restaurant foods must be made available. Clinical trials have demonstrated the feasibility and acceptability of lowering sodium intake by 30–50% or to levels of 70–100 meq/day. These reductions are accomplished 6–8 weeks before the beginning of a low sodium program, and these levels have been maintained for up to 4 years. Single short counseling sessions with advice on salt reduction have not been successful in producing dietary changes, and more comprehensive nutrition- and behavior-oriented programs that provide follow-up contacts have resulted in significant sodium and weight reductions in clinical settings.

Lower dietary sodium intake is consistent with dietary recommendations, not only for hypertensive persons but also the general population. However, any program aimed at the modification of eating behavior must address nutritional adequacy and not just emphasize a single nutrient. Extensive evidence is available.
showing that we can influence eating behaviors and that the public is keenly interested in making changes to improve their diets for disease prevention and control. Efforts that provide not only information but also practical food skills and support for behavioral change and look beyond a single nutritional focus can accomplish sodium reduction as well as weight control. These interventions are feasible and can have a positive effect on blood pressure control.

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