Changing Sodium Intake in Children
The Minneapolis Children's Blood Pressure Study

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SUMMARY To assess the effects of modifying dietary sodium intake, 80 school children with blood pressures above the 95th percentile for age and sex but below 130/90 mm Hg at school screening were randomized to a family intervention program or a control group. Twenty children aged 6 to 9 years and their families began a program to modify the family diet toward a goal of 70 mEq sodium per person per day. Adherence was assessed by 3-day food records and urine collections in children and adults. The sodium intakes and blood pressures of the intervention and control group were compared 1 year after randomization. Sodium intake was significantly lower in the intervention group only in the active participants as compared to dropouts and controls (87 vs 130 and 133 mmoles/24 hr). There were no significant differences between the groups in height, weight, or blood pressure. (Hypertension 3: 698-703, 1981)

KEY WORDS • sodium intake • children • Minneapolis Children's Blood Pressure Study • diet • lifestyle • family education • blood pressure

PRIMARY prevention of essential hypertension by hygienic means will be a major direction of hypertension research in the 1980s.1 Risk factors in youth for essential hypertension in adulthood have been identified in epidemiologic studies.2,3 Higher blood pressure (BP), body weight, and ponderal index at baseline, weight gain over the follow-up period, and family history of hypertension are the best established of these. Although data from follow-up studies reaching from early childhood to adulthood are lacking, the "tracking" of BP, weight, and other characteristics through childhood and adolescence has been well documented.4,5 Cross-cultural, clinical, and laboratory studies support the hypothesis that a high sodium intake, to which essentially all American children are exposed, is a risk factor for essential hypertension in adulthood.6 Hygienic measures have proven valuable in the management of established hypertension in adults.10 These include weight reduction,11,12 and extreme or even moderate sodium intake reduction.13-15 The role of other measures such as physical exercise and behavioral modification remains unclear.16

The feasibility and efficacy of hygienic prevention of essential hypertension remain to be established. The current study was designed to test the feasibility of producing lasting reduction in sodium intake of school children by a family education program. Documentation of feasibility is a prerequisite to mounting a trial of efficacy in children at high risk for essential hypertension.

Methods
In January through April, 1978, more than 99% of children enrolled in the first, second, and third grades of the Minneapolis Public School system were surveyed for BP, height, weight, and other measures. From among the 10,301 students surveyed, children were identified with systolic blood pressure (SBP) over the 95th percentile for age and sex. Children whose SBP was > 130 and/or whose fourth phase diastolic blood pressure (DBP) was > 90 mm Hg on two separate days were referred to their private physicians for follow-up and were excluded from the pres-
ent study. Detailed reports of survey methodology and results have been published. In May and the following months of 1978, the homes of consenting families whose children had BP over the 95th percentile for age and sex were visited. Demographic, medical, nutritional, and other data concerning the child and family were obtained by interview. The child's BP was measured in the home and an overnight urine collection obtained from the child and parents.

Study Population

Recruitment for the current study was begun in July, 1978, from among those whose home interview was completed and who still resided in Minneapolis. Because of plans to conduct a separate educational program for obese children, children whose weight was greater than the 95th percentile for age and sex were excluded. Eighty families gave preliminary consent and were randomized into two groups: 41 intervention families and 39 control families. The control group was not contacted again until 1 year later. The intervention group was asked to complete questionnaires, 3-day food records, and 24-hour urine collections coinciding with the third day of the food record were obtained at each of the intervention sessions. Specimens were obtained from the index child and both parents when possible. Total volume of each specimen was measured, and the sodium and potassium concentration determined by flame photometer. Creatinine concentration was determined by autonalyzer technique. Hourly excretion rates were determined based on the recorded collection duration. Overnight collection data are expressed as amount per 10 hours, and 24-hour collections are expressed as amount per 24 hours, to correct for individual collection times that usually deviated somewhat from these durations.

Height, weight, skinfold thickness, and BP was obtained in the school before and after the intervention period, using methodology described elsewhere. The BP was also determined at the first and 1-year follow-up home visit. For calculation of means and standard deviations (SD) within each group at a specified time, all available data points were used for each variable. For calculation of changes due to intervention, subjects with valid data at both times for each variable were included. This provided maximum precision of estimation for each variable even though the number of subjects tabulated varied among variables.

Statistical Analysis

The following statistical methods were used. Analysis of variance was used to compare the means and assess significance of differences among groups. Paired t tests were used to assess before and after changes within-group. A two-tailed p value of < 0.05 was required for statistical significance.

Results

Figure 1 illustrates the dropout rate among the 41 families randomly assigned to the intervention group. Most dropouts occurred before the actual start of intervention, as families gained more information about what was required for full participation in the study.
Demographic and medical characteristics of the groups are shown in Table 1. Control and intervention groups were comparable except for a higher proportion of female index children in the intervention group as well as somewhat more parental hypertension in that group. At baseline, overnight sodium excretion in mmoles/10 hrs was 27 ± 21 in girls and 33 ± 20 in boys in the control group, and 26 ± 13 in girls and 36 ± 19 in boys in the intervention group.

Table 2 shows the 3-day food record estimates of the children's sodium intake at the 1-year follow-up visit. Food records could not be obtained from 28 of the 80 children originally randomized. The intervention group as a whole had a significantly lower sodium intake reported than the control group. This difference was based entirely upon the contribution of the attenders, since the sodium intake of dropouts was similar to that of the control group. Three-day food records were not taken from the controls at baseline to avoid possible contamination. Therefore, it is not possible to compare changes between the groups.

Table 1. Demographic and Medical Characteristics of the Study Groups

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Control group</th>
<th>Total</th>
<th>Attenders</th>
<th>Dropouts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child's age (yrs)</td>
<td>8.0 (0.8)</td>
<td>7.8 (0.7)</td>
<td>7.8 (0.7)</td>
<td>7.9 (0.7)</td>
</tr>
<tr>
<td>Child's sex (% F)</td>
<td>31 (7)</td>
<td>61 (8)</td>
<td>65 (12)</td>
<td>58 (10)</td>
</tr>
<tr>
<td>Mother's age (yrs)</td>
<td>34 (5)</td>
<td>35.3 (6.0)</td>
<td>35.6 (5.6)</td>
<td>35.3 (6.4)</td>
</tr>
<tr>
<td>Mother's educ (% &lt; HS)</td>
<td>5 (3)</td>
<td>5 (3)</td>
<td>6 (5)</td>
<td>4 (4)</td>
</tr>
<tr>
<td>Income (% &lt;$10,000)</td>
<td>13 (5)</td>
<td>20 (6)</td>
<td>18 (9)</td>
<td>21 (8)</td>
</tr>
<tr>
<td>Parent on diet (%)</td>
<td>18 (6)</td>
<td>17 (5)</td>
<td>12 (7)</td>
<td>25 (8)</td>
</tr>
<tr>
<td>HBP mother (%)</td>
<td>3 (3)</td>
<td>20 (6)</td>
<td>12 (7)</td>
<td>25 (8)</td>
</tr>
<tr>
<td>HBP father (%)</td>
<td>10 (4)</td>
<td>24 (7)</td>
<td>19 (10)</td>
<td>25 (8)</td>
</tr>
<tr>
<td>n of families</td>
<td>39</td>
<td>41</td>
<td>17</td>
<td>24</td>
</tr>
</tbody>
</table>

Parentheses indicated the mean or proportion measurement. HS = high school; F = female; HBP = high blood pressure; n = number.

Table 2. Three-day Food Record Estimate of Children's Sodium Intake (Average of 3 days) at 1-year Follow-Up

<table>
<thead>
<tr>
<th>Total group</th>
<th>n</th>
<th>Sodium intake (mmole/24 hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>31</td>
<td>133 (33.9)</td>
</tr>
<tr>
<td>Intervention</td>
<td>21</td>
<td>108 (37.4)</td>
</tr>
<tr>
<td>Attenders</td>
<td>11</td>
<td>87 (27.3)*</td>
</tr>
<tr>
<td>Dropouts</td>
<td>10</td>
<td>130 (35.0)†</td>
</tr>
<tr>
<td>Parents:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Father</td>
<td>20</td>
<td>171 (46.8)</td>
</tr>
<tr>
<td>Mother</td>
<td>30</td>
<td>134 (38.7)</td>
</tr>
<tr>
<td>Intervention</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Father</td>
<td>19</td>
<td>130 (40.0)</td>
</tr>
<tr>
<td>Mother</td>
<td>20</td>
<td>91 (28.1)</td>
</tr>
<tr>
<td>Attenders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Father</td>
<td>8</td>
<td>109 (39.3)</td>
</tr>
<tr>
<td>Mother</td>
<td>11</td>
<td>78 (20.6)</td>
</tr>
<tr>
<td>Dropouts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Father</td>
<td>11</td>
<td>146 (34.5)</td>
</tr>
<tr>
<td>Mother</td>
<td>9</td>
<td>106 (29.5)</td>
</tr>
</tbody>
</table>

Overall analysis of variance for groups (control, attenders, dropout): F = 8.158; p = 0.0009.
*Control vs attenders, p < 0.0002.
†Control vs dropout, p = 0.7729.
Twenty-four-hour urinary sodium excretion data were available for intervention families only. There was a significant decrease in urinary sodium excretion from the beginning of intervention to a 6-month follow-up point among subjects for whom data were available (table 3). Poor parent compliance with 24-hour urine collections hampered analyses of parental changes in sodium excretion. There was no significant change in excretion at 6 months among the parents for whom complete data were available.

Overnight urinary sodium excretion data were available both at baseline and 1 year on over three-fourths of the control and intervention children (table 4). There were no significant differences between groups for any of the values. Overnight excretion seemed to increase slightly in controls compared to intervention subjects. Normalizing the sodium excretion for creatinine excretion did not alter these results.

The effects of the intervention program on growth and development of the index children were examined. Table 5 shows the height and weight of children in the various groups before and after intervention. All groups showed similar increases in height and weight over the year. Table 6 shows average BPs taken at home in children before and 1 year after the intervention and the change in BP in each of the groups. No significant differences among the groups were noted, although the small sample size of the current study is not sufficient to exclude small differences with confidence. Thus, no adverse effects of intervention on growth or development were seen.
Possible adverse behavioral or psychological effects of intervention were examined by comparing school absenteeism rates between control and intervention subjects. No significant differences were noted in the groups.

Before intervention, all parents had been given the Missouri Children's Behavior Checklist, which identifies eight dimensions of children's behavior,\(^{16}\) and the Family Environment Scale, which identifies 10 dimensions of family environment.\(^{20}\) There were no significant differences between scores of control and intervention families on either of these instruments. In addition, in the home before and 1 year after intervention, all children were given the Missouri Children's Pictures Series (MCPS), a thematic apperception-type personality inventory developed by Sines et al.\(^{21}\) No significant differences were noted among groups in the eight scale scores before intervention, with one exception: the intervention group scored lower on the masculinity scale, a finding consistent with the lower percentage of boys in this group (table 1). The control group experienced no significant changes on any MCPS scale during the study period. The intervention group experienced small but statistically significant decreases on conformity, aggressiveness, and sleep disturbance scales. Further analysis revealed that these changes occurred only among dropouts, the attenders having no decreases in scores on these scales. Although the significance of the MCPS scale changes among dropouts is difficult to interpret, it is reassuring to note that they were not in an undesirable direction. Thus, there was no evidence of adverse behavioral or psychological effects of the intervention program.

**Discussion**

The current study demonstrates the feasibility of producing long-term changes in sodium intake by family intervention in children with high normal BP. Sodium intake among children decreased by about 40% to near goal levels at 6 months and 1 year in the active intervention attenders. No adverse physical or behavioral effects of the intervention were identified.

These conclusions are supported by the data, despite the apparent design error in the study, namely, that randomizing too early in the recruitment process resulted in a high dropout rate. Had randomization occurred only after consent had been signed and one group information session held, the dropout rate would probably have been minimal, since only three of the 20 subjects who attended the first intervention session dropped out during the following year. Although the dropouts did not receive the complete intervention, it was possible to obtain 1-year follow-up on over three-fourths of the entire intervention group.

Data for the group as a whole, as well as attenders and dropouts, have been presented and are consistent with the conclusions above. For each outcome variable, the number of subjects for whom data are available varies; for example, only 11 attenders completed food records but 16 completed overnight urine collections. This is particularly true for the 24-hour urinary data during intervention, where compliance was a problem. Both the 24-hour urinary data with the 3-day food record data indicate a fall in sodium excretion and intake. However, each measure is subject to error or bias in an unblinded study. For example, it is possible that the intervention group changed their diets only at the time they were recording their 3-day food record and at other times they were eating their usual sodium intake. Change data for neither are available in the control group for comparison, because the amount of baseline data for the control group was limited, with a view to avoiding an “intervention effect” of collecting extensive dietary data. In retrospect, it would have been better to accept this risk and collect both 24-hour urines and food records for controls as well as intervention families at baseline. A stratified analysis of change in overnight urinary sodium excretion revealed no confounding by child's sex. A factor that limited the intensity of the intervention was the lack of control of school lunches. We have documented that a single school lunch in the Minneapolis Public Schools may contain as much as 80 mmoles of sodium. Families were encouraged to send lunches from home when possible and children instructed in making low-salt choices and not adding salt to school lunches.

Although these conclusions seem valid with respect to the subjects studied, some cautions about generalization of the results seem warranted. First, the group was highly selected in several respects. Children with an SBP over 130 mm Hg or a DBP over 90 mm Hg on two occasions were excluded, as were obese children. The age range was limited to 6 through 9 years, and the population was relatively affluent and mainly white. The BP rankings were determined on the basis of two readings made on a single day. The design of a trial of sodium restriction with BP measurement as outcome should base eligibility on persistence on several occasions of BP readings in the upper percentiles and a family history of essential hypertension. Furthermore, a more intensive, longer intervention on a larger number of subjects would be desirable to confirm the negative results presented here. In addition, readers should interpret the before and after BP changes with caution because of the strong effect of regression to the mean, which, however, operates equally among the groups and should not affect intergroup comparisons.

The lack of BP change observed could be explained in several ways:

1. A change in sodium intake of the magnitude achieved has no causal effect on BP in nonhypertensive children.
2. Bias in ascertainment of sodium intake by food record and 24-hour urine collections caused an apparent reduction in intake in the intervention group when there was, in fact, very little over the entire study period.
3. Bias in measurement of BP obscured a true fall in the intervention group compared to controls.
4. The lack of association of sodium intake change and BP change could be spurious due to confounding by some unmeasured factor not controlled by randomization.

5. The observed result may be due to chance and would not be observed in most future replications. Of these, the first, second, and fifth points seem most plausible, and should be evaluated in a future study.

The authors could find no published reports of the feasibility of sodium reduction in school children. Results of other lifestyle interventions in well children, e.g., weight control and physical fitness, indicate that reduced sodium intake reduction is at least as feasible as other long-term lifestyle changes. In addition, based on evidence from other cultures and the current experience over a 1-year period, a 70 mmole per day sodium diet seems safe for school-age children as well as adolescents and adults. Increasing intake of foodstuffs high in iodine (seafoods), avoiding excessive intake of goitrogens (cabbage), and the use of iodized salt substitutes or iodine-enriched bread in countries with goiter-belt areas, should eliminate problems resulting from the loss of iodine from iodized table salt.1

Clinical trials should be designed and implemented to test the effect of hygienic interventions on children's BP. These trials should include lowering sodium intake of children and adolescents with mild essential hypertension, as defined by the National Heart, Lung, and Blood Institute Task Force and others,20 and of those with BP levels consistently over the 95th percentile for age and sex. Such trials should utilize behavioral strategies for family motivation and retention, should ensure the availability of low-sodium food products and school meals, and provide prolonged follow-up. In addition, such trials should include a substantial number of black children to allow for separate estimates of benefit for blacks and whites.

Acknowledgments

We are grateful to Dr. Kaner and Dr. Kenney of the Minneapolis School System for their help. We are indebted to all of the school principals and school nurses who helped schedule and facilitate our work in their schools. We acknowledge the special efforts of our field supervisor, M. Dunn. Key to our work were the efforts of the data-processing team, J. Vilandre, R. Hilk, and M. Dauphinais. Great effort and care in standardization was also shown by all of the field technicians and their supervisors, D. Buckingham and A. Olson. Lines of communication were maintained efficiently by the study secretary, N. Horie.

References


