Effects of alterations in fatty acid intake on the blood pressure of adolescents: the Exeter-Andover Project¹⁻³

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ABSTRACT  To judge the effect on blood pressure, the ratio of polyunsaturated to saturated fatty acids (P:S) of foods served to students at two boarding high schools was modified alternately at each school for one school year. The average P:S of the diet of males increased from 0.53 to 0.93 during the intervention whereas among females it increased from 0.64 to 0.98. Comparison of repeated systolic and diastolic blood pressure measurements near the end of the school year did not demonstrate a beneficial effect of the dietary fat changes on the blood pressure of these normotensive adolescents. Compared with the blood pressure patterns during control years, the dietary intervention resulted in slightly higher systolic (+0.88 mm Hg; 95% CI = −0.66, +2.42) and diastolic (+1.23 mm Hg; 95% CI = +0.04, +2.42) blood pressure readings among males. Among females the intervention resulted in slightly lower systolic (−0.54 mm Hg; 95% CI = −1.95, +0.88) and diastolic (−0.80 mm Hg; 95% CI = −2.18, +0.58) blood pressure readings. Am J Clin Nutr 1992; 56:71–6.

KEY WORDS  Dietary fat, blood pressure, preventive cardiology, cardiovascular epidemiology

Introduction

Hypertension is a prevalent and severe health problem throughout the world. Evidence that the precursors of hypertension have their roots in childhood and that blood pressure tracks over time suggests that efforts for the primary prevention of hypertension should begin early in life (1, 2). One of many dietary measures that have been proposed as possible approaches for preventing the development of hypertension is an increase in the intake of polyunsaturated fatty acids, especially linoleic acid. Linoleic acid supplementation of the diet has resulted in lower blood pressure in animals (3). A higher intake of polyunsaturated fatty acids, as well as a higher polyunsaturated to saturated (P:S) fatty acid index, has been shown to be associated with lower blood pressure in some human studies (4–10), especially among adults with hypertension; not all studies, however, have shown a beneficial effect on blood pressure (11–13). Lower blood pressure among vegetarians has been postulated to result from their higher polyunsaturated fatty acid intake (14, 15).

As part of the Exeter-Andover Project we tested the effects of changes in the P:S of the diet on the blood pressure of normotensive young people. Modifications of the P:S among students at two boarding high schools were achieved through environmental changes in institutional food purchasing and preparation practices (16, 17). This report examines the effects of such dietary changes in P:S on the blood pressure of students at each institution for one school year.

Methods

The study design was that of a nonrandomized, concurrently controlled longitudinal investigation, with the application of the intervention being applied in alternating school years at each of two boarding high schools (Phillips Exeter Academy, Exeter, NH, and Phillips Academy, Andover, MA) (Fig 1). The aim of the study was to examine the effects of changes in dietary polyunsaturated and saturated fatty acid intakes on the blood pressure of students over an intervention period lasting 24 wk. The dietary changes were the result of changes in food purchasing and preparation practices by the schools’ food-service departments. The goal was to decrease saturated fatty acids and replace it with polyunsaturated fatty acids while keeping total fat intake unchanged; the intakes of dietary sodium, potassium, calcium, and other nutrients were kept at usual amounts. During school vacation periods, students were not provided with any specific dietary recommendations to alter their specific total fat or fatty acid contents of their diet.

Although the entire student body at each school during the intervention period was exposed to the dietary changes, intervention effects were monitored only among students at the two schools taking basic courses in science. Each of these students participated in the monitoring aspects of the study for one school year.

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year during which there were either changes in food preparation (intervention year) or no changes in food preparation carried out (control year). The study protocol was approved by the human subjects committee at the University of Massachusetts Medical School. Approximately 75% of participating students were white; the average age was 15 y and none of the students had baseline blood pressure readings > 130 mm Hg systolic or 90 mm Hg diastolic. Each year a new cohort of students (those taking basic science courses) was recruited in whom the effects of the dietary intervention were examined.

Changing the fatty acid content of the diet

The steps taken to modify food purchasing and preparation practices, and the impact of such changes on the fat content of foods served to students, were previously described (16–18). In brief, during the year that a school was the intervention site, food purchasing and preparation practices were modified so that certain food products had some of their saturated fatty acid content decreased and replaced with sunflower oil or other vegetable oils high in linoleic acid. Because the aim of this project was to determine the effects of a passive dietary intervention involving changes by the institutional food service departments on blood pressure, and not to study the effects of an active educational intervention, students were not instructed to modify their usual eating practices and were advised to eat as usual.

Monitoring nutrient intake

Students being monitored at control and intervention schools during each study year were asked to complete 24-h food diaries on one assigned weekday or weekend day each week during the first 6 wk of school, during 2 wk in the winter and during 4 wk in the spring. All foods ingested were recorded and described, whether they were obtained from the dining hall, from school snack bars, or from outside the school. Dietary analyses indicate that ≈28% of total energy intake came from foods obtained outside the school. Analysis of food diaries and recipes was performed by trained registered dietitians using the “Food Finder” program (19). Fatty acid profiles for foods served during both regular and increased polyunsaturated fatty acid periods, obtained from chemical analysis by food companies or calculated from recipes, were added as needed to the computerized nutrient data bank.

Monitoring blood pressure

As an ongoing class project for certain basic courses in biology and chemistry at the schools during the 2 study years, students were asked to measure their own blood pressure each week during the usual science laboratory period. At the beginning of each school year, each student was instructed in the use of the automatic blood pressure monitoring devices. For those students unable to measure their blood pressure during the usual science laboratory period on a given week, students were instructed to come to the science laboratory and have their blood pressure measured at any other time during the week convenient for them. As described previously, Dinamap automatic blood pressure devices were used for monitoring blood pressure (20). On each occasion that students sat down to have their blood pressure measured, three readings of systolic and diastolic blood pressure and heart rate were recorded on a floppy disk. For each set of three blood pressure readings recorded at a sitting, the average of the second and third was taken as the blood pressure for that session unless differences between the two readings was > 15 mm Hg for systolic blood pressure or > 10 mm Hg for diastolic blood pressure. In such instances the average of readings one and three or one and two was taken for the systolic or the diastolic reading. Students were not given their blood pressure data until the end of the school year.

Each of eight blood pressure devices used during the study were sent to the factory for testing and recalibration before each school year. After maintenance procedures the machines were distributed randomly to the two schools for each study year. Static calibration of each machine with a mercury manometer was done at the beginning of each school year and at ≈4-wk intervals thereafter.

Outcome measures and statistical methods

The primary outcome measures of interest were the changes in systolic and diastolic blood pressure readings of subjects between the beginning and end of the school year. The baseline blood pressure for each student was taken as the average of all measurements obtained during 4 wk near the beginning of the school year (the second to fifth weeks after school began) when both schools were having food prepared by usual methods. The follow-up blood pressure was the average of all measurements obtained during a 4-wk period near the end of the school year (taking into account school vacations). The intervention period was ≈24 wk during the school year ranging from November through May. Data from an individual student were included in subsequent analyses if a student had at least one set of blood pressure measurements during both the baseline period and the follow-up period. In addition to assessing effects of the intervention on blood pressure between the baseline (pre) and follow-up (post) periods, average blood pressure readings during the baseline period were also related to average blood pressures from five subsequent periods of ≈4–5 wk each during the school year. In this way, blood pressure patterns over the school year could be compared for students in the control and intervention groups. Reported changes in nutrient intake are based on data from all subjects furnishing food-diary data during each period. Nutrient changes were reported in detail previously (16, 17, 21, 22).

The primary methods of statistical analysis used were one and two sample t tests. In addition, multiple-regression analysis was used to obtain adjusted effects of the intervention. Statistical
analyses of changes in nutrient intake required calculation of the variance of the ratio of two means based on different sample sizes; this was accomplished by using the delta method with estimation of the parameters based on all available data (23).

Results

Dietary changes and blood pressure responses during intervention years were very similar in the two schools, and were also similar during control years. Therefore, data were combined for the schools and are presented for control years (control group) and for intervention years (intervention group). Thus, the control group consists of students at Andover in year 1 and Exeter in year 2, and the intervention group consists of students at Exeter in year 1 and Andover in year 2.

The distribution of selected baseline demographic- and nutrition-related characteristics of the control and intervention groups, stratified by sex, were similar (Table 1). There were no significant differences in body weight between control and intervention groups at the end of the school years.

Changes in dietary fat intake during control and intervention years have been reported in detail previously (17) and are summarized in Table 2. The intervention resulted in an 81% increase in P:S for males and a 47% increase for females. Despite these differences in the types of fats consumed, the total fat intake changed very little: a decrease of 2% (95% CI −7%, +3%) for males and a decrease of 8% (95% CI −12%, −3%) for females. There were no significant differences among participating students during control and intervention years in the intakes of other recorded nutrients, including carbohydrates, sodium, potassium, and calcium.

Baseline and follow-up blood pressure readings for males and females during control and intervention years are shown in Table 3. During the control years, systolic blood pressure among males and females remained essentially unchanged whereas slight increases occurred in diastolic blood pressure in the two sexes.

### Table 1
Baseline demographic and nutrition data, by intervention status and sex*

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Males</th>
<th></th>
<th>Females</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control (n = 233)</td>
<td>Intervention (n = 226)</td>
<td>Control (n = 203)</td>
<td>Intervention (n = 201)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>174 ± 8.7</td>
<td>175 ± 8.5</td>
<td>165 ± 6.7</td>
<td>164 ± 6.9</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>63.1 ± 10.8</td>
<td>64.9 ± 10.8</td>
<td>56.7 ± 8.5</td>
<td>56.4 ± 8.2</td>
</tr>
<tr>
<td>Energy (kJ)</td>
<td>11 853 ± 3 534</td>
<td>11 870 ± 3 358</td>
<td>8541 ± 2311</td>
<td>8637 ± 2173</td>
</tr>
<tr>
<td>Total fat (% energy)</td>
<td>35.5 ± 5.0</td>
<td>34.5 ± 5.4</td>
<td>34.9 ± 5.5</td>
<td>34.2 ± 5.9</td>
</tr>
<tr>
<td>Polysaturated fatty acid (%)</td>
<td>6.1 ± 1.8</td>
<td>5.7 ± 1.8</td>
<td>6.5 ± 2.3</td>
<td>6.4 ± 2.0</td>
</tr>
<tr>
<td>Monounsaturated fatty acid (%)</td>
<td>12.5 ± 2.4</td>
<td>12.5 ± 2.4</td>
<td>11.7 ± 2.5</td>
<td>11.6 ± 2.6</td>
</tr>
<tr>
<td>Saturated fatty acid (%)</td>
<td>12.3 ± 2.6</td>
<td>12.2 ± 2.6</td>
<td>12.1 ± 2.9</td>
<td>11.8 ± 2.8</td>
</tr>
<tr>
<td>P:S†</td>
<td>0.54 ± 0.20</td>
<td>0.53 ± 0.21</td>
<td>0.62 ± 0.28</td>
<td>0.64 ± 0.25</td>
</tr>
</tbody>
</table>

* ± SD.
† Ratio of polyunsaturated to saturated fatty acids.

### Table 2
Changes from baseline to follow-up in fat intake, and estimates of intervention effect*

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Intervention</th>
<th>Intervention effect†</th>
<th>95% CI‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of total energy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polysaturated fatty acid</td>
<td>−10</td>
<td>+39</td>
<td>+49</td>
<td>(+34, +63)</td>
</tr>
<tr>
<td>Saturated fatty acid</td>
<td>−2</td>
<td>−21</td>
<td>−19</td>
<td>(−25, −13)</td>
</tr>
<tr>
<td>P:S§</td>
<td>−6</td>
<td>+75</td>
<td>+81</td>
<td>(+60, +120)</td>
</tr>
<tr>
<td>Total fat</td>
<td>−5</td>
<td>−8</td>
<td>−3</td>
<td>(−7, +3)</td>
</tr>
<tr>
<td>Females</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polysaturated fatty acid</td>
<td>0</td>
<td>+22</td>
<td>+22</td>
<td>(+11, +33)</td>
</tr>
<tr>
<td>Saturated fatty acid</td>
<td>−3</td>
<td>−22</td>
<td>−19</td>
<td>(−25, −12)</td>
</tr>
<tr>
<td>P:S§</td>
<td>+6</td>
<td>+53</td>
<td>+47</td>
<td>(+31, +62)</td>
</tr>
<tr>
<td>Total fat</td>
<td>−2</td>
<td>−10</td>
<td>−8</td>
<td>(−12, −3)</td>
</tr>
</tbody>
</table>

* Changes for each variable are calculated as follow-up value minus the baseline value divided by baseline value, with fats being expressed as percent of total energy.
† Intervention minus control.
‡ 95% Confidence intervals for the intervention effect.
§ Ratio of polyunsaturated to saturated fatty acids.
TABLE 3
Blood pressure data and estimates of intervention effects, by sex

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Intervention</th>
<th>Intervention effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline (197 M, 184 F)</td>
<td>Follow-up (197 M, 184 F)</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic (mm Hg)</td>
<td>107.8 ± 9.3†</td>
<td>107.2 ± 8.9</td>
<td>108.4 ± 9.2</td>
</tr>
<tr>
<td>Diastolic (mm Hg)</td>
<td>62.1 ± 6.7</td>
<td>62.4 ± 6.6</td>
<td>61.4 ± 6.3</td>
</tr>
<tr>
<td>Females</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic (mm Hg)</td>
<td>101.1 ± 6.7</td>
<td>101.0 ± 7.2</td>
<td>100.9 ± 7.3</td>
</tr>
<tr>
<td>Diastolic (mm Hg)</td>
<td>63.1 ± 6.6</td>
<td>63.6 ± 7.1</td>
<td>61.9 ± 6.6</td>
</tr>
</tbody>
</table>

* ± x (95% confidence intervals for the intervention effect).
† ± x ± SD.

During the intervention years systolic and diastolic blood pressure increased slightly among males and decreased slightly among females.

The estimated intervention effects for systolic blood pressure [differences in the changes (baseline—follow-up) in systolic and diastolic blood pressure between the intervention and control groups] were +0.88 mm Hg (95% CI -0.66, +2.42) in males and -0.54 mm Hg (95% CI -1.95, +0.88) in females. For diastolic blood pressure, these differences were +1.23 mm Hg (95% CI +0.04, +2.42) in males and -0.80 mm Hg (95% CI -2.18, +0.58) in females. When combined for the two sexes, the intervention effects were +0.19 mm Hg (95% CI -0.86, +1.24) for systolic and +0.28 mm Hg (95% CI -0.50, +1.06) for diastolic blood pressure. Except for the intervention effect on diastolic blood pressure in males, none of the observed effects were statistically significant. All estimates of effects were unchanged when adjusted for potential confounding variables.

Patterns of blood pressure during the school year, as reflected by average differences in blood pressure from baseline to each of five subsequent periods of approximately 1 mo’s duration, gave no evidence of a significant effect of an increase in P:S on blood pressure. Among both males and females, no pattern of either higher or lower blood pressure was seen with these interim measurements.

Discussion

Animal studies have suggested a blood pressure-lowering effect of linoleic acid in the diet (3). This effect has been postulated to be mediated through increased prostaglandin synthesis and a concomitant vasodilatory effect (24, 25). Studies among humans are more difficult to interpret because changes in P:S of the diet have frequently been associated with concomitant changes in total fat intake; changes in the consumption of meat, vegetables, carbohydrates, or other nutrients; or changes in body weight and other lifestyle characteristics. Furthermore, some studies have been carried out among normotensive individuals, whereas others have been done among hypertensive subjects and there have been varying sociodemographic and clinical characteristics of the populations under study.

Early studies in vegetarian populations, particularly among those people adhering to a strict nonanimal product vegetarian diet (which tends to be lower in fat with a higher P:S), suggested a blood pressure-lowering effect of such a diet (14, 15). However, given differences in the consumption of other nutrients other than fat, as well as possible differences in other lifestyle characteristics related to blood pressure, it was difficult to assess the specific dietary factors contributing to the apparent blood pressure-lowering effect of a vegetarian diet.

Retrospective studies and randomized clinical trials examining the relation between the intake of dietary fat and blood pressure were recently reviewed (26). In summarizing the results of a variety of observational studies carried out in diverse study samples from varied population settings (including Finland, Germany, Italy, the United States, and Wales), total dietary fat was not shown to be related to blood pressure readings in almost any of these studies; only one of the studies reviewed observed an association between high dietary intake of linoleic acid and low blood pressure (26). The limitations of these nonrandomized cross-sectional observational studies were appropriately addressed in this summary review. Many of the studies did not adjust for potentially confounding variables, including changes in body weight, physical activity, and alcohol intake. Many controlled clinical trials have also addressed the relationship between intake of dietary fat and blood pressure and were recently reviewed (26). These trials varied in the size and characteristics of the study samples; some were carried out in hypertensive and others in normotensive individuals. The trials also varied in the duration of the dietary intervention, with the majority of studies modifying nutrient intake for a relatively brief period (eg, 4–6 wk). The consensus from these studies in adults was that neither systolic nor diastolic blood pressure was significantly lowered through reductions in either total fat intake or through changes in the P:S.

Studies among children and adolescents of the relation between alterations in dietary fat intake and blood pressure have been scarce (27, 28). Vartiainen et al (27) in a study of 36 normotensive children and adolescents aged 8–18 y, reduced total fat intake as a percentage of total energy from 35% at baseline to 24% during a 12-wk intervention period and increased the P:S from 0.18 to 0.61. These investigators observed a 4 mm Hg decrease (118–114 mm Hg) in systolic blood pressure by the end of the dietary intervention and a 3 mm Hg reduction (72–69 mm Hg) in diastolic blood pressure (27). Among a small
We acknowledge the invaluable support of the study by Donald Doane, Thomas Poole, Walter Griffin, and other members of the Food Service Departments at the academies. We also acknowledge the valuable assistance of Priscilla Harris, Nancy Brown, and Deborah Sullivan in coordinating study activities: Ellen Glovsky for the analysis of food diaries; and Kelley Baron for preparation of the manuscript. We thank Thomas Hamilton, James Ekstrom, John Tuthill, and other members of the faculty and staff and particularly the students at Phillips Exeter Academy, Exeter, NH, and Phillips Academy, Andover, MA, for their cooperation in this project.

References


DIETARY FATS AND BLOOD PRESSURE

The number of adolescents aged 15-18 y with elevated blood pressure (the majority of whom were also substantially overweight), Stern et al (28) observed a decrease in systolic blood pressure, especially among lean subjects, resulting from an increase in polyunsaturated fatty acid intake that was estimated to reach 20% of total energy.

The present study failed to provide support for a blood pressure–lowering effect of increasing the P:S in the diet of normotensive young people. It is possible that we did not increase the linoleic acid intake adequately or for a long enough period to produce a lowering of blood pressure. There is little doubt, however, that the change in diet occurred while the students were at school, because the changes were made at the level of food procurement and preparation, and students received the intervention without modifying their individual dietary habits. The intake of nonmodified food products from outside of the school setting, as well as during school vacation periods, may have affected the lack of observed change in the principal study outcomes. However, even in the interim periods, when students had been at school for prolonged periods of time without school breaks, no evidence of a beneficial effect in blood pressure was seen. As for the total duration of the intervention, 24 wk actually exceeds the intervention periods in the majority of studies in adults and adolescents that have examined the effect of alterations in fatty acid intake on blood pressure. Even if greater amounts of polyunsaturated fatty acids would lower blood pressure, such a finding might be of limited relevance because at our level of intervention we achieved a P:S of almost 1.0, the upper level currently considered safe and desirable. If increasing the P:S of the diet is associated with a decrease in blood pressure among normotensive young people, we believe that such a change should have been demonstrated in this study.

The failure to reduce blood pressure in the present study may relate to the fact that we changed the type of fat in the diet without changing the total fat content and without changing amounts of carbohydrate, protein, energy, or other nutrients. Furthermore, our intervention did not lead to weight loss. Some of the apparent blood pressure responses to changing the P:S in previous studies may actually have been related more to changes in other nutrients, weight loss, or other unmeasured factors rather than to changes in the fatty acid composition of the diet.

We do not know whether or not the slightly higher blood pressure readings found in males in the intervention group is real or spurious. Previous studies have not demonstrated an increase in blood pressure to be associated with an increase in the P:S of the diet. Given the different directions of the trends in males and females, and the minimal differences between the intervention and control groups, it is believed that the most appropriate conclusion is that variations in the P:S of the diet in the 0.5 to 1.0 range observed in the present investigation have no effect on the blood pressure of normotensive young persons.

In summary, this study demonstrated that it is feasible to modify food product procurement and food preparation practices in an institutional setting to produce marked increases in the dietary intake of polyunsaturated fatty acids, with little effect on total fat intake. These changes increased the P:S of the diet to levels currently recommended for Americans. Although such changes could relate to more favorable concentrations of blood lipids, which were not measured in this study, they did not demonstrate a beneficial effect on blood pressure among the young people enrolled in this study.


