Whole-Grain Diets Reduce Blood Pressure in Mildly Hypercholesterolemic Men and Women

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ABSTRACT

The objective of this study was to compare the effects on blood pressure of predominantly insoluble fiber (whole wheat and brown rice) and soluble fiber (barley) in a whole-grain diet. Subjects (seven men, nine premenopausal women, and nine postmenopausal women) consumed a controlled Step I diet for 2 weeks; then about 20% of energy was replaced with whole wheat/brown rice, barley, or half wheat-rice/half barley, for 5 weeks each. Blood pressure was determined weekly and weight daily before breakfast. Urinary excretions of minerals that might affect blood pressure and urea nitrogen were determined each period. Systolic pressure was lower after the wheat/rice and half-and-half diets. Diastolic and mean arterial pressures were reduced by all whole-grain diets. No differences were observed in urinary measurements. In a healthful diet, increasing whole-grain foods, whether high in soluble or insoluble fiber, can reduce blood pressure and may help to control weight.

METHODS

The study was approved by the Johns Hopkins University Bloomberg School of Public Health Institutional Review Board and conforms to regulations governing human research supported by the US government. Written informed consent was obtained from each subject after an oral explanation of the study. Healthy men and women with blood pressures <140 mm Hg systolic and <90 mm Hg diastolic and cholesterol levels 200 to 240 mg/dL (5.18 to 6.22 mmol/L) were recruited. Exclusion criteria included substantial weight change the previous 6 months, taking medication known to affect blood pressure, lipids, or glucose. Physicians from Johns Hopkins University Bloomberg School of Public Health conducted the medical evaluations and provided medical supervision. Twenty-seven subjects were selected; two withdrew for personal reasons. One subject completed three of the four periods; one subject completed two of the four periods. Baseline characteristics of the seven men, nine premenopausal women, and nine postmenopausal women who participated in the study are listed in Table 1.

Subjects discontinued all vitamins and supplements and agreed to consume only those foods presented to them or approved by the investigators. All foods were prepared and weighed to within 0.5 g at the Beltsville Human Study Facility. Details of the design, methods, menus, height, weight, lipids, and diet intake measures were reported previously (25). Subjects consumed the Step I American Heart Association diet (26) with a 7-day rotating menu for 2 weeks. After this equilibration period, whole-grain foods replaced refined carbohydrates present in the Step I diet. The whole-grain diets (barley, whole wheat/brown rice, and half barley/half whole wheat-brown rice) were consumed for 5 weeks each so that an equal number of subjects consumed each diet during each period and all subjects consumed all diets. Whole-grain diets contained 0 to 2.2 g/1,000 kcal soluble fiber from barley and 9.7 to 11.9 g/1,000 kcal total dietary fiber. Subjects were instructed to take the elevator, not stairs, to the Human Study Facility. After a minimum 5-minute rest, duplicate blood pressure readings were taken by the same two trained personnel 5 minutes apart each week before breakfast. Subjects who climbed the
stairs rested an additional 5 minutes before the initial blood pressure reading. Blood pressure readings were made using a Dinamap Pro Series 100 (Critikon, LLC, Tampa, FL). Mean arterial blood pressure (MAP) was calculated as \(\frac{2}{3}(\text{systolic pressure}/2)\). Stressful occurrences such as car trouble, family illnesses, or crises were recorded and the associated readings were excluded from the analyses. This amounted to eight duplicate readings out of a total of 450.

Twenty-four-hour complete urine samples were collected during the last 3 days of each period to assure that there was no variation in minerals or dietary factors that might affect blood pressure or indicate noncompliance (sodium, potassium, calcium, magnesium, phosphorus, creatinine, urea nitrogen, and uric acid) (Dimension Xpand, Dade Behring Inc, Newark, DE).

Data were analyzed using mixed procedure analysis of variance (SAS version 8.2, 2001, SAS Inc, Cary, NC). Subjects were their own controls. Statistical significance was defined as \(P<0.05\). Data reported are least squares mean±standard error of mean.

RESULTS AND DISCUSSION

Baseline values (Table 1) were similar among the three groups with the exception of height, body mass index, and body fat (measured using the Futrex 5000xl body fat analyzer; Medica, Gaithersburg, MD). Women were shorter and fatter, but age, weight, blood pressure, and blood lipids were not different. Consumption of all whole-grain diets resulted in decreases in blood pressure (systolic: \(P<0.021\), diastolic: \(P<0.009\), mean arterial blood pressure: \(P<0.050\)) (Table 2). Systolic blood pressure declined 2.2 mm Hg (not significant) while subjects consumed the Step I diet and an additional 1.4 to 6.7 mm Hg while subjects consumed the whole-grain diets. Diastolic blood pressure declined 2 mm Hg (not significant) while subjects consumed the Step I diet and an additional 2.9 to 3.7 mm Hg while subjects consumed the whole-grain diets. Men had the greatest reduction in MAP while consuming the half-and-half diet (10.8 mm Hg). For women, the greatest reductions in MAP occurred while they consumed the barley diet (pre, 10.8 mm Hg; post, 9 mm Hg). Of the three groups, postmenopausal were the least responsive with significant declines in MAP only when consuming the barley diet.

Although subjects lost only about 1 kg during the study, this was a statistically significant \((P<0.01)\) difference (Table 2). Energy intakes were significantly higher (average 100 kcal; \(P<0.036\)) with the three whole-grain diets than with the Step I diet. Energy intake per pound body weight was higher \((P<0.0138)\) during the whole-grain periods, reflecting the increased energy intake necessary to maintain body weight. Overall, men had significantly higher energy intake and energy per kilogram body weight than did either group of women (38 vs 31 and 32 kcal/kg for men, premenopausal women, and postmenopausal women, respectively).

Total daily urinary excretion of uric acid, creatinine, and urea nitrogen was not significantly affected by diet; however, men excreted more creatinine than women (1.7 vs 1.2 g/day). Mean mineral excretion did not vary by period indicating consistency in the mineral content of the diets.

By simply replacing white with whole wheat, or barley flour, white rice with brown rice, and standard cereals with barley or whole wheat cereals, we were able to lower blood pressure and maintain or lower body weight while increasing energy intakes in overweight/obese women and overweight men. Because hypertension is so prevalent in the United States (>50 million people) (27), the modest change in an already healthful diet we employed to lower blood pressure could have great beneficial effects. Hypertension has been reported to be an independent predictor of vascular damage. As the population ages, the prevalence of hypertension increases. The Framingham Study indicates that 90% of those who are

| Table 1. Baseline characteristics, blood lipids, and blood pressures of mildly hypercholesterolemic men and women before consumption of controlled American Heart Association Step I and whole-grain diets containing soluble and/or insoluble fiber |
|--------------------------------------------------|------------------|------------------|
| **Baseline characteristics**                       | **Men**          | **Women**        |
| **Men**                                          | **(n=7)**        | **Premenopausal**| **Postmenopausal**|
| **(n=9)**                                        | **(n=9)**        |                  |
| Age (y)                                          | 43±5\*           | 47±4\*           | 50±3\*           |
| Height (cm)                                      | 176.0±3.7\*      | 160.8±2.8\*      | 164.3±1.3\*      |
| Weight (kg)                                      | 80.0±4.1\*       | 89.5±7.8\*       | 80.3±7.3\*       |
| BMI\*                                           | 26±1\*           | 34±3\*           | 30±3\*           |
| Body fat (%)                                     | 23±2\*           | 38±3\*           | 35±3\*           |
| Cholesterol (mg/dL)b                            | 218±9\*          | 220±9\*          | 237±8\*          |
| Triglycerides (mg/dL)c                           | 143±37\*         | 140±33\*         | 138±33\*         |
| Systolic blood pressure (mm Hg)                  | 119.3±4.2\*      | 121.8±3.9\*      | 121.2±3.9\*      |
| Diastolic blood pressure (mm Hg)                 | 71.7±4.2\*       | 69.6±2.9\*       | 69.1±2.9\*       |

*BMI—body mass index; calculated as kg/m^2.

\(\text{To convert mg/dL cholesterol to mmol/L, multiply mg/dL by } 0.026.\) Cholesterol of 5.00 mmol/L—193 mg/dL.

\(\text{To convert mg/dL triglycerides to mmol/L, multiply mg/dL by } 0.0113.\) Triglyceride of 1.80 mmol/L—159 mg/dL.

Means within a row with different superscripts are significantly different \((P<0.05)\) based on least-squares means.
normotensive at 55 years can expect to develop hypertension in their lifetime (27). Guidelines of the seventh Joint National Committee on Hypertension recommend some treatment should begin at a more modest blood pressure range (prehypertension 120/80 to 140/90 mm Hg) than previously recommended (28).

Weight loss during our study was an unwanted result. Energy levels were adjusted weekly in 250-kcal increments if a subject’s weight changed over 1 kg. Predicting an individual’s energy expenditure is difficult (29). Although we did request that subjects not change their usual physical activity programs, this variable is difficult to control and subjects may have increased activity as the length of daylight and the study progressed. The experimental design, which required each of the whole-grain diets to be consumed each period by one third of the subjects should eliminate this time effect in all but the Step I period. Fiber intake and not weight loss was the determining factor in blood pressure changes reported in previous studies (19,20,30).

We observed increases in energy intake during the whole-grain diet periods without increases in weight as reported by other researchers (18,24). This apparent loss of available energy might be considered a beneficial characteristic in Western societies where obesity and excess nutrient intake are major health problems. Subjects participating in our study are those that would benefit most from increasing whole-grain consumption (older, hypercholesterolemic, prehypertensive, obese, and at risk for the metabolic syndrome). The incidence of the metabolic syndrome, a cluster of factors that includes hypertension, abdominal obesity, elevated plasma glucose and/or insulin, insulin resistance, and dyslipidemia is increasing with the rise in obesity in the United States (31-33).

Diets containing whole grains have not consistently lowered blood pressure. Some of the difficulties in comparing studies are differences in subjects, sources, and amounts of grains, length of consumption, and extent of dietary control (1-2,18-29). We made every effort to control diet, weight, and other dietary factors that might affect blood pressure, including protein, calcium, magnesium, sodium, and potassium (34-41). The lack of differences in excretion of all urinary minerals indicates that we were fairly successful in this control and suggests compliance of the subjects.

### CONCLUSIONS

Consumption of a healthful diet high in fiber from whole-grain foods lowers systolic and diastolic blood pressure in mildly hypercholesterolemic men and women whether sources are barley (soluble fiber), whole wheat and brown rice (insoluble fiber), or a combination of these whole-grain foods. Replacement of white rice with brown rice, white bread with whole-grain bread, and low-fiber cereals with barley or whole wheat cereals in a Step I diet can reduce blood pressure in middle-aged men and women and may help to control weight.

This controlled human diet study was approved by the Johns Hopkins School of Public Health Institutional Review Board. The research was supported entirely by intramural US Department of Agriculture, Agricultural Research Service funds.

### Table 2. Body weights, energy intakes, and means of weekly blood pressures of mildly hypercholesterolemic men and women initially and after consuming whole-grain diets containing soluble and/or insoluble fiber from barley, whole wheat, and brown rice

<table>
<thead>
<tr>
<th>Time</th>
<th>Initial&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Step I</th>
<th>Whole wheat/brown rice</th>
<th>Half/half&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Barley</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight (kg)</td>
<td>83.9±5.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>83.5±5.4&lt;sup&gt;y&lt;/sup&gt;</td>
<td>82.7±5.4&lt;sup&gt;x&lt;/sup&gt;</td>
<td>82.6±5.4&lt;sup&gt;x&lt;/sup&gt;</td>
<td>82.6±5.4&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td>Energy intake (kcal/d)</td>
<td>—</td>
<td>2,642±95&lt;sup&gt;y&lt;/sup&gt;</td>
<td>2,751±96&lt;sup&gt;y&lt;/sup&gt;</td>
<td>2,739±96&lt;sup&gt;y&lt;/sup&gt;</td>
<td>2,727±96&lt;sup&gt;y&lt;/sup&gt;</td>
</tr>
<tr>
<td>Energy intake (kcal/kg/d)</td>
<td>—</td>
<td>32.3±0.8&lt;sup&gt;y&lt;/sup&gt;</td>
<td>34.0±0.8&lt;sup&gt;x&lt;/sup&gt;</td>
<td>34.0±0.8&lt;sup&gt;x&lt;/sup&gt;</td>
<td>33.6±0.8&lt;sup&gt;x&lt;/sup&gt;</td>
</tr>
<tr>
<td>Systolic blood pressure (mm Hg)</td>
<td>117.6±2.4&lt;sup&gt;y&lt;/sup&gt;</td>
<td>115.4±2.4&lt;sup&gt;y&lt;/sup&gt;</td>
<td>110.2±2.4&lt;sup&gt;y&lt;/sup&gt;</td>
<td>108.7±2.4&lt;sup&gt;y&lt;/sup&gt;</td>
<td>114.0±2.4&lt;sup&gt;y&lt;/sup&gt;</td>
</tr>
<tr>
<td>Diastolic blood pressure (mm Hg)</td>
<td>71.0±1.6&lt;sup&gt;y&lt;/sup&gt;</td>
<td>69.0±1.7&lt;sup&gt;y&lt;/sup&gt;</td>
<td>65.3±1.7&lt;sup&gt;y&lt;/sup&gt;</td>
<td>65.8±1.7&lt;sup&gt;y&lt;/sup&gt;</td>
<td>66.1±1.7&lt;sup&gt;y&lt;/sup&gt;</td>
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<tr>
<td>Mean arterial pressure (mm Hg)</td>
<td>85.8±1.9&lt;sup&gt;y&lt;/sup&gt;</td>
<td>85.3±1.9&lt;sup&gt;y&lt;/sup&gt;</td>
<td>81.5±2.0&lt;sup&gt;y&lt;/sup&gt;</td>
<td>79.1±1.9&lt;sup&gt;y&lt;/sup&gt;</td>
<td>81.0±2.0&lt;sup&gt;y&lt;/sup&gt;</td>
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<tr>
<td>Men (7)</td>
<td>87.4±3.6&lt;sup&gt;y&lt;/sup&gt;</td>
<td>88.4±3.6&lt;sup&gt;y&lt;/sup&gt;</td>
<td>82.7±3.7&lt;sup&gt;y&lt;/sup&gt;</td>
<td>76.6±3.7&lt;sup&gt;y&lt;/sup&gt;</td>
<td>82.7±3.8&lt;sup&gt;y&lt;/sup&gt;</td>
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<tr>
<td>Women pre (9)</td>
<td>87.6±3.2&lt;sup&gt;y&lt;/sup&gt;</td>
<td>79.6±3.2&lt;sup&gt;yz&lt;/sup&gt;</td>
<td>83.0±3.2&lt;sup&gt;y&lt;/sup&gt;</td>
<td>78.6±3.2&lt;sup&gt;yz&lt;/sup&gt;</td>
<td>76.8±2.0&lt;sup&gt;y&lt;/sup&gt;</td>
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<tr>
<td>Women post (9)</td>
<td>82.4±3.2&lt;sup&gt;y&lt;/sup&gt;</td>
<td>84.7±3.2&lt;sup&gt;y&lt;/sup&gt;</td>
<td>79.9±3.3&lt;sup&gt;y&lt;/sup&gt;</td>
<td>81.9±3.3&lt;sup&gt;y&lt;/sup&gt;</td>
<td>73.4±3.3&lt;sup&gt;y&lt;/sup&gt;</td>
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<sup>a</sup> Mixed procedure analyses of variance for 25 subjects completing at least two periods. Body weight, P<0.01; intake: kcal, P<0.036; intake: kcal/kg, P<0.0138; systolic blood pressure, P<0.003; diastolic blood pressure, P<0.0003; mean arterial pressure: diet, P<0.0001, diet-by-group, P<0.0485.

<sup>b</sup> Measurements taken before breakfast the first day of the Step I diet.

<sup>c</sup> Half barley, half whole wheat/brown rice.

<sup>xyz</sup> Means within a row with different superscripts are significantly different (P<0.05) based on least-squares means.

### References


34. Kynast-Gales SA, Massey LK. Effects of dietary calcium from dairy products on ambulatory blood press-