

Blood pressure and diet in normotensive volunteers: absence of an effect of dietary fiber, protein, or fat¹⁻³

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ABSTRACT In the course of four controlled experiments on the effect of specific dietary components on cardiovascular risk factors, the effects on blood pressure of various sources of dietary fiber, of type and amount of dietary fat, and of animal versus plant protein were measured in young normotensive volunteers. In each of the four experiments a group of 50 to 75 healthy student volunteers received a control diet for 1½ to 2½ wk. They were then randomized into subgroups which received various test diets for periods ranging from 4 to 12 wk. In each experiment one group received the control diet throughout the whole experimental period. Diets differed between groups in one dietary component only. All foodstuffs were weighed out individually according to each person's energy needs. Body weights and Na intake were controlled. Initial blood pressures were about 120 mm Hg systolic and 70 mm Hg diastolic. Both systolic and diastolic blood pressure decreased during the test period in all four experiments on almost every diet, including the control diets, by about 0 to 5 mm Hg. However, changes in blood pressure over the test period were never significantly different between the test groups and the control groups. Thus, none of the investigated dietary factors had a demonstrable effect on blood pressure in young normotensive persons. *Am. J. Clin. Nutr.* 34: 2023-2029, 1981.

KEY WORDS Blood pressure, hypertension, dietary fiber, soy, protein, fat, polyunsaturated fatty acids

Introduction

Hypertension is one of the most important risk factors for the development of cerebrovascular, coronary and aortic atherosclerosis (1, 2) and is present in about 15% of the adult American population (3). It has been clearly established that antihypertensive drug treatment reduces not only the morbid complications of hypertension but also total mortality (3, 4). For obvious reasons, however, primary prevention of the disease would be preferable to widespread drug treatment.

In many primitive communities, hypertension is virtually absent, because the rise of blood pressure with age which is common to Western societies does not occur (5-7). Among the many determinants of lifestyle, several authors have stressed the importance of diet in the emergence of widespread hypertension in affluent societies. There is good evidence for a role for dietary sodium in the development of high blood pressure (for a

review see Reference 8); it has also been suggested that a high intake of potassium might be protective (8, 9). In addition to sodium and potassium intake other dietary factors may be important. There is evidence that dietary linoleic acid will lower blood pressure in hypertensive animals (10) while epidemiological studies and controlled trials in man also suggest a slight beneficial effect (11-14). Other studies suggest a beneficial effect on blood pressure of dietary fiber (15), or a deleterious effect of sugar (16) and animal products (17). However, controlled studies in man on the effect of fiber or animal products on blood pressure are rare or absent.

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In the course of four controlled trials on the effect of specific dietary components on cardiovascular risk factors we have measured the effects of various sources of dietary fiber, type and amount of dietary fat, and type of protein on blood pressure in young, normotensive volunteers. It was found that none of these factors had a measurable effect on blood pressure.

Methods

The primary aim of the four experiments was to test the effect of various dietary components on cholesterol metabolism. The details of each trial have been described elsewhere (18-22; J. H. Brussaard, M. B. Katan, P. H. E. Good, A. M. Havelies, and J. G. A. J. Hautvast, unpublished data). The general design of the experiments was as follows (Table 1). The subjects were young healthy student volunteers; their age ranged from 18 to 30 yr (median: 21 yr).

In each of the four trials a group of 50 to 75 volunteers received a control diet for 1½ to 2½ wk. They were then randomized into subgroups stratifying for initial serum cholesterol level, male/female ratio, and energy intake. The subgroups received various test diets for periods ranging from 4 to 12 wk.

Diets differed between groups in one dietary component only; one group always received the control diet throughout the test period as a check against base-line drift. Throughout each experiment, all foodstuffs were individually weighed out and supplied according to each person's energy needs.

Dietary composition

Fiber experiment (18). In the fiber experiment the control diet was a relatively low-fiber diet with a mean intake of 18 g total dietary fiber per day. During the test period of 5 wk one group continued on the control diet. A 2nd group received 43 g dietary fiber per day on the average, which came mainly from vegetables and fruit. A 3rd group received the low fiber diet plus on the average 9 g isolated citrus pectin (National Formulary) (degree of esterification 78%) per day so that the total dietary fiber intake was 28 g/day on average. A 4th group received the low-fiber control diet enriched with on the average 38 g coarse wheat bran per day (dietary fiber content 50 g/100 g fresh weight); mean intake of total dietary fiber in this group was 37 g/day. Consumption of polygalacturonic acid (pectin) amounted to 1.7, 7.5, 8.8, and 1.7 g/day in the control, vegetables/fruits,

citrus pectin, and bran group, respectively. The diets provided 37% of total energy intake as fat (4% of total energy as linoleic acid), 13% as protein, 48% as carbohydrate (23% of total energy as oligosaccharides), and 142 mg cholesterol/4.2 MJ.

Protein experiment (19, 20). In the protein experiment all diets contained 38% of total energy as fat (8% of total energy as linoleic acid), 47% as carbohydrates (23% of total energy as oligosaccharides), and 12 to 13% as protein. Cholesterol intake was 146 mg/4.2 MJ per day. Of the protein in the diets 65% consisted of casein or soy protein isolate or a 2:1 mixture of casein and soy protein isolate (control diet). The test period lasted 4 wk.

Fat experiment 1 (21). The control diet in this experiment contained 11% of total energy as polyunsaturated fat (PUFA); in total, fat provided 30% of daily energy. A low fat, low PUFA diet provided 22% of energy as total fat (3% of daily energy as PUFA); a high fat, high PUFA diet provided 40% of daily energy as total fat (19% of daily energy as PUFA); and a high fat, low PUFA diet provided 39% of daily energy as total fat (3% of daily energy as PUFA). The test period lasted 5 wk. In all diets protein provided 13% of daily energy, while carbohydrates made up the total energy balance. Intake of oligosaccharides was 23% of daily energy in all groups; cholesterol intake was 110 mg/4.2 MJ.

Fat experiment 2 (22). In the 2nd fat experiment the control diet and the low fat, low PUFA diet of fat experiment 1 were tested again, but this time the test period lasted 12 wk instead of 5 wk.

Intake of Na and K

Customary amounts of salt were added to dishes by us during preparation. No further addition of salt was permitted. Na and K content of the diets were measured by analysis of double portions (18). Diets provided on the average 170, 168, 171, and 190 mmol Na/day and 98, 58, 83, and 90 mmol K/day in the fiber, protein, fat 1, and fat 2 experiment, respectively. There were only minor differences between groups and between control and test period in each experiment, with the exception of the fiber experiment: the vegetables/fruits diet contained more Na and K and the bran diet more K than the control diet, resulting in Na/K ratios of 0.90, 0.95, 1.11, and 1.22 in the vegetables/fruits, bran, control, and pectin diet respectively. As an additional check on Na and K consumption, 24-h urinary excretion of Na and K was measured in the protein and fat 1 experiment. The results confirm the dietary analysis data (Table 2). At the end of the test period in the fat experiment 1, the excretion of Na was slightly higher in the low fat low PUFA group than in the other groups. However, the excretion of K was also higher, so that the Na/K ratio was not different from the other groups. In the protein experiment there were only minor differences between groups.

Body weights

None of the participants had body fat percentages above 23% (male) or 30% (female). From the 60 to 100 subjects who volunteered per experiment 2 to 6 persons had to be rejected on this criterion. For the combined population the P5, P50, and P95 for body weights for females were 50, 60, and 73 kg; for males these values

TABLE 1
General design of experiments

Group	Control period (1½-2½ wk)	Test period (4-13 wk)
Control group	Control diet	Control diet
Diet group A	Control diet	Test diet A
Diet group B	Control diet	Test diet B
Diet group C	Control diet	Test diet C

TABLE 2
Excretion of Na and K in urine during the control and test period of the various experiments (mean \pm SD)

Group	n	Na		K	
		Control* period	Change over† test period	Control* period	Change over† test period
		<i>mmol/day</i>			
Fiber experiment	62	‡	‡	‡	‡
Protein experiment					
Cassoy (control) group	20	195 \pm 60	-23 \pm 67	55 \pm 18	21 \pm 23†
Casein group	25	188 \pm 51	-21 \pm 58	55 \pm 12	19 \pm 17†
Soy group	24	183 \pm 48	-14 \pm 69	52 \pm 9	17 \pm 20†
Fat experiment 1					
Moderate fat, high PUFA (control) group	15	165 \pm 51	11 \pm 64†	78 \pm 18	3 \pm 17†
Low fat, low PUFA group	16	156 \pm 57	40 \pm 49†	79 \pm 21	8 \pm 14†
High fat, high PUFA group	15	153 \pm 82	8 \pm 77†	76 \pm 19	-9 \pm 23
High fat, low PUFA group	14	148 \pm 53	6 \pm 30†	76 \pm 22	-8 \pm 20
Fat experiment 2	35	‡	‡	‡	‡

* Duration of control period: fiber, fat 1, fat 2: 2½ wk; protein 1½ wk.

† Duration of test period: fiber 3 wk; protein 4 wk; fat 1: 4 wk; fat 2: 12 wk.

‡ Not measured.

were 60, 71, and 84 kg. For males these values are slightly lower than the body weights of male North American subjects (23); for females the values agree well. In each experiment body weight was recorded weekly and energy intake was adapted when necessary to maintain stable weight. Mean change in body weights per diet group from start to finish of the test periods was -0.2 to +0.3 kg in the fiber experiment; -1.0 to -1.6 kg in the protein experiment; -0.4 to -0.8 in fat experiment 1, and -1.3 and -1.6 kg in fat experiment 2.

Measurement of blood pressures

Blood pressures were measured before the start of each experiment for familiarization of the participants with the measurement and elimination of hypertensives. Measurement was repeated at the end of the control period and in the test period; after 3 wk in the fiber experiment, after 4 wk in the protein experiment and fat experiment 1, and after 12 wk in fat experiment 2. From all subjects who volunteered for these experiments only one or two in each trial exceeded our criteria for participation (150 mm Hg systolic and/or 95 mm Hg diastolic in the protein experiment and fat experiment 2; 90 mm Hg diastolic in the fiber experiment and fat experiment 1). No restrictions were made as to performing physical activity, eating or smoking before the blood pressure determinations. (Forty-three of the 139 males and 14 of the 86 females smoked cigarettes; however, only five subjects, all males, smoked more than 15 cigarettes per day.)

The measurement was performed in a quiet room in the department after a 5- to 10-min rest. During the measurement the subjects were sitting (fiber experiment) or lying down (protein, fat experiments 1 and 2). In the fiber experiment the mean of two consecutive measurements on 1 day was recorded. In the protein and fat experiments blood pressure was measured twice on 2

consecutive days and the mean of these four measurements was used. Care was taken that each person was measured at the same time of day during all measurements and that the subjects in different diet groups were measured in random order. All measurements in each trial were performed by the same person.

An automatic recording sphygmomanometer type BE 207S (Elag, Köln, Germany) which uses phase IV (Korotkoff) as diastolic blood pressure was used. This instrument uses an inflated cell inside the cuff to detect movements of the arterial wall. The pressure waves are converted into electronic signals by means of a microphone. The instrument was recalibrated periodically against a mercury column manometer. For all subjects combined, the median blood pressure before the experiments was 115/68 mm Hg (systolic/diastolic) for females and 129/67 mm Hg for males. The 5th to 95th percentile ranges were 93 to 132/50 to 85 (systolic/diastolic) for females and 107 to 156/46 to 88 for males. These values are in excellent agreement with values for the general Dutch population in this age group (24) and are similar to what has been reported for North-American populations (23). The subjects in fat experiment 2 had somewhat higher mean systolic and diastolic blood pressures than in the other groups, but were still well within normal range.

For statistical evaluation mean changes per group over the test period were compared between groups using 2-tailed Student's *t* test.

Results

Mean blood pressures per diet group at the end of the control periods and mean changes per group over the various test periods are given in Table 3.

In all four trials systolic blood pressures

TABLE 3

Effect on blood pressure in normotensive subjects of dietary fiber from various sources (Stasse-Wolthuis et al., 18), casein and soy protein (van Raaij et al., 19) or different types and amounts of dietary fat (Brussaard et al., 21) (mean \pm SD)

Group	n	Systolic		Diastolic	
		Control period* (mean \pm SD)	Change over test period† (mean \pm SD)	Control period* (mean \pm SD)	Change over test period† (mean \pm SD)
<i>mm Hg</i>					
Fiber experiment					
Low fiber (control)	16	124 \pm 12	-4.6 \pm 9.3	63 \pm 11	-4.4 \pm 10.1
Vegetables/fruits	15	117 \pm 15	-2.0 \pm 7.4	58 \pm 14	+1.2 \pm 11.4
Citrus pectin	15	125 \pm 15	-1.1 \pm 7.0	59 \pm 11	-0.5 \pm 5.8
Bran	16	128 \pm 18	-1.0 \pm 10.1	65 \pm 8	-3.4 \pm 11.0
Protein experiment					
Casoy (control)	20	127 \pm 12	-3.0 \pm 6.0	73 \pm 8	-5.8 \pm 7.6
Casein	25	123 \pm 11	-3.1 \pm 8.9	69 \pm 10	-2.7 \pm 6.6
Soy	24	124 \pm 15	-2.5 \pm 5.9	69 \pm 11	-2.5 \pm 6.1
Fat experiment 1					
Moderate fat, high PUFA (control)	15	119 \pm 12	-4.8 \pm 10.3	67 \pm 6	-3.4 \pm 6.7
Low fat, low PUFA	16	122 \pm 11	-5.0 \pm 6.0	64 \pm 9	-4.4 \pm 4.9
High fat, high PUFA	15	116 \pm 15	-5.1 \pm 5.4	65 \pm 7	-2.7 \pm 8.1
High fat, low PUFA	14	115 \pm 17	-3.3 \pm 6.4	65 \pm 9	-3.1 \pm 5.7
Fat experiment 2					
Moderate fat, high PUFA (control)	17	130 \pm 10	-7.1 \pm 6.4	80 \pm 10	-8.3 \pm 9.2
Low fat, low PUFA	18	131 \pm 6	-5.5 \pm 5.9	79 \pm 8	-10.5 \pm 11.6

* Duration of control period: fiber, fat 1, fat 2: 2½ wk; protein 1½ wk.

† Duration of test period: fiber 3 wk; protein 4 wk; fat 1: 4 wk; fat 2: 12 wk.

decreased in all test groups as well as in the control group. In almost all cases these changes were significantly different from zero. However, the differences in blood pressure changes over the test period between test groups and the control group were not significant in any experiment.

Diastolic blood pressures decreased also in all test groups as well as in the control group, with the exception of the change in the vegetables/fruits group in the fiber experiment (+1 mm Hg). But again the differences in blood pressure changes over the test period between test groups and the control group never attained statistical significance.

Discussion

Because of the importance of primary prevention of hypertension attention has been focussed on dietary changes to lower blood pressure. Kempner (25) has shown that a rice-fruit diet low in sodium can lower blood

pressure in hypertensive patients by as much as 30 mm Hg. There is also evidence from recent controlled trials (26, 27) that a modest reduction in salt intake can produce a modest reduction of blood pressure in hypertensive patients. The effect of changes in other dietary components has not been satisfactorily tested. In our experiments we found no effect of changes in intake of dietary fiber, type of protein or type or amount of fat on blood pressure in young normotensive men and women.

Fiber

It has been suggested that a high-fiber diet could lower blood pressure through its high content of potassium (9, 28). A lowering of blood pressure by 4 to 8 mm Hg systolic and 3 to 4 mm Hg diastolic on diets rich in dietary fiber (mainly from cereals) was reported by Wright et al. (15). Kelsay et al. (29) reported a lower diastolic blood pressure during a high fiber diet than during a low fiber diet. Their

conclusion, however, was due to misinterpretation of results that could be completely accounted for by regression toward the mean. In our experiment with dietary fiber the effect on blood pressure of the vegetables/fruits diet and the bran diet was not different from the low fiber control diet, despite the lower Na/K ratio of these test diets. The intake of K-rich foodstuffs on these diets was quite high: the subjects consumed on average 600 g apples plus 400 g cooked vegetables plus 170 g tomatoes or 38 g bran per day. We think it would be very difficult to increase the potassium intake further if only natural foodstuffs are to be used.

Protein

Armstrong et al. (30) and Sacks et al. (17) suggested from their studies with vegetarians that a higher consumption of animal protein or animal products is accompanied by higher blood pressures. To our knowledge no controlled experiments on the effect of type of protein on blood pressure in humans have been published. We found no difference in effect on blood pressure of a diet rich in animal protein (casein) or plant protein (soy).

Body weights decreased to some extent in this experiment and this is known to affect blood pressure (31). However, it seems unlikely that this could have interfered with the results because the decrease in body weight was small and was very similar in all three diet groups.

Fat

A lowering of blood pressure on diets rich in linoleic acid has been reported by several authors (12-14, 32). Iacono et al. (13) reported that a diet containing 25% of total energy as fat and 6.5% as linoleic acid lowered blood pressure by 13 mm Hg systolic and 7 mm Hg diastolic in normotensive persons compared with their habitual diet; systolic blood pressure remained low after switching to a diet with 35% of total energy as fat and 9% as linoleic acid, but diastolic blood pressure increased by 3 mm Hg. It was concluded that lowering the intake of dietary fat and raising the intake of polyunsaturated fat had a beneficial effect on blood pressure. Although blood pressures were within the nor-

mal range they were higher than in our participants, which may partially account for the discrepancy with our results.

Judd et al. (32) compared the effect of diets containing 43 and 25% of total energy as fat, each with P/S ratios of 0.3 and 1. They conclude that a lowering of total fat intake as well as a rise in linoleic acid consumption can lower blood pressure. Maximum effects were observed in the group with the highest initial blood pressure level.

In the experiment of Stern et al. (14) blood pressure was lowered in overweight hypertensives on a linoleic acid-rich diet. However, the interpretation of this experiment is hampered by the absence of details on diet composition and control of nutrient intake. There was no control group in this experiment; thus it is possible that the experimental conditions themselves caused a lowering of blood pressure, independent of dietary composition.

Oster et al. (12) reported a small tendency towards lower blood pressures (2 to 4 mm Hg) on a diet containing 70 g cornoil per day in subjects with blood pressures comparable to our participants. Weak although significant negative correlations between C 18:2 content of adipose tissue and blood pressure ($r = -0.11$ for systolic and -0.07 for diastolic blood pressure) were found in an epidemiological study (11). In contrast to these observations we found no effect on blood pressure of diets rich in linoleic acid, nor did we find an effect of the amount of dietary fat. As changes in body weight in the fat experiments were slight and very similar in the different diet groups, it does not seem likely that this could have disturbed our results. Also a confounding influence of Na consumption is unlikely, because Na-intake was controlled in all four trials.


Although we did not find an effect of dietary fiber, fat, or protein on blood pressure, our results do not rule out the possibility that these dietary components can indeed lower blood pressure.

First, the small number of participants in this type of controlled experiment and the large range of individual changes in blood pressure, resulting in a poor estimate of the change difference between groups, render a considerable risk of committing a type II error (i.e., not detecting an actually existing

difference between dietary effects). When testing the difference of two group means, two-sided on for example 5% level, the power of the test (i.e., the probability of rejecting the null hypothesis of no effect in case of a real effect) depends on the magnitude of the true effect and the standard error of its estimate. In experiments like ours, a typical value of the standard deviation of blood pressure change is $SD = 7$. Kelsay et al. (29), Morgan et al. (26), and Iacono et al. (13) found lower SD's, but similar values are reported by Parijs et al. (27), Oster et al. (12), and Stern et al. (14). With about 16 persons per group, the probability of detecting a difference between diet groups of 2 mm Hg is only about 11%; for 4 mm Hg this is 31%, and for 7 mm Hg it is 75%.

It should be noted that a lowering of blood pressure by only 4 mm Hg was found to cause a marked reduction in mortality from all causes in the Hypertension Detection and Follow-up Program (3). To increase the power of the test up to 80% for a difference of 2 mm Hg between the diet groups, each group has to comprise about 200 persons. In our experiment the probability that we missed a difference of 7 mm Hg is only 25%, but almost 70% that we missed a 4 mm Hg difference. Thus we must face the possibility that we missed an effect of this magnitude purely by chance.

Second, our participants were young healthy men and women, who were not obese and had low to normal blood pressures. This makes it perhaps more difficult to lower blood pressures. The investigated dietary components might be effective in lowering blood pressure in older persons with higher blood pressure levels, as was also indicated in the experiment of Judd et al. (32). Third, the relatively short duration of our experiments could obscure an effect of diet on blood pressure in the long run.

In summary, we have not been able to show an effect of dietary fiber from different sources, type of protein, or type and amount of dietary fat on blood pressure in normotensive subjects. However, the possibility that these dietary components can influence blood pressure in persons with higher initial levels of blood pressure or to an extent of less than 5 to 7 mm Hg in young normotensive people cannot be ruled out. 

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