

Nutritional effects on blood pressure

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Purpose of review

There has not been a thorough recent evaluation of the nutritional effects on blood pressure. Apart from outstanding clinical trials like Dietary Approaches to Stop Hypertension, there have been controversial papers on a number of factors influencing blood pressure. This paper is a systematic review of the current literature as it relates to hypertension.

Recent findings

Results from many meta-analyses and well controlled clinical trials on the effects of a variety of nutritional factors are presented in this review. Evidence suggests that dietary sodium intake needs reduction. There is a seemingly inverse relationship between protein intake and blood pressure, but data are inconclusive. High monounsaturated fat and fish oil appear to be beneficial. Several studies on dietary fiber indicate that the strongest evidence for blood pressure lowering effects is in hypertensive as opposed to normotensive participants. Vegetarians seem to have lower levels of hypertension and cardiovascular disease risk. Low carbohydrate diets show short-term beneficial effects but are not sustained. High levels of potassium, magnesium, calcium and soy seem to have some benefit, but results remain inconclusive. Weight reduction positively impacts blood pressure.

Summary

More compelling research defining specific factors is needed to inform the public as to steps needed to reduce blood pressure and improve cardiovascular risk.

Keywords

blood pressure, DASH, dietary components, nutritional factors

Abbreviations

BP	blood pressure
CVD	cardiovascular disease
DASH	Dietary Approaches to Stop Hypertension
DBP	diastolic blood pressure
SBP	systolic blood pressure

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Introduction

More than 25% of American and Canadian adults are affected by high blood pressure (BP) and the rate of hypertension is reportedly higher in some European countries. There is a racial aspect to the disease in that African Americans typically have higher rates of hypertension than whites. Two-thirds of people older than 65 years of age are also affected by high BP, and the elderly population is one that is often untreated. The lifetime risk of developing hypertension for middle-aged and elderly individuals is 90% [1].

Recently, new guidelines suggest that the previous values of 120 mmHg/80 mmHg should not be considered normal. The revised categories of systolic/diastolic BP label normal or desirable as under 120 mmHg/under 80 mmHg; prehypertensive as 120–139 mmHg/80–89 mmHg; stage 1 hypertension as 140–159 mmHg/90–99 mmHg; and stage 2 hypertension as ≥ 160 mmHg/ ≥ 100 mmHg [2,3]. The recommendations for management of hypertension include lifestyle modification for all categories, with drugs not typically promoted until the patient presents with minimum stage 1 hypertension or other compelling disease/comorbidity risk. The purpose of this paper is to review the currently available literature defining the impact of nutritional factors on the risk of developing high blood pressure.

The Dietary Approaches to Stop Hypertension diet

To date, the most definitive trials directed toward the nutritional management of hypertension are the Dietary Approaches to Stop Hypertension (DASH) and DASH-Sodium trials [4••]. Briefly, DASH focused on establishing dietary patterns to lower BP, with typical sodium consumption [5]. DASH-Sodium was designed to address the effects of low, medium, and high levels of sodium in conjunction with the DASH diet to determine any additional effects [6]. These feeding trials conducted at four metabolic centers in the US, enrolled more than

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400 total participants each. As a follow-up to these controlled feeding trials, the PREMIER trial tested whether individuals on their own could lower BP by implementing established guidelines for treating hypertension and included the DASH diet in addition to the established recommendations. PREMIER used a lifestyle counseling approach and randomized more than 800 participants [7].

Traditionally, the following lifestyle modifications have been established for the treatment of hypertension: if overweight, lose weight; reduce intake of salt and sodium; increase physical activity; limit intake of alcohol; stop smoking; control stress. These established recommendations for lifestyle modification, in addition to modifications of total and saturated fat and the DASH diet were used in the PREMIER trial [7].

Sodium intake

Sodium reduction typically results in lower BP in industrialized societies [1]. Current guidelines in the US suggest reducing the daily intake of sodium to approximately 100 mmol, or approximately 2.4 g of sodium or less per day. The DASH-Sodium trial demonstrated that reducing sodium intake from 100 to 50 mmol per day significantly reduced blood pressure in individuals, whether on the DASH diet or the typical US diet [6]. Results of the Trials of Hypertension Prevention Phase II (TOHP2) and Trials of Nonpharmacologic Interventions in the Elderly (TONE) indicated that reducing sodium can either prevent hypertension or facilitate hypertension control [8,9].

Dietary protein consumption

Results of meta-analyses from several investigators and other epidemiological studies indicate an inverse association between dietary protein and BP levels [10–12,13^{*}]. The research on plant versus animal protein, however, has remained inconclusive. Specifically, some studies have found that plant protein but not animal protein is associated with reduced BP [14,15]. A recent study by Hodgson and colleagues (2006) [16^{*}], however, demonstrated that partial substitution of carbohydrate intake with animal protein from lean red meat leads to healthy reductions in BP and other cardiovascular markers in persons with hypertension. Compared with the control participants, hypertensive persons consuming 35–40 g/day higher amounts of lean red meat had statistically significant reductions in systolic blood pressure (SBP).

As a point of reference, the DASH diet contained approximately 18% of energy from protein compared to 15% of energy from protein in the other diets tested. Because of the addition of low-fat dairy foods and the reduced emphasis on high-fat meats, it can be assumed

that this elevation in protein was brought about by foods that contributed protein from perceived beneficial sources. Lowering of BP was probably in part due to this aspect, but this area needs further research.

Fatty acid consumption

Studies suggest that an intake of fish oil at a level of approximately 4 g/day reduces SBP by approximately 1.7–2.1 mmHg and diastolic blood pressure (DBP) by 1.5–1.6 mmHg [17]. These effects tend to be larger in individuals older than 45 years of age and in populations with BP readings greater than 140/90 mmHg. Generally, there have been differences associated with fish oil capsules compared to naturally occurring sources of eicosapentaenoic and docosahexaenoic acids from fatty fish, again indicating dietary pattern rather than consumption of individual items may be crucial.

Monounsaturated fatty acids, particularly olive oil, may help lower BP [18]. Olive oil is a rich source of monounsaturated fatty acids, and has typically been associated with the popularized Mediterranean diet, which has been promoted as a treatment for cardiovascular disease (CVD). Small clinical studies of the Mediterranean diet have shown reduced BP [19], improved lipid profiles [20,21], and reduced markers of vascular inflammation [22,23]. Other oils (e.g., canola and peanut oil) and tree nuts have a high monounsaturated fat content as well, and may have similar cardiovascular benefits. Frequent nut intake has been associated with decreased CHD [24]. Prevencion con Dieta Mediterra (PREDIMED) is an on-going large-scale feeding trial that will assess the effects of two Mediterranean diets, one supplemented with virgin olive oil and the other supplemented with mixed nuts, compared to a low-fat diet on CVD outcomes [25^{**}]. Completion of the trial will be in 2010, but 3-month outcome data have been published. Interim results demonstrated significant reductions in SBP and DBP in the participants in the two Mediterranean diet conditions compared to low-fat diet controls (olive oil condition SBP -5.9 mmHg, 95% CI, -8.7 to -3.1 , $P < .001$; DBP -1.60 mmHg, 95% CI, -3.00 to -0.01 , $P < 0.048$; mixed nuts condition SBP -7.1 mmHg, 95% CI, -10.0 to -4.1 , $P < 0.001$; DBP -2.6 mmHg, 95% CI, -4.2 to 1.0 , $P < 0.001$). Notably, participants with hypertension showed even higher reductions in SBP in the two Mediterranean diet conditions: -6.2 mmHg (95% CI, -8.4 to -4.0) for olive oil, and -7.4 mmHg (95% CI, -9.9 to -5.0) for nuts. Although this randomized clinical trial is in its early stages, preliminary results seem to corroborate previous findings that diets high in monounsaturated fat may have beneficial cardiovascular effects.

Dietary fiber

Dietary fiber influences satiety and reduces energy intake. Therefore, it may influence BP by a mediating

effect through weight reduction. Observational and controlled clinical trials have demonstrated mixed results on the consumption of dietary fiber and CVD risk. Observational studies suggest an inverse relationship between dietary fiber consumption and hypertension risk [26,27]. Clinical trials of dietary fiber have demonstrated variation in BP effects. If dietary fiber is proven efficacious, increased dietary fiber intake would provide a simple, noninvasive, and tolerable approach for BP reduction. In a recent meta-analysis of randomized controlled clinical trials of dietary fiber on BP [28**], results of 25 studies suggested that dietary fiber intake may reduce BP in patients with hypertension with smaller, inconclusive reductions in normotensive participants. Specifically, overall dietary fiber was associated with a significant reduction in both DBP (-4.20 mmHg, 95% CI, -6.55 to -1.85) and SBP (-5.95 mmHg, 95% CI, -9.50 to -2.40) for patients with hypertension in trials with a duration of at least 8 weeks. In normotensive and hypertensive participants combined, dietary fiber was associated with significant reductions in DBP (-1.65 mmHg, 95% CI, -2.70 to -0.61), but nonsignificant reductions in SBP (1.15 mmHg, 95% CI, -2.68 to 0.39). In a separate meta-analysis of dietary fiber, similar findings revealed nonsignificant changes in SBP (-1.13 mmHg, 95% CI, -2.49 to 0.23) and significant reductions in DBP (-1.26 , 95% CI, -2.04 to -0.48) [29*]. The effects of fiber supplementation on BP were larger in persons over the age of 40 years, but this trend was only statistically significant for SBP. Blood pressure reductions tended to be greater in hypertensive persons than those with normal BP, but this trend lost statistical significance when age was controlled for in the analysis. Weight and sex did not influence the effect of dietary fiber intake on BP.

Overall, research on fiber supplementation is mixed. Intake of dietary fiber appears, however, to demonstrate downward trends in BP with statistically significant improvements for individuals with hypertension. It is unclear whether the effects of BP in these studies may be a result of increased magnesium and potassium intake, or whether the effects of insoluble and soluble fibers on mineral absorption in the gastrointestinal system may have indirect effects on favorable BP reductions.

Vegetarian diets

Research suggests that plant-based dietary patterns are associated with lower risk of CVD and prevalence of hypertension, and may be associated with BP reductions in both hypertensive and normotensive individuals [30*]. Persons from cultures with traditionally plant-based diets have historically shown lower BP levels than individuals consuming a diet of plants and meat [30*]. Individuals from more traditionally omnivorous cultures have demonstrated lower BP levels when selecting vegetarian diets than nonvegetarian dietary patterns. In a review of vegetarian

diets and BP regulation, Berkow *et al.* (2005) [30*] reported that SBP of vegetarians was 3–14 mmHg lower and DBP was 5–6 mmHg lower than nonvegetarians in observational studies. Furthermore these observational studies revealed that prevalence of hypertension ranges from 2 to 40% among vegetarians and 8 to 60% among nonvegetarians. Notably, few randomized controlled clinical trials have been conducted in the recent past. Although the research is scarce, findings included reductions in BP for both normotensive and hypertensive persons when animal products are replaced with vegetable products.

Low-carbohydrate versus low-fat diets

Low-carbohydrate diets enjoyed a short-lived popularity in recent years with interest waning in 2004, but data on the effects of these diets on CVD risk factors remain inconclusive. Protein and fat make up a large proportion of the energy intake in low-carbohydrate diets, therefore eliciting concern about the potentially adverse effects this type of diet may have on lipid levels and cardiovascular risk. Recent clinical trials and uncontrolled studies have yielded insufficient evidence to support a recommendation for use of low-carbohydrate diets. A recent meta-analysis of six randomized controlled clinical trials comparing the effects of low-carbohydrate to low-fat diets yielded similar inconclusive recommendations [31*]. The meta-analysis found that after 6 months individuals receiving low-carbohydrate diets lost more weight than those persons receiving a low-fat diet (-3.3 kg, 95% CI, -5.3 to -1.4), but these weight differences were no longer obvious at 1 year (-1.0 kg, 95% CI, -3.5 to 1.5). Those individuals in the low-carbohydrate condition trended towards lower SBP and DBP at 6 months (-2.4 mmHg, 95% CI, -4.9 to 0.1), but this trend was undetectable after 12 months. The low carbohydrate diets yielded potentially beneficial changes in triglyceride and HDL levels, but unfavorable and potentially detrimental changes in LDL cholesterol levels were also present. The authors concluded that there was still unconvincing evidence to make recommendations for or against the use of low-carbohydrate diets and additional clinical trials data are needed.

Positive impact of minerals (potassium, magnesium, and calcium)

Observational studies have demonstrated an inverse relationship between potassium consumption and BP [30*]. Meta-analyses [32,33] have revealed that potassium intake significantly lowered SBP and DBP in hypertensive and normotensive individuals. A meta-analysis by Dickinson *et al.* [34**], however, revealed that among randomized controlled trials potassium showed a moderate but statistically nonsignificant reduction in SBP (3.9 mmHg, 95% CI, -0.8 to 8.6) and little reduction in DBP (1.5 mmHg, 95% CI, -3.1 to 6.2). Research in this area remains inconclusive.

Magnesium as a dietary source is found in fruits, vegetables, dairy products, and certain grains. Magnesium through the use of supplements appears to be less impressive in its BP effects. Randomized controlled trials using supplements revealed nonsignificant effects on BP but downward trends in BP were present [34**].

Research suggests that calcium plays a role in BP, but the importance of calcium supplementation remains inconclusive. Randomized clinical trials suggest that supplemental calcium exerts small, statistically insignificant reductions in BP [34**]. A recent meta-analysis of randomized controlled trials examining the response of BP to calcium supplementation found that calcium (1200 mg/day) significantly reduced SBP by 1.9 mmHg and DBP by 1.0 mmHg [35**]. No further effects on BP were shown when calcium doses exceeded 1 g/day. The BP effect tended to be more pronounced in individuals with normally low calcium intake suggesting that supplemental calcium exerts a stronger effect on BP in calcium deficient persons.

Soy

Some soy foods may have an effect on lowering BP. It is uncertain, however, whether healthful BP effects are explained by the presence of isoflavones or amino acid content of soy protein. Several studies show BP improvements when soy protein supplementation is provided [36,37,38*], but a recent review of the literature by the American Heart Association Nutrition Committee shows inconclusive and mixed results [39**]. Specifically, this AHA review examined several studies of soy protein with isoflavones and isolated soy isoflavones, and found only one statistically significant study relating to BP effects.

Caffeine

Although a link between caffeine consumption (particularly coffee) and hypertension may exist, effects of coffee drinking on BP appear to be dependent on the time of consumption and subsequent determination of BP values [40]. Generally, a role for caffeine intake and development of hypertension is not believed to be significant.

Weight reduction

Obesity and overweight are considered independent risk factors for cardiovascular disease and are closely associated with hypertension. This linkage was demonstrated in the 1960s by the Framingham Heart Study investigators in the US [41]. Obesity in the industrialized world has been increasing in epidemic proportions. The relationship between increasing body weight and increasing BP has been termed obesity hypertension, and treatment requires consideration of physiologic changes related to this disorder [42]. Although efforts have been under way in the US to reduce overweight and obesity, it is estimated that the age-adjusted prevalence of overweight and obesity [body

mass index (BMI) ≥ 25.0] among adults aged 20 or older is 64%; for those considered obese (BMI ≥ 30.0) is 30%. During a 25-year period in the US, this reflects approximately a 36% increase in the combined levels of overweight and obesity and essentially a doubling of obesity rates. The increase in obesity is seen in all ethnic, sex, and age groups. This epidemic has spread to children, with 17.6 million children younger than 5 years of age estimated to be overweight worldwide. Data from the US indicate that 15% of children and adolescents 6–19 years of age are overweight, a figure at least three times higher than that reported in the period from 1960 to 1970. Overweight children are at risk of becoming overweight adults but, more important, are likely to experience chronic health problems (including hypertension) associated typically with only adult obesity.

Conclusion

Hypertension is a common chronic disease impacting many populations, with increasing risk associated with the aging process. Without a doubt, there are a multitude of nutritional factors affecting blood pressure. While there seems to be clear cut evidence for certain factors (e.g., the DASH dietary pattern, sodium reduction), more research will undoubtedly reveal impact of additional nutrients or dietary lifestyles to lower blood pressure and decrease risk of hypertension.

For additional information relating to specific guidelines for managing hypertension by nutritional manipulation, the reader is referred to Champagne [43**].

References and recommended reading

Papers of particular interest, published within the annual period of review, have been highlighted as:

- of special interest
- of outstanding interest

Additional references related to this topic can also be found in the Current World Literature section in this issue (p. 101).

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