Chapter 7
Hypertension

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Key Points

- To identify the nutrients and foods most commonly believed to be associated with blood pressure
- To evaluate the evidence for or against the effect of certain nutrients and food groups on blood pressure
- To discuss the current dietary recommendations for the prevention and treatment of hypertension
- To describe how current dietary recommendations for hypertension apply to people with chronic kidney disease

Keywords Blood pressure • Sodium • Potassium • DASH diet • Calcium • Omega-3 fatty acids • Monounsaturated fatty acids • Vitamin C • Protein • Magnesium

Introduction

According to national data, approximately 29 % of US adults had hypertension in 2007–2008. The prevalence has changed little in the previous 10 years [1]. A significant number of patients with chronic kidney disease (CKD) have hypertension. Hypertension can be treated and sometimes prevented with the proper dietary intake. Some studies suggest that certain nutrients, including sodium, potassium, calcium, magnesium, protein, unsaturated fats, and vitamin C, may have an effect on blood pressure level. Research has also found associations of blood pressure (BP) with food groups such as fruits, vegetables, and dairy products. This chapter will review the evidence for treating hypertension with diet modification.

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Nutrients and Blood Pressure

Sodium

Although the debate over the extent of dietary sodium's influence on BP has raged for decades, Intersalt, the cross-sectional epidemiological study conducted in 32 countries in the mid-1980s, found that higher 24-h urine sodium excretion (a marker for sodium intake) was positively associated with higher BP [2, 3]. The association was stronger for the older participants (40–59 years old). Other cross-sectional studies have also found an association between sodium intake and blood pressure [4].

Randomized controlled trials (RCTs) that reduce sodium intake have also found significantly lower BP in the sodium restricted group [5–7]. A meta-analysis of 167 RCTs that included only studies that confirmed sodium intake through 24-h urine sodium excretion found that normotensive people who had a low sodium intake had lower systolic blood pressure (SBP) than those with a high sodium intake [8]. Hypertensive people with a low sodium intake had lower SBP and diastolic blood pressure (DBP) than those with a high sodium intake. The second trial of Dietary Approaches to Stop Hypertension (DASH) tested both the DASH diet—a diet high in fruits, vegetables, and low-fat dairy foods—and sodium intake [9]. Participants with an SBP of 120–139 mmHg and/or DBP of 80–99 were randomized into the typical US diet (control) or the DASH diet in a parallel group design and spent a month consuming that diet at each of three sodium levels: high, intermediate, and low. In both diet groups, BP was significantly lower for the lower sodium levels, showing an independent effect of sodium on BP.

One 2-year prospective study did not find a significant association between sodium excretion and BP, but found that fewer than 20 % of 296 healthy participants experienced a significant increase in BP at high sodium intakes [10]. Indeed, some people seem to be more sensitive than others to sodium's effect on BP. Despite this fact, most recent studies show that sodium restriction does reduce BP. The effect is more pronounced in African Americans, older people, and persons diagnosed with hypertension.

Limiting sodium intake is especially important in CKD because excess sodium increases extracellular fluid volume, which may not only increase BP but also weight gain, increasing the amount of fluid to be removed in dialysis [11].

The 2004 Dietary Reference Intake (DRI) for sodium recommends consuming no more than 1,500 mg of sodium per day, 1,300 mg for those over age 50 [12]. The 2010 Dietary Guidelines for Americans recommends that most people consume less than 2,300 mg/day, but highlights the 1,500 limit for people with hypertension [13]. The mean intake of sodium among US adults is 3,266 mg/day [14]; in 2005–2006 only 5.5 % of US adults consumed less than 1,500 mg of sodium daily [15]. The food category contributing the most sodium to the US diet was breads and rolls (7.4 %) due to the high rate of consumption of these products [14]. Additionally, 65 % is from store-bought foods, and 24.8 % comes from restaurants. These categories of foods present opportunities for intervention.

Potassium

Both observational and experimental studies have shown that potassium intake is inversely associated with BP. In a meta-analysis of five RCTs of at least 8 weeks in duration, potassium supplementation reduced SBP and DBP in three of the trials, but in the five trials, overall supplementation did not affect BP [16]. In contrast, a meta-analysis of 33 RCTs conducted from 1981 to 1995 found that potassium supplementation (from the diet in six of the studies) significantly reduced SBP by 3.11 mmHg and DBP by 1.97 mmHg [17]. It is of note that this analysis included interventions of short duration.

Another meta-analysis also found that low potassium significantly increased risk of hypertension [18]. In addition to interventions, cross-sectional epidemiological studies suggest the same result [4, 19]. Even a low dose (600 mg) of potassium can significantly reduce BP [20]. Since potassium is readily available in the food supply, it is recommended to achieve the recommended level of potassium through foods instead of supplementation.

Increasing potassium intake can have a greater effect on BP when sodium intake is high [21]. This association may be due to the increase in sodium excretion that results from increasing potassium intake. Data suggest that the sodium–potassium ratio may be more important than potassium intake alone [2, 6, 22]. Intersalt and other studies have also found a significant association of BP with the sodium–potassium ratio, the lower the sodium–potassium ratio, the lower the BP [2, 4, 17]. However, the literature does not mention an ideal ratio.

The DRI adequate intake of 4,700-mg potassium per day [12] was instituted in large part in an effort to prevent and treat hypertension. However, because of the increased risk of hyperkalemia in CKD, KDOQI recommends limiting potassium to no more than 2,000–4,000 mg/day in stages 3 and 4 [23].

Calcium and Dairy Foods

Data from the 1999 to 2004 NHANES found an inverse association between fluid milk and SBP and DBP [24]. A systematic review and meta-analysis of prospective cohort studies by Ralston et al. [25] found that consuming more low-fat dairy foods reduced risk of elevated BP (RR = 0.87). A review of milk products and BP management found that in most cross-sectional and prospective studies, dairy intake was associated with SBP [26]. An association was seen with DBP less often, and fluid milk and low-fat dairy foods were more likely to be associated with reduced BP. Results from some cross-sectional studies and RCTs examining dietary and supplementary calcium and BP have been mixed [4, 27–32]. However, two meta-analyses that examined 13 and 40 RCTs ([33] and [34], respectively) found that supplementation with an average of about 1,200-mg calcium significantly lowered SBP but not DBP. Additionally, a pooled analysis of 42 RCTs found a small BP reduction from calcium supplements and dietary calcium [35]. Dietary calcium had almost twice the reduction in BP compared to supplemental calcium, but the difference was not significant.

Some studies have shown that diets high in calcium, mostly from dairy products, have a BP lowering effect. Of greatest note, the DASH trials found that increasing low-fat dairy intake in a diet high in fruits and vegetables reduced BP even further than high fruit and vegetable intake alone [36]. However, a study that examined BP and milk intake included three treatment groups: (1) skim milk, (2) high-calcium skim milk, and (3) high-calcium skim milk enriched with potassium. Only the group consuming the high-potassium milk significantly reduced BP [37]. Any association between dairy consumption and BP may be due to calcium, but may also involve other nutrients present in milk. More studies are needed to determine the extent of the influence of calcium intake on BP.

Magnesium

Magnesium's role in vascular tone and contractility suggests that it can aid in BP reduction [38], but trials examining the effect of magnesium intake on BP have yielded inconsistent results. This may be due in part to the variety of methods used in the studies. Meta-analyses in 2012 and 2002 of trials administering magnesium supplements suggest small, but clinically significant dose-dependent reductions in BP [39, 40]. A more recent review of magnesium supplementation in hypertension found mixed results [41]. Most of the trials that have included magnesium to date have had small sample sizes, which limit the conclusions that can be drawn from the data. As with calcium, more carefully controlled studies are needed to further elucidate any association between magnesium and BP.

Protein

A 1996 review of studies examining the association of dietary protein with BP found little or no effect of protein intake on BP among intervention studies [42]. However, some observational studies did find decreased BP with higher protein intake. Since that review, the cross-sectional Intersalt study found that total and urea nitrogen excretion, as markers of protein intake, were associated with lower BP when adjusting for age, sex, alcohol intake, BMI, and urinary sodium, potassium, calcium, and magnesium excretion [43]. The INTERMAP study suggests that the effect of protein on diet may vary depending on the type of protein. The cross-sectional study found an inverse association between vegetable protein intake and BP, but a positive association between animal protein intake and BP [19]. A prospective cohort study and a systematic review had similar findings [44, 45]. In addition, three randomized trials that found an inverse association between protein and BP increased the protein levels in the diet by adding vegetable protein [46–48]. These studies suggest that vegetable protein may be beneficial in controlling BP, but more examination is needed.

Fatty Acids

A population-based study of Japan, the People's Republic of China, the United Kingdom, and the United States found that a high intake of omega-3 fatty acids from food was associated with small but significant reductions in SBP and DBP when considering the fatty acids separately or together and across countries [49]. Three meta-analyses of RCTs administering large doses of omega-3 oils to people with hypertension found an inverse association with BP [50–52]. There was a greater effect on BP for persons 45 years or older [50]. However, there was little effect of omega-3 fatty acids on healthy adults or in trials using small doses of the oil. Although the evidence for this association is relatively strong, the potential side effects associated with consuming large doses of fish oil may be prohibitive.

Some studies suggest that monounsaturated fat can also reduce BP in people with hypertension. The OmniHeart Study examined the effects of a high-carbohydrate diet, a high-protein diet, and a diet rich in mono-unsaturated fatty acids (MUFAs) in the form of olive, canola, and safflower oils and nuts and seeds [41]. The MUFA diet lowered BP more than the high carbohydrate and had a similar effect to the high-protein diet. These and other studies [53, 54] suggest that omega-3 and MUFAs may have a beneficial effect on BP. However, most of these studies had small sample sizes and involved people with hypertension, limiting the generalizability of the results.

Vitamin C

Baseline data from a prospective study showed an inverse association between plasma vitamin C concentration and SBP [55], as have cross-sectional studies examining dietary vitamin C [56, 57]. However, this association may just be a marker for fruit and vegetable intake. Although a 2012 meta-analysis found that vitamin C supplementation significantly reduced both SBP and DBP, the reduction was small and the studies were short term [58]. One cross-sectional study divided survey respondents into four groups: high vitamin C-high fruits and vegetables, high vitamin C-low fruits and vegetables, low vitamin C-high fruits and vegetables, and low vitamin C-low fruits and vegetables (control) [59]. The women in the two high fruits and vegetables groups had lower SBP compared to the control group, but the high vitamin C-low fruits and vegetables group did not have improved BP compared to the control group. This suggests that any differences in BP may largely be due to fruit and vegetable intake, not dietary vitamin C intake. Additionally, two interventions found little difference in BP between vitamin C and placebo groups [60, 61].

The DASH Diet

The key to modifying diet to reduce BP may rest in overall dietary patterns as opposed to consumption of a single nutrient or food. The DASH studies illustrate how a dietary pattern can successfully affect BP level. The original DASH study featured three treatment arms: (1) a usual intake that mirrored the typical US diet; (2) the typical diet modified to include higher amounts of fruits, vegetables, and fiber and lower in snacks and sweets; and (3) a diet high in fruits, vegetables, and low-fat dairy foods and lower in total fat, saturated fat, and cholesterol [36]. Table 7.1 shows the components of the DASH (combination) diet. Participants ate the assigned diet for 8 weeks. At the end of the 8 weeks, participants eating the fruits and vegetables diet had SBP and DBP 2.8 and 1.1 mmHg lower than the mean BP in the control group ($p<0.001$ and $p=0.07$, respectively). The combination fruit, vegetable, and low-fat dairy diet group had SBP 5.5 mmHg and DBP 3.0 mmHg lower than the control group ($p<0.001$ for both). The effect of the diet was greater for African Americans and for those with hypertension.

The second investigation into this diet compared the control and combination (DASH) diets at three different sodium levels as described above and found that BP decreased as sodium intake decreased [7]. Consuming the DASH diet at the lowest sodium level (50 mmol/day) resulted in lowest BP. A behavioral intervention using the DASH diet (Premier) showed that it is possible to successfully incorporate the DASH dietary pattern and reduce BP in a community setting [62]. The results of these carefully controlled studies and the subsequent behavioral study show that an eating pattern can be an effective tool in reducing BP.

Table 7.1 The DASH eating plan (based on 2,000 cal diet)

Food group	Servings per day	Nutrient sources
Grains and grain products	7–8	Major sources of energy and fiber
Vegetables	4–5	Rich sources of potassium, magnesium, and fiber
Fruits	4–5	Important sources of potassium, magnesium, and fiber
Low-fat or fat-free dairy foods	2–3	Major sources of calcium and protein
Meats, poultry, and fish	2 or less	Rich sources of magnesium and protein
Nuts, seeds, and dry beans	4–5 per week	Rich sources of magnesium, potassium, protein, and fiber
Fats and oils	2–3	27 % calories as fat
Sweets	5 per week	

Taken from "Facts about the DASH Eating Plan." National Institutes of Health, Department of Health and Human Services. NIH Publication No. 03-4082. May 2003

Table 7.2 JNC 7 diet-related lifestyle modifications

Modification	Recommendation	Approximate systolic BP reduction, range
Weight reduction	Maintain normal body weight (BMI, 18.5–24.9)	5–20 mmHg/10-kg weight loss
Adopt DASH eating plan	Consume a diet rich in fruits, vegetables, and low-fat dairy products with a reduced content of saturated and total fat	8–14 mmHg
Dietary sodium reduction	Reduce dietary sodium intake to no more than 100 mEq/L (2.4-g sodium or 6-g sodium chloride)	2–8 mmHg
Moderation of alcohol consumption	Limit consumption to no more than two drinks per day (1-oz or 30-mL ethanol [e.g., 24-oz beer, 10-oz wine, or 3-oz 80-proof whiskey]) in most men and no more than one drink per day in women and lighter-weight persons	2–4 mmHg

Taken from ref. [63]

Table 7.3 KDOQI nutritional recommendations

Nutrient	Stage of CKD	
	Stages 1–4	
Sodium (mg/day)	<2,400	
Total fat (% of energy)	<30	
Saturated fat (% of energy)	<10	
Cholesterol (mg/day)	<200	
Carbohydrate (% of energy)	50–60	
	Stages 1–2	Stages 3–4
Protein (g/kg/day, % of energy)	1.4 (~18)	0.6–0.8 (~10)
Phosphorus (g/day)	1.7	0.8–1.0
Potassium (g/day)	>4	2–4

Reprinted with permission from ref. [23]

Dietary Recommendations for Hypertension

The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC 7) Recommendations

The importance of lifestyle modification, especially dietary change, in prevention and treatment of hypertension is well recognized. JNC 7 was written in 2003 to incorporate results from the latest hypertension studies and trials into useful guidelines for preventing and treating hypertension [63]. JNC 7 sees lifestyle modification as a critical component of hypertension management. Its dietary recommendations (Table 7.2) include losing weight if overweight or obese, reducing sodium intake to less than 100 mEq/L (2.4 g) of sodium, limiting alcohol consumption to no more than two drinks per day, and adopting the eating pattern shown to effectively lower BP in the DASH studies. The report also includes an approximate amount of reduction in systolic BP that can be achieved for each of these dietary changes. It advocates adopting more than one strategy to achieve even greater results.

KDOQI Guidelines

Dietary modification is a critical component of managing CKD. The National Kidney Foundation Kidney Disease Outcomes Quality Initiative (KDOQI) has guidelines for diet in hypertension in CKD (Table 7.3) [23]. With the exception of potassium and protein intake, the KDOQI recommendations for macronutrient intake in CKD largely mirror the recommendations for the general population. The sodium recommendations are in keeping with the sodium recommendations described above. However, because of potassium retention in kidney disease, the recommended intake of 4,700 mg/day is not advisable for CKD patients, especially for those with GFR <60 mL/min/1.73 m^2. Similarly, protein intake should be lower in CKD (about 10 % of energy), especially in stages 3 and 4, to reduce the production of nitrogenous wastes and to try to slow the progression of the disease. Although the DASH diet is beneficial in lowering BP, the higher potassium and phosphorus intakes that result from the diet may lead to hyperkalemia and hyperphosphatemia, respectively, especially in patients with GFR <60 mL/min/1.73 m^2. Recommendations for adopting a DASH dietary pattern should be made with these considerations.

Summary

In summary, current evidence suggests that lowering sodium intake and increasing intake of potassium, vegetable protein, omega-3 and monounsaturated fatty acids, fruits, and vegetables can help lower BP. In CKD, however, increasing some of these nutrients and food groups, especially potassium, dairy, and protein, may be contraindicated.

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