Review Paper • CME

# Dietary Influences on Blood Pressure: The Effect of the Mediterranean Diet on the Prevalence of Hypertension

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*Hypertension has long been recognized as a major risk factor for several common cardiovascular diseases. The World Health Organization reports that the number of people with hypertension worldwide is estimated at 600 million, while 3 million will die annually as a result of hypertension. There is evidence to support that several factors related to lifestyle habits may influence blood pressure levels. Among these, the beneficial effect of diet on human health, as well as on the control of hypertension, has been underlined in several studies. Moreover, adherence to a Mediterranean diet has been associated with reduced all-cause mortality and, especially, coronary heart disease. The effect of this traditional diet on blood pressure levels has not been well understood and appreciated. This review summarizes the current understanding of the dietary influences on blood pressure control and the findings of observational and clinical studies that have evaluated the effect of the Mediterranean dietary pattern on the prevalence of chronic essential hypertension. (J Clin Hypertens. 2005;7:165–170)* ©2005 Le Jacq Ltd.

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Chronic essential hypertension is a major risk factor for cardiovascular (CV) disease, including coronary heart disease (CHD), cerebrovascular disease, and heart failure, as well as a major health problem for industrialized societies. The World Health Organization reports that the number of people with hypertension worldwide is estimated at 600 million, of whom 3 million will die annually as a result of hypertension. It is also estimated that in the United States, only about one third of people with hypertension achieve blood pressure (BP) control.[1–3] Positive lifestyle modifications may potentially contribute to the prevention of chronic hypertension as well as the normalization of elevated BP.[3]

Among these lifestyle modifications, the beneficial effect of diet has been emphasized in several studies.[4–7] The National High Blood Pressure Education Program[3] suggests nonpharmacologic interventions, such as diet, weight loss, and physical activity for the primary and secondary prevention of hypertension. There is increasing scientific evidence of the protective health effects of diets that are high in fruits, vegetables, legumes, and whole grains, and also include fish, nuts, and low-fat dairy products. Such diets need not be restricted in total lipid intake as long as energy intake does not exceed expenditure, and the emphasis is on vegetable oils that are low in saturated fats and partially hydrogenated oils. The traditional Mediterranean diet, whose principal source of dietary lipids is olive oil, includes these dietary characteristics.[7,8] In recent decades, a large body of evidence has related adherence to a Mediterranean diet to a lower all-cause mortality, as well as a lower incidence of CHD and certain types of cancer.[9–11] In this review,

we summarize the nutritional guidance for BP control, and the findings of observational studies that evaluated the effect of comprehensive dietary approaches, i.e., the Dietary Approaches to Stop Hypertension (DASH)[6] diet and the Mediterranean diet, in the prevention of chronic hypertension.

## DIET AND HYPERTENSION

Current recommendations from the National High Blood Pressure Education Program[3] suggest weight control, reduction of sodium and alcohol intake, and an increase in potassium and magnesium consumption.

### Sodium Intake

Increased fluid volume as a consequence of excess sodium intake has received much attention. A number of investigators believe that excess sodium intake contributes to the occurrence of hypertension (BP >140/90 mm Hg).[12] A rise in BP is seen when people on low-salt diets with normal BP adopt Western lifestyles and increase their intake of sodium[13]; however, confounding factors such as the lower incidence of obesity, high levels of physical activity, and perhaps a less stressful lifestyle in these populations were not considered in these studies. Most experimental studies indicate that sodium restriction in hypertensive patients decreases BP.[13,14] The Trials of Hypertension Prevention,[15] a randomized controlled study, also showed that individuals with high–normal BP who restricted sodium intake moderately for 1.5–5 years had lower BP and a lower incidence of hypertension than those who did not change sodium intake. Although epidemiologic and experimental findings support the role of excess sodium intake in hypertension, only half of the population in Western societies, where high sodium consumption is prevalent, develop hypertension. This suggests that some may have a sensitivity to sodium or that sodium excretion may be impaired. Impairment of renal sodium excretion is supported by experimental studies in rats bred to be salt-sensitive or resistant to the hypertensive action of increased dietary sodium intake. When the kidney from a normotensive rat is transplanted to a hypertensive rat, BP decreases to normal. Conversely, when a normotensive rat receives a kidney from a hypertensive rat, BP increases.[16]

Impairment in sodium excretion at the tubular level may contribute to hypertension. Some investigators have proposed that sodium retention leads to water retention and an increase in blood volume. This, in turn, increases cardiac output resulting in higher BP.[17] Others have argued that excess sodium may increase sympathetic activity which, in turn, will enhance vasoconstriction.[18] The role of sodium in the pathogenesis of hypertension is still being debated. Most recently, in a meta-analysis that included 56 randomized, controlled trials, Midgley et al.[19] concluded that dietary sodium restriction may provide some benefits for hypertensive individuals over the age of 45 years; however, normotensive individuals may have nothing to gain from limiting sodium intake. These findings were corroborated by the Trial of Hypertension Prevention-II (TOHPII),[20] the largest and longest study ever executed to assess the role of sodium restriction on BP control and the prevention of hypertension.

### Potassium Intake

Evidence from population studies and clinical trials suggests a weak inverse association between estimates of potassium intake and BP; low potassium intake may increase BP.[21,22] The effect appears to be more pronounced in individuals exposed to high dietary sodium intake. The hemodynamic effects of potassium may be linked to potassium-mediated sodium excretion (distal tubular effect).[22] Potassium supplementation may be therapeutic in the treatment of hypertension in some patients; however, the risk of hyperkalemia for subgroups of patients should be considered, and large doses of potassium should be avoided.

### Magnesium Intake

Epidemiologic studies suggest an inverse relationship between BP and dietary magnesium; however, well-designed, randomized trials are few and their findings are inconsistent.[23,24] These studies suggest that BP reduction with supplemental magnesium may occur only in patients with baseline low magnesium levels. Intracellular concentrations of magnesium may play a key role in regulating vascular tone and insulin-mediated glucose uptake.[24] It is further postulated that reduced levels of intracellular magnesium may explain the association between insulin resistance and hypertension.

### Calcium Intake

Epidemiologic evidence suggests an increased prevalence of hypertension with a low dietary calcium intake.[25] The theoretical basis for the role of calcium in the pathogenesis of hypertension is provided by the central role calcium plays in the modulation of vascular smooth muscle contraction. Alterations in smooth muscle contraction resulting from abnormalities in calcium metabolism may ultimately increase peripheral resistance and therefore increase BP. Most, but

not all, studies observed reductions in BP with oral calcium supplementation in hypertensive patients.[26] Two recent meta-analyses of randomized controlled calcium supplementation trials have identified a small, but consistent, reduction in BP in normotensive and hypertensive subjects who increased their calcium consumption. For an average calcium intake from 0.5–2.0 g/d, the authors observed a 0.53 mm Hg decrease for systolic BP in subjects with normal BP and a 1.68 mm Hg decrease for systolic BP in subjects with hypertension; however, the modest reduction in systolic BP identified by these meta-analyses do not justify the use of calcium supplementation for BP control in hypertensive patients.[27,28]

### Alcohol Intake

Epidemiologic findings have provided conflicting reports on the association of alcohol consumption and BP. In one study, subjects who drank daily had higher BP levels than heavy weekend drinkers, while in another study, a J-shaped association between alcohol consumption and BP, as well as CV risk, was observed. [29–31] The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC 7)[3] identifies excessive alcohol consumption (e.g., more than 4–5 drinks of whiskey per day) as a risk for hypertension and stroke; this degree of use may cause resistance to antihypertensive medication. It is estimated that alcohol-related hypertension may account for as much as 30% of cases of essential hypertension.[3] This, and the high prevalence of alcohol consumption in several cultures, makes alcohol consumption a considerable, but modifiable, risk factor for hypertension. Thus, efforts to implement lifestyle changes in the prevention and treatment of hypertension should include abstention from, or at least moderation of, alcohol consumption.

## COMPREHENSIVE DIETARY CHANGES

For decades, public policy recommendations regarding dietary approaches in the management of hypertension have emphasized restrictions of sodium.[7] However, recent research suggests that comprehensive dietary changes other than sodium restriction alone play a more important role in the etiology, prevention, and treatment of hypertension.[32]

### The Mediterranean Diet

Clinical trials report lower BPs in vegetarians than in non-vegetarians and people with diets rich in minerals and fiber[33]; however, vegetarian diets are not practical for most people. An alternative to a vegetarian diet is the Mediterranean diet.[34,35] Olive oil is the most important element in this diet, not only because it has several beneficial properties, but also because it encourages the consumption of large quantities of vegetables in the form of salads and equally large quantities of legumes in the form of cooked foods. This is perhaps the single most important difference between the Mediterranean diet and the new dietary guidelines proposed by the Center for Nutrition Policy and Promotion at the United States Department of Agriculture.[36] Other essential components of the Mediterranean diet are wheat, olives, grapes, and their various derivative products. This traditional diet may be thought of as having nine components: high consumption of olive oil, legumes, cereals, fruits, vegetables; moderate-to-high consumption of fish; moderate consumption of wine, dairy products (mostly as cheese and yogurt), and beans; and a low consumption of meat and meat products. Alcohol is consumed in moderation and almost always during meals. This diet is low in saturated fat (less than 9% of energy), with total lipid intake ranging from <30% to >40% of energy from one area to another. Moreover, the ratio of monounsaturated to saturated fats is about 2:1, which is higher than in the usual diet in the United States.

The high content of vegetables, fresh fruits, and cereals, and the liberal use of olive oil in the Mediterranean diet guarantees an adequate intake of beta carotene, vitamin C, tocopherols, linolenic acid, various important minerals, and several possibly beneficial non-nutrient substances such as polyphenols and anthocyanins. The Mediterranean diet can be represented in the form of a triangle (pyramid), the base of which refers to foods which are to be consumed most frequently and the top to those to be consumed rarely, with the remaining foods occupying intermediate positions.[37] Compared with the US Food Guide Pyramid from the United States Department of Agriculture,[36] the Mediterranean diet includes less meat, less saturated fats, and more fruits and vegetables.

***The Epidemiologic Evidence.*** Epidemiological data have provided evidence that the health status of Mediterranean populations may have benefited from this specific diet. Although interpretations of these data are difficult, a potential explanation of the lower CV mortality rates among Mediterranean populations is their traditional diet, as suggested by the Seven Countries Study.[9] The investigators—based on the two Greek cohorts of Corfu and Crete—reported the protective role of the Mediterranean

diet against atherosclerosis, mainly due to lower levels of BP and body mass index. Many years later, the CARDIO2000 investigators[38] studied a sample of approximately 2000 middle-aged patients with a first myocardial infarction or unstable angina and matched by age and sex from various Greek regions. They reported that the adoption of a Mediterranean diet was related to an adjusted 7%–10% reduction in the coronary risk in treated, untreated, or uncontrolled hypertensive subjects. Recently, in a large prospective survey involving 22,043 middle-age and older adults from Greece, Trichopoulou and colleagues[39] from the Greek cohort of the European Prospective Investigation Into Cancer and Nutrition (EPIC) study reported that an inverse association with greater adherence to the Mediterranean diet was observed for death due to CHD, irrespective of gender, smoking status, level of education, body mass index, and level of physical activity. Martinez-Gonzalez et al.,[10] in a case-control study that included about 350 patients and controls, reported that the higher the Mediterranean diet score, the lower the odds ratio of myocardial infarction, mainly due to lower BP levels, after adjustment for other CV risk factors. Schroder et al.,[40] studying a Mediterranean population in Spain, emphasized the importance of diet and sodium intake as a nonpharmacologic approach in the prevention and treatment of essential hypertension.

In other studies, Alonso et al.,[41] in a cross-sectional analysis of 4393 participants in Spain, observed that a high fruit and vegetable intake was inversely associated with BP levels in a population with a high fat consumption. Comparing those in the highest quintile of both fruit and vegetable consumption with those in the lowest quintile of both food groups, the odds ratio of hypertension was 0.23 (0.10–0.55) after adjusting for other risk factors and other dietary exposures. Ruiz-Gutierrez et al.[42] studied the effect of a diet rich in monounsaturated fatty acids from high-oleic sunflower oil and olive oil on BP levels in hypertensive women. They observed a significant reduction in systolic and diastolic BPs after the ingestion of olive oil. Finally, Strazzulo et al.[43] observed that a decrease in the saturated fatty acid content of the diet with a moderate change in the ratio of dietary polyunsaturated to saturated fat significantly reduced BP levels.

***A Pathophysiologic Explanation.*** The Mediterranean diet is low in saturated fat and high in monounsaturated fat (mainly from olive oil), high in complex carbohydrates from legumes, and high in fiber (mostly from vegetables and fruits). Total fat is high, i.e., about 40% of total energy intake, but the ratio of monounsaturated to saturated fat is approximately 2:1. The high content of vegetables, fruits, cereals, and olive oil guarantees a high intake of beta carotene, vitamins C and E, polyphenols, and various important minerals. These key elements have been suggested to explain the beneficial effect of diet on human health, and especially CV disease.[34,35,39,44] Simopoulos[45] suggests that the Mediterranean dietary pattern includes a number of protective substances such as selenium, glutathione, a balanced ratio of (n-6):(n-3) essential fatty acids, high amounts of fiber, antioxidants (especially resveratrol from wine and polyphenols from olive oil), as well as vitamins E and C, which may be associated with a lower risk of hypertension, CHD, and cancer.

## DIETARY APPROACHES TO STOP HYPERTENSION (DASH)

The Dietary Approaches to Stop Hypertension (DASH) clinical trial[6] lends support to a comprehensive dietary intervention similar to that of the Mediterranean diet. This study enrolled 459 adults with systolic BPs of <160 mm Hg and diastolic BPs 80–95 mm Hg. At first, the subjects were fed a control diet that was low in fruits, vegetables, and dairy products, and a diet that has a fat content typical of the average US diet. Then they were randomly assigned to receive: 1) the control diet; 2) a diet rich in fruits and vegetables; or 3) a "combination" diet rich in fruits, vegetables, and low-fat dairy products with reduced saturated and total fat. The objective of this study was to assess whether a diet rich in fruits, vegetables, and low-fat dairy foods, with sodium held constant, could substantially lower BP. The "combination" diet was associated with 5.5 mm Hg and 3.0 mm Hg lower systolic and diastolic BPs, respectively, than the control diet ($p<0.001$), while the fruits-and-vegetables diet reduced systolic BP by 2.8 mm Hg more ($p<0.001$) than the control diet. Among the 133 subjects with hypertension, moreover the combination diet reduced systolic and diastolic BP by 11.4 mm Hg and 5.5 mm Hg more, respectively, than the control diet ($p<0.001$ for each). Among the 326 subjects without hypertension, the corresponding reductions were 3.5 mm Hg ($p<0.001$) and 2.1 mm Hg ($p=0.003$).[6] All of these findings strongly suggest that the focus of dietary changes for the control of BP should not be on a single nutrient alone. A low-fat diet rich in fruits and vegetables and adequate intake of calcium, magnesium, and potassium should be recommended.

Diet and nutrition have been extensively investigated as risk factors for major CV diseases and are also linked to other metabolic diseases, such as diabetes, high BP, and obesity. There is now evidence that an adequate intake of fruits and vegetables, olive oil, fiber, and moderate alcohol are protective against hypertension. Sufficient knowledge exists to suggest that composite diets like the DASH diet or the Mediterranean diet may reduce the risk of hypertension and, consequently, CHD. De Lorgeril and Salen[46] suggest that in addition to its gastronomic appeal, the cardioprotective effects of the Mediterranean diet—with a reduction of blood lipids and BP levels—makes this dietary pattern attractive for public health purposes. Kouris-Blazos et al.[47] suggest that the Mediterranean dietary pattern can easily be translated into other cultures; other food options can be employed to increase the intake of monounsaturated fats. Others have suggested, however, that this traditional dietary pattern is difficult to adapt to other populations due to differences in cultural and environmental conditions.[48]

## CONCLUSION

There is ample evidence that diets low in saturated fats and sodium and rich in fruits, vegetables, and fiber, with adequate amounts of potassium, calcium, and magnesium, are effective in the prevention and treatment of hypertension alone or as an adjunct to pharmacologic therapy. Such dietary combinations are provided by the Mediterranean diet.

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# CME Questions

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**INSTRUCTIONS FOR COMPLETING THIS FORM:** Read the selected paper and answer all the questions that follow. After each question there is a series of possibly correct answers. Please select the one best answer for each and place your selection on the answer grid. **YOU MUST ALSO COMPLETE THE CME EVALUATION SECTION** and return the form within 6 months of the paper's publication to receive credit. Letters of credit will be mailed to participants biannually.

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**OBJECTIVE AND TARGET AUDIENCE:** All primary care physicians and cardiologists are eligible to receive credit. At the conclusion of this activity, participants should be able to: 1) summarize the important points discussed in the paper reviewed; 2) identify patients to whom the paper is relevant; 3) modify management practices as new information is learned; and 4) identify deficiencies in their knowledge base.

## Please Select the One Best Answer for Each Question and Place Your Selection on the Answer Grid.

1. Which of the following is not a feature of the Mediterranean diet?
   A __ Marked restriction of fat intake
   B __ Balancing caloric intake with energy expenditure
   C __ Low intake of saturated fats
   D __ Principal source of dietary fat is olive oil

2. Which of the following statements is not true regarding sodium intake in hypertension?
   A __ Evidence favors the fact that sodium restriction in hypertensive patients decreases blood pressure.
   B __ Impairment of sodium secretion likely predicts a hypertensive response to a high sodium intake.
   C __ Sodium retention leading to an increased blood volume may result in an increase in blood pressure.
   D __ Normotensive individuals benefit from a sodium-restricted diet.

3. Which of the following statements regarding dietary intake and blood pressure is false?
   A __ There is some evidence to suggest that a low potassium intake may increase blood pressure.
   B __ Some studies suggest that magnesium supplementation in hypomagnesemic patients may lower blood pressure.
   C __ An increase in calcium intake may result in a slight reduction in blood pressure.
   D __ Alcohol intake is not a risk factor for the development of hypertension.

4. Which of the following would not be a part of the dietary recommendations for a hypertensive patient?
   A __ Reduce intake of saturated fats
   B __ Increase intake of simple carbohydrates
   C __ Increase intake of fiber
   D __ Ensure adequate intake of calcium

5. Which of the following statements regarding epidemiologic evidence supporting the benefits of a Mediterranean diet is false?
   A __ A diet rich in monounsaturated fats and rich in fruits and vegetables has been shown to reduce blood pressure.
   B __ A Mediterranean diet did not have an effect on the blood pressure of normotensive patients.
   C __ An important component of the diet is combining the reduction of polyunsaturated fats with an increase in fiber, fruits, and vegetables.
   D __ All of the above statements are true.

CME Answers are available from *The Journal of Clinical Hypertension* page at www.lejacq.com

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**Answer the questions from the previous page by selecting the best choice of A, B, C, or D.**

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