



## A plant-based diet and hypertension

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Hypertension is an insidious, common, and deadly disease, often detected incidentally at a routine doctor's visit or workplace health screening. Worldwide, it is estimated that one billion people have hypertension and approximately 80 million Americans 20 years of age and older are hypertensive.<sup>[1]</sup> The National Health and Nutrition Data Examination Survey found that only 54% of hypertensive adults in the United States had their high blood pressure controlled and 17% remained undiagnosed.<sup>[1]</sup> These findings translate into poor outcomes as the number of deaths due to hypertension increased by 35% from 2003–2013.<sup>[1]</sup> In the Global Burden of Disease 2010 study, hypertension was identified as the number one risk factor worldwide for deaths and disability-adjusted life years.<sup>[2]</sup> In the United States, clinic visits, medications and the treatment of complications from hypertension, including heart failure, stroke, and renal disease now account for a substantial portion of the Medicare budget.<sup>[3]</sup>

First line therapies for all stages of hypertension include exercise and weight loss.<sup>[4]</sup> However, results from one small cross-sectional study suggest that a plant-based diet is the more important intervention. This study compared the blood pressure of sedentary vegans, endurance athletes (matched for body mass index with the vegan group) consuming a Western diet and running an average of 48 miles per week, and sedentary subjects consuming a Western diet. Blood pressure was significantly lower in the vegan group.<sup>[5]</sup> Although the benefits of exercise and weight loss seem to be inherently understood by most, the definition and perception of a "healthy" diet is one that has not yet reached consensus.

In the late 1930s, Dr. Walter Kempner of Duke University introduced the "rice diet" as therapy for renal failure and hypothesized that "we could radically alter the patients' diets and thereby save lives."<sup>[6]</sup> The rice diet was high in

complex carbohydrates, consisting mainly of rice and fruit, and low in fat, protein (< 20 g/day) and sodium (< 150 mg/day). He first demonstrated its effectiveness in a diabetic, hypertensive patient with renal and congestive heart failure: post intervention, this patient exhibited decreased cardiac silhouette size as measured by chest X-ray, normalization of a left ventricular strain pattern on ECG, and improvement in hypertensive retinopathy. Similarly, in his first cohort of hypertensive patients, 107 of 192 patients demonstrated marked improvement, including decreased blood pressure, cholesterol levels, retinopathy, and cardiac silhouette size. Despite his findings, Kempner's work was not widely accepted by the scientific community, which favored randomized control trials to substantiate these findings.

The first, major randomized control trial to evaluate diet and hypertension was the Dietary Approaches to Stop Hypertension (DASH) study of the mid-1990s. DASH, a controlled feeding study, examined three different diets: (1) a control diet, representative of a "typical" American diet, (2) the DASH diet, high in fruits and vegetables and low in saturated and total fat, and (3) a diet high in fruits and vegetables but otherwise similar to the control diet. Patients were given standardized meals, and their weight and dietary sodium intake were kept stable.<sup>[7]</sup> The DASH diet reduced both systolic and diastolic blood pressure by 5.5 mmHg and 3.0 mmHg, respectively, when compared to control. The diet high in fruits and vegetables but otherwise similar to the control diet also lowered blood pressure but not to the same extent as the DASH diet. The DASH collaborative research group stated that they could not identify the individual components of the DASH diet that made it effective, but other studies have shown that specific components of the DASH diet, such as fruits, vegetables, whole grains, and nuts were each associated with decreased blood pressure.<sup>[8–16]</sup>

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The Coronary Artery Risk Development in Young Adults (CARDIA) study prospectively followed 5115 young (aged 18 to 30 years), black and white men and women over a 15 year time period and monitored them for the development of cardiovascular disease risk factors.<sup>[10]</sup> A CARDIA hypertension sub-study of 4304 subjects revealed a dose dependent inverse relationship between plant-based food consumption, including fruits, whole grains, and nuts, and blood pressure. The opposite relationship was found, however, with meat intake. Greater red and processed meat intake was associated with higher blood pressure. Accordingly, in a cross-sectional analysis of 11,004 British men and women in the European Prospective Investigation into Cancer and Nutrition-Oxford study, among four dietary types: (1) meat eaters, (2) fish eaters, (3) vegetarians, and (4) vegans, the vegans had the lowest prevalence of hypertension.<sup>[17]</sup>

Similarly, Borgi, *et al.*,<sup>[18]</sup> found a positive association between animal flesh consumption and hypertension risk in an analysis of three prospective cohorts [Nurses' Health Study I (NHS I), Nurses' Health Study II (NHS II), and Health Professionals Follow-up Study (HPFS)] totaling 188,518 participants with 2,936,359 person-years of follow-up. In this largest prospective study to date on animal consumption and incident hypertension, the positive relationship between animal flesh (including red and processed meat, poultry and seafood) and hypertension was independent of fruit, vegetable, and whole grain consumption. Whereas, red and processed meats were associated with increased hypertension risk in all three cohorts, poultry and seafood intake were correlated with higher rates in two (NHS II, HPFS). The findings of greater animal flesh (red meat, processed meat, and poultry) consumption and increased hypertension risk are consistent with other prospective cohort studies.<sup>[19–21]</sup> In the few published prospective studies of seafood consumption and hypertension risk, greater seafood consumption appears either positively associated with hypertension risk or neutral.<sup>[18,20,22]</sup>

The first study to compare blood pressure among habitual vegans, lacto-ovo vegetarians, and non-vegetarians was the Adventist Health Study-2 (AHS-2) calibration sub-study, which included a cohort of 500 mostly white subjects.<sup>[23]</sup> Of note, non-vegetarian Seventh Day Adventists tend to consume less meat than persons consuming a typical Western diet.<sup>[24,25]</sup>

Nevertheless, the investigators found that vegans and lacto-ovo vegetarians had significantly lower systolic and diastolic blood pressure, and significantly lower odds of hypertension (0.37 and 0.57, respectively), when compared to non-vegetarians. Furthermore, the vegan group, as compared to lacto-ovo vegetarians, not only was taking fewer antihypertensive medications but, after adjustment for body

mass index, also had lower blood pressure readings. Another sub-study of AHS-2 examined hypertension in a black population and found that the combined vegetarian/vegan group had significantly lower odds of hypertension (0.56) compared to non-vegetarians.<sup>[26]</sup>

Other studies found similar results. In a prospective cohort study of 1546 non-hypertensive subjects followed for three years, those consuming more phytochemical rich foods (plant-based foods) had lower risk of developing hypertension.<sup>[27]</sup> In a matched cohort study of 4109 non-hypertensive subjects followed for a median of 1.6 years, vegetarians had a 34% lower risk of developing hypertension than non-vegetarians.<sup>[28]</sup> In studies of 5046 and 1615 subjects encouraged to adopt a plant-based diet as part of a health improvement program for 30 days and 7 days, respectively, systolic and diastolic blood pressure fell significantly in both.<sup>[29,30]</sup> In a study of 26 subjects with medically treated hypertension and then placed on a vegan diet for one year, blood pressure fell, and 20 of the 26 subjects were able to discontinue their anti-hypertensive medications.<sup>[31]</sup> In a cohort study of 272 non-hypertensive men followed for five years, greater plant protein intake was associated with lower blood pressure.<sup>[32]</sup> The totality of evidence taken from these studies indicates that plant-based diets have a meaningful effect on both prevention and treatment of hypertension.

There are a variety of mechanisms proposed by which plant-based nutrition leads to decrease in blood pressure. They include improved vasodilation,<sup>[33–36]</sup> greater antioxidant content and anti-inflammatory effects,<sup>[37–44]</sup> improved insulin sensitivity,<sup>[33,45–48]</sup> decreased blood viscosity,<sup>[49,50]</sup> altered baroreceptors,<sup>[33]</sup> modifications in both the renin-angiotensin,<sup>[36,51–53]</sup> and sympathetic nervous systems,<sup>[33,54]</sup> and modification of the gut microbiota.<sup>[53]</sup>

Long-term randomized controlled trials examining the impact of plant-based diets on various health outcomes, including hypertension, will further inform medical guideline creation and refine our understanding of the relationship between diet and disease. However, in lieu of such information and in the context of the data within this Special Issue, we believe that consuming a diet that is mostly or exclusively plant-based appears prudent for the prevention and treatment of hypertension.

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