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DIET-CENTERED STRATEGIES FOR HYPERTENSION CONTROL: MECHANISMS, CLINICAL EVIDENCE, AND PUBLIC HEALTH IMPLICATIONS

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ABSTRACT

Besides being among the major risk factors of cardiovascular disease, cerebrovascular accidents and renal disease (including end-stage renal disease), the global community regards hypertension as one of the critical issues of public health. One of the nonpharmacological methods of treating and preventing hypertension has been found to be through dietary modifications which had been shown beyond reasonable doubt. There is evidence that dietary interventions result in the radical decrease in blood pressure and cardiovascular health of individuals with high blood pressure. Nutritional measures are also lifestyle changes that can play a role in non-pharmacological treatment. Such diets as dietary approaches to stop hypertension (DASH) and the Mediterranean diet, which place heavy emphasis on the intake of fruits and vegetables, have proven to be effective in lowering blood pressure. Some of these nutrients include potassium, calcium and magnesium that pose great impact on blood pressure. In addition, dietary fibers have an important part in managing the level of arterial blood pressure in hypertensive and pre-hypertensive subjects. This diet may be useful in helping to manage one's blood pressure. The DASH dietary pattern could significantly decrease the systolic and diastolic blood pressure of a person. In addition, it is proven that the effect of a healthy diet on lowering blood pressure is increased when sodium consumption is decreased further. Two other dietary options also associated with increased cardiovascular outcomes are consuming less processed food and more plant-based food. Consequently, diet intervention remains critical in the management and prevention of hypertension.

Keywords: *Hypertension, Dietary interventions, DASH diet, Mediterranean diet, Blood pressure regulation, Sodium reduction, Potassium intake*

INTRODUCTION

Hypertension is defined as consistently elevated blood pressure ≥140/90 mmHg. It is a chronic health condition with approximately 7.5 million premature deaths annually. No doubt that it is a

significant global health burden with rising cases each year (Elendu et al., 2024). There are two types of hypertension: Primary hypertension and secondary hypertension. Primary hypertension occurs due to some unknown cause either from environmental or lifestyle changes and 90 percent cases of this type. Secondary hypertension is caused by another disease, various toxicities, congenital diseases and iatrogenic diseases (Kokubo et al., 2015). Patients suffering from hypertension have a higher risk of developing insulin resistance and diabetes than normotensive persons. Cardiovascular disease, which is aggravated by hypertension, is a major cause of mortality and morbidity worldwide. Both hypertension and diabetes are closely interlinked as they have similar risk factors like vascular inflammation, endothelial dysfunction, atherosclerosis, arterial remodeling, obesity and dyslipidemia (Petrie et al., 2018). As far as non-pharmaceutical interventions are concerned, nutritional strategies along with lifestyle modifications are important. DASH diet and Mediterranean diet, which emphasize vegetable and fruit composition are the most significant approaches in reducing hypertension. Micronutrients such as sodium, calcium, potassium and magnesium have substantial effects on blood pressure. All these strategies have underlying mechanisms such as improvement in endothelial function, vasodilation, mitigation of oxidative stress and regulation of sodium balance (Aloo, 2018). Five diet strategies have been found to be beneficial: the DASH diet, Mediterranean diet, low-sodium diet, vegetarian diet, and portfolio diet. Dietary Approaches to stop Hypertension (DASH) diet limited in beverages, red meat, added fats and sugar sweetened foods; limited in whole grains, vegetables, fruits, low fat dairy products; also include nuts, beans, poultry, fish and meat. Low sodium diet which includes 1500 to 2300 milligrams of sodium restriction per day. Vegetarian diet consisting of fruits, nuts, legumes, seeds and whole grains; may include eggs and dairy products with exclusion of animal and meat products. Portfolio diet is a plant-based diet which includes plant sterols, soy, high fiber foods and nuts (Altawili, 2023). Some studies have shown that fiber supplementation improves reduction in blood pressure and alters composition of microbiota (Farras, 2024). Electrolyte balance maintenance is a crucial step in managing hypertension as it is one of the reasons for morbidity and mortality in world. In a study conducted in an area with high salt intake, it is found that serum calcium, magnesium and chloride show the most significant association with isolated hypertension (IP) and primary diastolic hypertension (PDH) (Wu et al., 2019). Various factors can be a cause of hindrance in these implications such socioeconomic disparities, adherence challenges and cultural preferences (Burnier and Egan, 2019). The present review aims to comprehensively evaluate diet-centered strategies for hypertension control, with particular emphasis on established dietary patterns, electrolyte balance, macronutrient composition, and bioactive food components, as well as their underlying mechanisms and clinical applications.

Role of Dietary Patterns in Hypertension Control

Non-drug-based interventions play an important role in reducing daily dosage of antihypertensive medications and in delaying the progression from prehypertension to hypertension. Non-drug-based interventions mainly involve lifestyle changes such as dietary adjustments, exercise, stress reduction, and limiting intake of alcohol. The Nutritional needs of individuals with hypertension can be addressed by adopting Dietary Approaches to Stop Hypertension (DASH) diet or by following a traditional Mediterranean diet. Dietary Recommendations support increased intake of plant foods, dairy sources, potassium, magnesium, and phosphorus (Mahmood et al., 2019). Preventions and effective control of hypertension are essential for reducing cardiovascular mortality and morbidity. Effective blood pressure lowering can be achieved through modifications in lifestyle (Hermansen, 2000). The Dietary Approaches to Stop Hypertension (DASH) diet is universally recommended for individuals with hypertension, regardless of whether pharmacological treatment is used. A diet which increases the consumption of potassium and fibre through vegetables and

fruits,lowering total and saturated fat via a reduction in meat and animal products, and consuming sufficient protein through lean meats and low- fat dairy ,rather than high-fat or processed meats (Wang et al., 2011). More than two decades ago, the blood pressure –reducing potential of the DASH dietary pattern was identified through the first DASH clinical trial ,which was conducted as a control feeding study to assess the influence of three distinct diets on blood pressure outcomes. Reduction in both systolic and diastolic blood pressure were observed with the" combination diet"-later named as DASH diet-which contains fruits, vegetables, and low-fat dairy products, when compared with both the control diet and fruit-and-vegetable diet. Since that time, evidence from multiple clinical trials has indicated that blood pressure can be effectively lowered by the DASH dietary pattern when followed alone or when combined with other lifestyle changes, including sodium limitation, weight reduction, and regular physical exercise across a broad range (Filippou et al., 2020). Reports by some studies suggest that the modified DASH diet could reduce blood pressure, blood glucose levels, body mass index and lipid disturbances although some studies suggested that modified DASH diet increases the blood glucose, resistance to insulin and blood pressure. The underlying mechanisms through which dietary interventions influence blood pressure are illustrated in Figure 1.

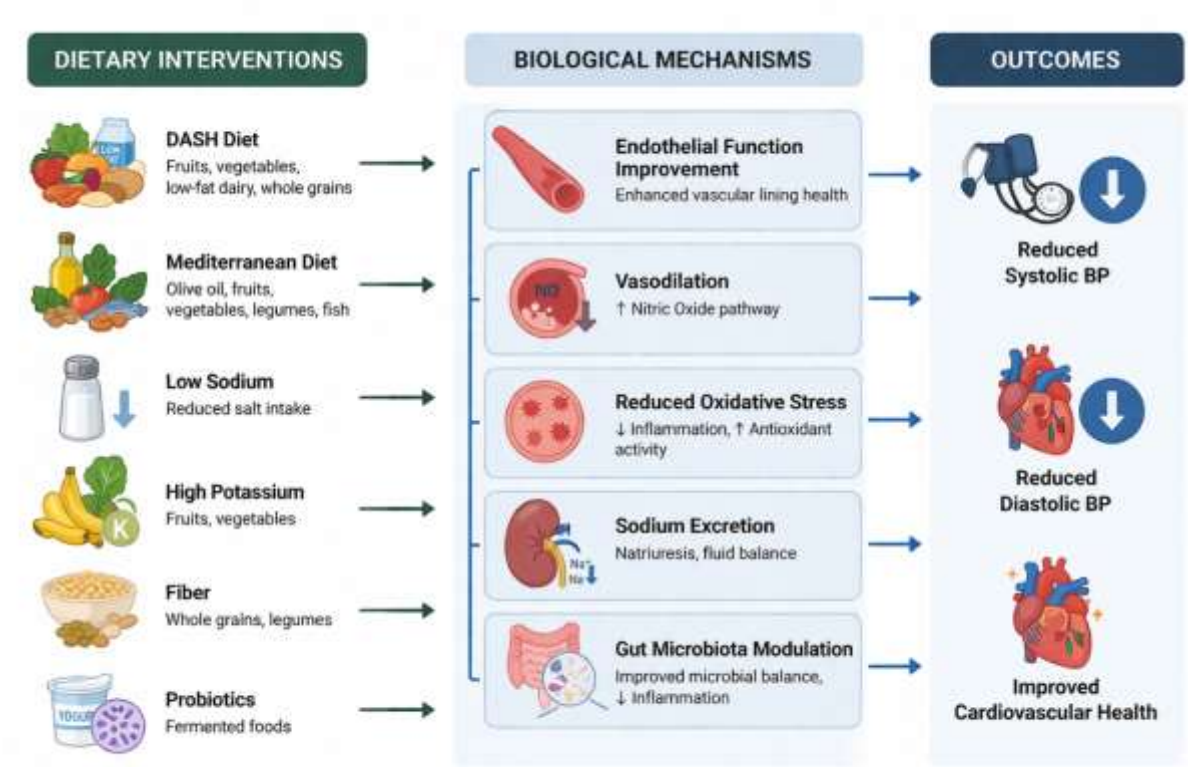

Figure 1. Mechanistic pathways linking dietary interventions with blood pressure regulation, including vascular, renal, and metabolic processes.

Strong evidence supporting the recommendation of the DASH diet for blood pressure reduction was presented in the American Heart Association report; however, evidence for recommending the Mediterranean diet was limited (Nissensohn, et al., 2016). A high consumption of plant-based foods, including fruits, vegetables, breads, and other cereals-traditionally minimally refined-together with potatoes, legumes, nuts, and seeds, is characteristic of the traditional Mediterranean

dietary patterns. Preference is given to fresh, locally produced, and seasonally available foods, with fresh fruit commonly used as dessert and sweet foods containing sugar or honey consumed only a few times weekly. Olive oil ,particularly virgin and extra virgin olive oil is used as the primary fat source, while dairy products mainly cheese and yogurt are consumed in moderate quantities.Wine is taken in moderation and usually with meals (Guasch-Ferré & Willett, 2021). Improvements in cardiovascular health among older adults have been associated with adherence to a Mediterranean style diet ,with clinically reductions in blood pressure and arterial stiffness being observed (Jennings et al., 2019). In older adults at increased cardiovascular risk, Mediterranean dietary pattern was linked to a decreased requirement for initiating or increasing antihypertensive medications and lower probability of treatment progression (Ribó-Coll et al., 2021). Much of the benefit of the Mediterranean diet appears to arise from the combined influence of overall dietary pattern, although particular foods may contribute more strongly than others. From this perspective, olive oil may represent one of the most important elements of the Mediterranean diet. When examining the impact of this dietary pattern on blood pressure ,the combine effects of sodium and potassium intake should also be considered (De Pergola & D'Alessandro, 2018). A strong association between hypertension and sodium consumption has been documented in the literature. Intake of excess sodium defined by the World Health Organization as more than 5g per day has been linked to elevated blood pressure and the development of hypertension along with cardiovascular complications. Reducing dietary sodium leads to declines in blood pressure and a lower prevalence of hypertension and reduced cardiovascular illness and mortality(Grillo et al., 2019). Evidence derived from randomized and non-randomized clinical trials indicates that diet centered on plant foods functions as an effective behavioral approach for the control of elevated blood pressure. For many years, limiting sodium intake has been emphasized as a primary nutrition measure in hypertension management, reflecting its key influence on blood pressure regulation within public health research. In addition a wide range of laboratory, clinical,and population – based studies has explored the separate roles of minerals such as potassium, calcium, and magnesium in maintaining blood pressure homeostasis (Wabo et al., 2022). Characteristics of plant based dietary patterns that may contribute to lower blood pressure include reduced energy density promoting weight loss, decreased sodium intake, increased potassium levels, enhanced nitric oxide bioavailability diminished oxidative stress and favorable modulation of the gut microbiome (Joshi et al., 2020). A diet centered on plant foods promotes the consumption of nutrient-rich items such as vegetables, whole grains, legumes and fruits while limiting animal-derived and processed foods. Such diets are high in fibre ,vitamins, potassium, unsaturated fats, and polyphenols, and low in sodium and saturated fat, thereby supporting the maintenance of normal blood pressure (Aljuraiban et al., 2020). In Western countries, the number of people with high blood pressure has increased. This rise may be caused by lower fibre intake in daily diet. Recently, more attention has been given to the possible connection between gut bacteria and high blood pressure. Hypertension is now understood as condition linked with mild, long-term inflammation. Inflammation can be reduced by healthy gut bacteria and because of this ,blood pressure may also decrease. Overall, these findings highlight the importance of improving diet in the management of hypertension (Aljuraiban et al., 2020).Several dietary patterns have demonstrated clinically significant reductions in blood pressure (Table 1)

Table 1: Major Dietary Patterns for Hypertension Control and Their Mechanisms

Dietary Pattern	Key Components	Mechanism of Action	Clinical Effects on BP	Supporting Evidence
DASH Diet	Fruits, vegetables, low-fat dairy, whole grains, nuts, reduced red meat & sugar	Improves endothelial function, increases potassium & magnesium, reduces sodium	↓ SBP (8–14 mmHg), ↓ DBP	Appel et al., 1997; Filippou et al., 2020
Mediterranean Diet	Olive oil, fruits, vegetables, legumes, fish, moderate dairy	Anti-inflammatory, antioxidant, improves vascular function	Moderate BP reduction, improved arterial stiffness	Estruch et al., 2018; Jennings et al., 2019
Low-Sodium Diet	Sodium restriction (1.5–2.3 g/day)	Reduces plasma volume, decreases vascular resistance	Significant BP reduction	Whelton et al., 2018
Vegetarian / Plant-Based Diet	Fruits, legumes, whole grains, nuts, minimal animal products	High fiber, low sodium, improved gut microbiota	Reduced BP & cardiovascular risk	Joshi et al., 2020
Portfolio Diet	Plant sterols, soy protein, nuts, viscous fiber	Lipid-lowering + vascular benefits	Improved BP & lipid profile	Altawili et al., 2023

Sodium, Potassium and Electrolyte Balance

High input of sodium is nearly associated with hypertension and cardiovascular threat. A variety of pathways were posited to regard for swab-touched off hypertension, including sodium reabsorption in the feathers, enhanced sympathetic exodus, endothelial dysfunction and arterial stiffening, as well as inflammation intermediated by vulnerable cells. Both hypertensive and normotensive subjects have a large range of salt sensitivity, i.e. blood pressure changes in response to sodium intake. According to evidence from random clinical trials, such as the DASH study. There is conflicting data, nevertheless, about the long-term cardiovascular effects of sodium shortage. While some observational studies support the idea that consuming too much salt increases the risk of stroke, other studies propose that consuming moderate amounts of sodium in combination with a high potassium intake may lower the risk of cardiovascular disease. The total amount of salt consumed is still far higher than recommended, even under strict guidelines. Given that many interventions are resource-intensive and challenging to sustain at the community level, this gap may be characterised by the limited viability of low-sodium diets in routine practice (Kim et al., 2024).

Potassium is essential for blood pressure control, which is mediated through its action on renal sodium excretion and vascular smooth muscle tone. Somewhere along the way, we evolved to be a species that holds on to sodium and let's go of potassium, but this information did not get sent out via our dietary guidelines. Fluid retention and hypertension result from increased salt reabsorption in the kidneys, particularly in the distal convoluted tubule, when dietary potassium levels are lower. Potassium deficit promotes vasoconstriction at the vascular level by increasing the intracellular calcium content in smooth vascular muscle cells. Conversely, increased potassium inflow leads to membrane hyperpolarization with vasodilation and decreased peripheral resistance. Additionally, new studies show that WNK kinase signalling pathways control the sodium transport impacted by potassium sensitivity. While low plasma potassium activates the sodium-chloride cotransporter

(NCC), increasing sodium retention and raising blood pressure, high potassium intake suppresses this route, encouraging natriuresis and lowering blood pressure. The preventive effect of increased dietary potassium intake in avoiding hypertension can be explained by these processes taken together (Sriperumbuduri et al., 2024).

Nowadays, the average individual consumes significantly more salt (sodium) and considerably less potassium than our forebears. A high sodium intake coupled with low potassium levels raises the likelihood of developing high blood pressure, heart problems, and even mortality from various causes. Even when salt intake stays constant, the DASH diet is shown to reduce blood pressure. This diet includes a range of foods high in potassium, but it does not provide a precise amount to be ingested. Many experts think that the high potassium level of the DASH diet is responsible for a significant amount of its health benefits (Sacks et al., 2001). Low potassium (K^+) input has been linked to increased blood pressure and an increased threat of heart complaint death, according to two recent worldwide studies (Mente et al., 2014; O'Donnell et al., 2014). It's still unclear exactly how potassium (K^+) influences blood pressure. To maintain swab balance, the feathers reabsorb sodium (Na^+) along the entire nephron; still, the aldosterone-sensitive distal nephron (ASDN) is particularly pivotal for potassium regulation. The collecting conduit (CD), connecting tubule (CNT), and distal sophisticated tubule (DCT) are ordered parts that are included in the ASDN. There are two sections in the DCT: The primary absorbers of sodium and chloride (NaCl) are DCT1 (proximal portion). Both the active movement of sodium (Na^+) and potassium (K^+), as well as neutral NaCl transport, are managed by DCT2 (distal portion) (Subramanya and Ellison, 2014).

Sodium excretion rises in tandem and increases sodium consumption. Other variables promote sodium excretion, as demonstrated by experiments that block the effects of salt loading on glomerular filtration rate (GFR) and aldosterone secretion. It is unknown what physiological functions the different natriuretic peptides serve. Blood volume changes directly affect blood pressure and cardiac output. This causes the kidneys to excrete more salt and water, regardless of humoral and neurological processes. Patients with significant inappropriate aldosterone secretion (primary hyperaldosteronism) are typically not substantially volume overloaded, which may be explained by pressure natriuresis. The proximal tube is where the maturity of filtered potassium is reabsorbed. Although the distal nephron receives only about 5 of the filtered cargo, it's the primary position where potassium excretion is regulated. Because it stimulates potassium reabsorption from the luminal membrane of the main cells of the cortical collecting conduit, aldosterone plays a significant part in potassium balance. Also, ADH promotes potassium excretion in the distal tubules (Louden, 2009). Essential electrolytes like sodium and potassium are vital for whim-whams transmission, muscle compression, fluid balance, and general fleshly equilibrium. Potassium is the primary intracellular cation essential for membrane eventuality and cellular metabolism, whereas sodium is the primary extracellular cation that aids in controlling extracellular fluid volume. By managing their filtration, reabsorption, and excretion, the feathers are the main organs in charge of maintaining the proper balance of sodium and potassium. In the nephron's distal tubules, hormonal processes, particularly aldosterone, affect potassium excretion and swab retention. This regulation is essential for maintaining blood pressure and extracellular fluid volume. The feathers respond to disturbances in sodium or potassium balance by modifying excretion rates to restore homeostasis. Blood pressure and cardiovascular health can be greatly impacted by sodium and potassium imbalance, which can be brought on by illness, poor renal function, or salutary input. For example, whereas a advanced potassium input promotes sodium excretion and lowers blood pressure, a low potassium input might affect increased sodium reabsorption, swab retention, and elevated blood pressure. Therefore, it's pivotal to maintain a balanced sodium- to- potassium rate to lower the threat of hypertension and associated conditions (Wu et al., 2019).

All effects considered, electrolyte homeostasis, which includes regulated potassium and sodium situations, is essential for regular physiological function. Blood pressure, fluid balance, and electrolyte situations are all acclimated by healthy order function and hormone operation. In order to help imbalances and support cardiovascular and order function, it can be helpful to cover electrolyte balance and maintain a suitable diet high in potassium (similar as fruits and vegetables) while limiting sodium input (Khan et al., 2024).

Macronutrients and blood pressure

Diet is a key factor in both the prevention and management of hypertension. In many Asian countries, carbohydrates provide nearly 60% of total daily energy intake, whereas in Western countries carbohydrate consumption is typically below 50%. Although research strongly supports the role of macronutrients in blood pressure regulation, most studies focus on fats and proteins, while carbohydrates receive comparatively less attention (Yang et al., 2022).

According to some studies, the effect of the total carbohydrate consumption could be independent of hypertension and cardiovascular risk, though the results were inconclusive. A cohort study conducted by a large Chinese group of people showed that the lower quality of carbohydrates like refined rice and noodles increased the risk of developing hypertension. On the contrary, lower quality carbohydrates such as whole grains, legumes, and fruits were associated with the lesser risk (Li et al., 2021). This relationship may be explained by several biological mechanisms. High refined carbohydrate diets may elevate blood glucose levels and oxidative stress, as well as damage endothelial function and elevate blood pressure. However, whole grains, vegetables, fruits and food rich in antioxidants on the other hand can enhance vascular performance and decrease oxidative injury, thus lowering blood pressure. Differences in digestion, metabolism and physiological consequences of various types of carbohydrates might be the cause of inconsistent results of studies. At this point, there is no apparent agreement as to the effect of a particular type of carbohydrate e.g. fructose on hypertension risk (Ha et al., 2012). To elaborate on this problem, the cross-sectional study was carried out in Sabzevar, Iran, and the sample size was limited to 4,184 participants aged 35-70 years. Of them, 1,239 were hypertensive and 2,945 were normal blood pressure. The WHO definition of hypertension was used to define hypertension as systolic BP of 140mmHg and above and/or diastolic BP of 90mmHg and above, past diagnosis and/or use of antihypertensive medication. Those whose family history included hypertension, on drugs that influence blood pressure, or on carbohydrate supplements were not included. The findings revealed that the intake of carbohydrates, total sugars, glucose, fructose, sucrose, and total energy by people with hypertension was more than that of people with normal blood pressure. There were slight variations in the protein and fat intake, albeit significant. These results indicate that the amount and the quality of carbohydrates can be impactful in terms of hypertension (Rafieipour et al., 2024).

Protein in the diet has also been studied with reference to blood pressure. In the past, animal protein was believed to increase blood pressure because it has some negative implications on kidney operation. But, recent studies have indicated that protein consumption can also be of value especially since the 1980s. The cross-sectional studies tend to give weak inverse relationship between total protein intake and blood pressure whereas prospective studies have shown inconsistent findings. The source of protein (animal vs. plant) has also been debated. Traditionally, plant protein is considered protective, while animal protein is believed to increase blood pressure. However, observational and interventional studies have shown mixed findings, with no clear conclusion. Most large studies have been conducted in Western populations, and limited research is available from Eastern countries (Wang et al., 2008).

Hypertension is a multifactorial condition strongly influenced by dietary factors. Carbohydrate quality, protein source, sodium intake, potassium balance, body weight, and overall dietary patterns all contribute to blood pressure regulation. Further longitudinal research, particularly in

Eastern populations, is needed to clarify these relationships.

Micronutrients, Bioactive compounds, and functional foods

Micronutrients such as minerals and vitamins play a central role in the regulation of blood pressure (BP) and maintain overall health status. These nutrients contribute not only to the optimal functioning of macronutrients but also enhance the anti-hypertensive functions of some anti-hypertensive agent . Minerals which are present in ionic form in body perform many biochemical reactions including structure development, metabolic reaction and maintain the overall health status. They regulate function like acid–base balance, fluid osmotic pressure (equilibrium), muscle contraction, and relaxation. Several investigations reported that various minerals like sodium, pottasium, magnesium, zinc, selenium, copper, and calcium could have direct or indirect influence on BP (Chiu et al., 2021). Evidence supporting that sodium reduction is effective strategy to low bp is significant. Decreasing sodium intake has shown beneficial effect in prehypertensive individuals and those receiving antihypertensive medicine. Although research on patients with resistant hypertension who are on multiple medicines is limited due to ethical and logical challenges, available finding shows that sodium reduction improves blood pressure control (Appel, 2009). Calcium also plays an essential regulatory function in hypertension. Insufficient calcium intake increases risk of high BP and contributes to salt sensitivity. High sodium diet promotes calcium loss in urine thereby worsening the physiological consequences of inadequate calcium intake. This imbalance increases production of 1,25-dihydroxyvitamin D, which increases intracellular calcium level in vascular smooth muscle cells, which increases the peripheral vascular resistance which contributes to increase blood pressure. Taking adequate calcium suppress surplus 1,25-dihydroxyvitamin D, thereby normalizing intracellular calcium and ultimately reduce the peripheral vascular resistance (Zemel, 2001).

Blood pressure level is inversely related to dietary intake of potassium. Hundreds of observational studies, clinical trials and metal analysis prove the lowering of blood pressure in hypertensive and non-hypertensive subjects through increased dietary intake of potassium. The decreases seem to be dose dependent. Weight gain of 0.6 grams of dietary potassium lowers 1.0 mm Hg systolic BP and a 0.52 mm diastolic BP per. Dietary potassium intake of 4.7 g on average decreases BP by 8.0/4.1 mm Hg when supplemented appropriately with other minerals like sodium, magnesium and calcium (Houston, 2011).

Another significant mineral that have an effect on vascular tone and reactivity is magnesium. It acts as a calcium channel antagonist, and can increase the synthesis of vasodilating substances like prostacyclins and nitric oxide and also enhance the vasoactivity of blood vessels to the vasoactive substances. Magnesium deficiency leads to hypertension because of the heightened vascular resistance and because it leads to endothelial dysfunction. Some epidemiological and experimental research indicates that blood pressure is inversely correlated with serum magnesium levels (Sontia and Touyz, 2007). Hypertension has been well established as a complex disease caused by complex interactions between environmental factors and genetic predisposition. Nutrient gene-nutrient gene interactions are also implicated in vascular biology oxidative stress, inflammation and immune mediated vascular dysfunction. Endothelial stimulation and dysfunction of vascular smooth muscle is an initial event in the pathogenesis of essential hypertension and eventual damage to target organs. Optimization of micronutrient deficiencies can help ameliorate endothelial, reduce oxidative stress, and decrease cardiovascular risk. Balanced nutrition, weight management, physical activity, smoking and moderate use of alcohol and caffeine, in combination with appropriate pharmacological treatment is a holistic lifestyle intervention that can be used to manage blood pressure and avoid cardiovascular issues. (Houston, 2013). Numerous studies focused on determining the natural components of food, physiological process

and mode of action that enhance cardiovascular health are available. The notion of functional foods, first coined in the 1970s in Japan and the United States, came into being to explain food that offer health benefits beyond our normal nutritional requirements. They contain natural and processed food that is fortified with biologically active compounds like proiotics. Animal or plant-based ingredients both contribute to the better health status and cardiovascular health by influencing underlying mechanism related to the elevated blood pressure. They prevent the risk of heart diseases, diabetes, and dyslipidemia and high blood pressure (Ramezani and Mohammadi, 2023).

Traditional hypertension medications like calcium ion blockers, angiotensin II recediseases, diabetesd β-receptor blockers, often comes with side effects. However, new research highlights the gut microbiome's importance for health especially through the probiotics present. These beneficial microbes can reduce less blood pressure symptoms by reducing vascular oxidative stress, producing helpful fatty acids, improving blood vessel function, and lowering inflammation. There is evidence that probiotics rich functional foods can adjust gut flora to help manage hypertension. This suggests a side effect free approach to treat high blood pressure by combining probiotics with functional food. This study outlines the factors of hypertension and how probiotics help in lowering hypertension and fermented functional food with beneficial bacteria. The main aim is to create a foundation for developing functional food that use probiotics to potencially lower hypertension (Chen et al., 2023). Multiple micronutrients and bioactive compounds play a critical role in blood pressure regulation (Table 2).

Table 2: Key Nutrients and Bioactive Components Involved in Blood Pressure Regulation

Nutrient / Component	Primary Source	Mechanism	Effect on Blood Pressure	Key Reference
Sodium	Processed foods, salt	Fluid retention, ↑ vascular resistance	↑ BP	Grillo et al., 2019
Potassium	Fruits, vegetables	Promotes natriuresis, vasodilation	↓ SBP & DBP	Aburto et al., 2013
Calcium	Dairy products	Regulates vascular smooth muscle contraction	↓ BP	Zemel, 2001
Magnesium	Nuts, seeds, whole grains	Vasodilation, Ca-channel antagonism	↓ BP	Sontia & Touyz, 2007
Dietary Fiber	Whole grains, legumes	Improves gut microbiota, reduces inflammation	Moderate BP reduction	Xue et al., 2021
Polyphenols	Fruits, tea, olive oil	Antioxidant, endothelial protection	↓ BP	Huang et al., 2013
Probiotics	Fermented foods	Modulates gut microbiota, reduces inflammation	Emerging BP reduction	Chen et al., 2023

Clinical Applications of Diet Centered Strategies on Hypertension Control

Blood pressure is a serious health concern in the global healthcare system and one of the major modifiable risk factors of heart disease, brain stroke, and premature mortality. Persistent hypertension has been linked to dysfunction of the endothelium, hardening and destruction of the arteries and damage of the target organs. Despite the fact that there are good antihypertensive drugs, prevention of blood pressure is not always positive due to low compliance, absence of treatment side effects and costs. Thus, nonpharmacological interventions particularly diet focused interventions have been identified by the international clinical guidelines

as a significant component of hypertension prevention and management. The clinical importance of dietary change is that it is safe, affordable, and can lead to more sustained blood pressure changes in case used appropriately (Whelton et al., 2018; Reyhan, 2024). The most studied and clinically tested dietary pattern to manage the blood pressure is the Dietary Approaches to Stop Hypertension diet, one of the most diet oriented methods. DASH diet is devoted to the eating of more fruits, vegetables, whole grains, and legumes; nuts, low-fat dairy products, and the reduction of saturated fats, cholesterol, and refined sugars. There is always evidence that when people follow the DASH diet, they experience significant changes in systolic and diastolic blood pressure even in a very short duration, typically between two and four weeks. These are not conditional on weight loss, which means that the dietary pattern itself has antihypertensives (Appel et al., 1997). Clinically, DASH diet is similar to first line anti-hypertensive drugs in reducing blood pressure in individuals with mild to moderate hypertension. The DASH Sodium trial has demonstrated further that sodium reduction supplementation of the DASH diet has an additive and dose dependent effect on blood pressure. These are more beneficial to individuals with elevated baseline blood pressure and this justifies clinical use of DASH in primary intervention of prehypertensive and stage 1 hypertensive patients (Sacks et al., 2001).

DASH diet has also been successfully used in outpatient clinics, primary care practices and community based hypertension in practice and in real world clinical practice. It has been shown to be effective in a great variety of population including older people and ethnic groups that have a high rate of salt sensitivity. DASH diet also lowers blood pressure, lipid profiles and glucose metabolism and cardiovascular risk in general, particularly in patients with comorbid diabetes or dyslipidemia and hypertension (Appel et al., 2006; Reyhan, 2024). Hypertension management ranked other pillars of diet such as reduction of dietary sodium. Consumption of high sodium causes high blood pressures because it increases the plasma volume, increases the peripheral vascular resistance, and reduces renal sodium reabsorption. The clinical guidelines are; low sodium intake <2.3 g/day and optimal intake of 1.5 g/day in individuals with high-blood pressure or at risk of cardiovascular diseases. It is shown by randomized trials as well that the sodium cutting leads to clinically significant blood pressure drops and reduced cardiovascular risks in the population (Whelton et al., 2018; He and MacGregor, 2020). The association between the decrease in blood pressure and sodium was evidently graded in the DASH Sodium trial. The minimal sodium intake in the participants along with DASH diet reported the greatest changes in the systolic and diastolic blood pressures. These findings indicate that sodium restraint requires intervention on a nutrient-wide rather than an individual nutrient basis (Sacks et al., 2001). The reduction of sodium is among the clinical aspects of practice that have been given a greater focus particularly among patients of salt sensitive hypertension and resistant hypertension. The evidence based dietary recommendations must be translated into clinical outcome by giving individualized dietary counseling. The individualized counseling is taken into account in relation to cultural eating habits of patients, socioeconomic, health literacy, and comorbidities. Comparative study has established how much there is compliance and sustainability in personalized nutrition programs as opposed to the usual dietary recommendations. Dietary quality improvement is used alongside caloric restriction and weight loss in patients with obesity related hypertension dietary quality enhancement. A reduction in weight of 5 to 10 percent is demonstrated to produce potent reductions in blood pressure and reduce the need to take drugs (Whelton et al., 2018; Appel et al., 2006). A combined model of dietary and lifestyle intervention in hypertension management is given in Figure 2.

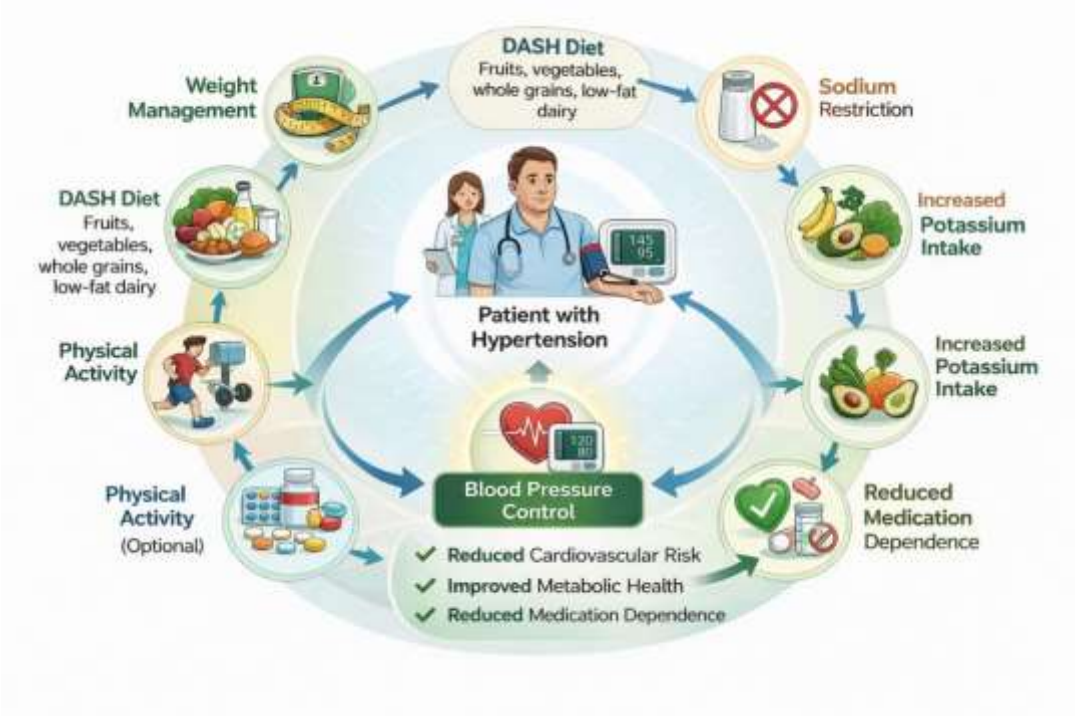

Figure 2. Integrated clinical model illustrating the role of diet-centered and lifestyle interventions in comprehensive hypertension management.

Mediterranean diet is another diet pattern that has been discovered to be utilized clinically to control hypertension. This diet is centered on the intake of fruits, vegetables, whole grains, and legumes and reduces the intake of red meat and ultra processed foods. It has also been shown in randomized controlled trials and observational studies that adherence to the Mediterranean diet is associated with moderate but significant blood pressure and endothelial function improvement and reduction in systemic inflammation. This is why it is highly suggested among hypertension patients with cardiovascular risk (Estruch et al., 2018; Filippo et al., 2021). Increase in dietary potassium is another effective diet focused intervention on blood pressure management. Potassium decreases blood pressure by increasing sodium excretion, relaxing smooth muscles in the blood vessels and decreasing sympathetic nervous system activity. Diets rich in fruits, vegetable and legumes naturally promote low amounts of potassium, which are associated with reduced blood pressure and reduced strokes. Whole foods but not supplements should contain potassium to prevent hyperkalemia in patients, particularly with impaired renal functioning (Aburto et al., 2013). It has also been discovered that dietary fiber intake helps in regulating blood pressure. This augmented consumption of fibers is associated with augmented insulin susceptibility, reduced swelling, and alterations in the composition of gut microorganisms. Meta-analyses have revealed that increased consumption of fiber results in minor but significant reductions in systolic and diastolic blood pressure. Preferred types of fiber rich foods in comprehensive dietary counseling are whole grains, fruits, vegetables, and legumes, particularly in patients with metabolic syndrome and type 2 diabetes (Xue et al., 2021). Multidisciplinary approaches to hypertension management can be most effective, used together with diet centered approaches. These programs involve dietary change and physical activity advocacy, behavioral therapy, stress management, and regular blood pressure monitoring. It is somewhat evident that treated patients with proper lifestyle control better

regulate their blood pressure than treated patients with usual care. DASH based dietary mobile health technology with self-monitoring and patient engagement has also been linked to enhanced engagement, self-monitoring, and adherence in clinical practice (Reyhan, 2024). Nutritional interventions may be applied at any age and any care setting. Older adults Diet centered approaches provide effective blood pressure control with minimal adverse effects and less risk of medication-related complication. Food based dietary interventions represent a sustainable, cost effective intervention in management of hypertension in low and middle income countries, eliminating chronic reliance on pharmacotherapy and the healthcare system (Whelton et al., 2018; He and MacGregor, 2020). Diet focused strategies are important in the clinical treatment of hypertension. Blood pressure reduces with robust clinical evidence have been demonstrated with the DASH and Mediterranean diets, sodium consumption, increased intake of potassium and fiber, and person-centered nutrition education. When implemented as a component of regular clinical practice, these strategies can be used as a supplement to pharmacological treatment, supplement cardiovascular and help address long-term management of hypertension (Appel et al., 1997; Whelton et al., 2018).

Conclusion:

In conclusion, nutrition interventions play a significant role in treatment and prevention of high blood pressure. The new systematic reviews and meta-analyses prove the significance of such healthy eating habits as the DASH diet and Mediterranean diet in reducing the systolic and diastolic blood pressure. These diets have a focus on excess use of salads, vegetables, whole grain, legumes, and low-fat dairy goods and avoidance of sodium, saturated fats, and processed food. The trends in such nutrition provide the fundamental micronutrients that include potassium, magnesium and calcium which control vascular activity and blood pressure rates. Another suggestion is that dietary modifications in addition to the other lifestyle modifications, such as physical activities and reduction of alcohol intake would also enhance the outcome of cardiovascular health. Overall, the introduction of a healthy diet is a cost-effective non-pharmacological intervention using the method of hypertension prevention in the long term. More research is suggested on the long-term adherence, nutrition guidelines in certain groups and combination of nutritional interventions and clinical treatment to reduce the global problem with hypertension and cardiovascular diseases.

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