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The influence of nutritional factors and dietary patterns on the prevention and control of arterial hypertension: a review

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Abstract

Arterial hypertension is a growing public health problem worldwide with serious health consequences. However, hypertension can be prevented and controlled with a healthy diet and physical activity. For this reason, we conducted a search of recent articles and reviews on the influence of nutritional factors and dietary patterns on the prevention and control of arterial hypertension, then sifted and aggregated the data. Results showed that guidelines such as sodium restriction, weight control and moderate alcohol intake, improved diet (following the DASH diet or Vegetarian diet), and physical activity significantly impacted blood pressure control. Likewise, consuming less saturated fat with an increase in monounsaturated fatty acids and omega-3s, providing adequate calcium, magnesium, protein, vitamin D and fiber, and improving the antioxidant capacity of the diet also plays an important role in blood pressure control. In short, an

appropriate diet combined with a healthy lifestyle will help achieve the best blood pressure, reduce cardiovascular risk factors, and thereby achieve many other health benefits.
Key words: hypertension; arterial hypertension; blood pressure; nutritional factors; dietary patterns

Introduction

Hypertension (HT) with systolic blood pressure (SBP) and/or diastolic blood pressure (DBP) levels greater than or equal to 140/90 mm Hg, respectively, or follow-up of antihypertensive treatment is a frequent problem and with great health impact by increasing the risk of suffering from coronary heart disease, stroke, cardiovascular accidents and kidney problems, together with premature death, the etiology of elevated blood pressure is a complex process involving the interaction of genetics, demographics, comorbid disorders, and environmental influences [1–6].

Arterial hypertension (AH) is a major cardiovascular risk factor, and its widespread prevalence across all age groups necessitates examining all potential causes and therapies [7]. It is characterized by vascular remodelling, sustained vasoconstriction, in situ thrombosis, and inflammation. World Health Organization (WHO) reports that about 600 million people worldwide suffer from AH, with a global rise of 60% in cases expected by 2025, as well as 7.1 million annual deaths [8, 9].

The prevalence of HT in low and middle-income countries has increased. Estimates that 31.1% of people globally (1.39 billion) had high blood pressure in 2010. The prevalence of HT in adults was greater in lower-middle-income countries (LMICs) (31.5%, 1.04 billion persons) than in high-income countries (28.5%, 349 million people). Some geographical heterogeneity in the prevalence of HT can be explained by differences in risk factors for HT, such as excessive sodium intake. Despite rising incidence, the prevalence of HT knowledge, treatment, and blood pressure control is low, particularly in low- and middle-income countries, and there are few comprehensive economic evaluations of HT [10].

The 2017 May Measurement Month of the International Society of HT documented cross-sectional survey included 1.201.570 individuals in 80 countries ≥ 18 years adults; these volunteers had no ideally their blood pressures measured in the past year. The results showed that 393.924 (34.9%) with the mean of the second and third readings had HT. The HT prevalence of 55% among European participants is considered the highest compared to other countries: America 41.0%, East Asia 34.5%, and South Asia 31.1% [11]. Between 1994 and 2018, the prevalence of HT in children increased, and the increase was associated with a higher body mass index (BMI), with a composite estimate of 4% in those 19 years of age and younger [12].

According to the WHO, an unhealthy diet and physical inactivity contribute to around 30% of preventable morbidity and mortality from non-communicable diseases, including morbidity and mortality due to HT [13]. Therefore, dietary modification is one of the initial steps in cardiovascular disease treatment. Routine treatment of systemic arterial HT includes reduced salt consumption, red

meat, and alcohol; increased eating of vegetables, fresh fruits, whole grains, soluble fiber, fish, nuts, and olive oil [14].

Thus, this review discusses the evidence that nutritional factors and dietary patterns play a role in prevention and control of hypertension.

Evidence regarding the influence of nutritional factors on the prevention and control of hypertension

Body weight

In both children and adults, excess weight increases the chance of HT [15–18]. The responsible mechanism is that obesity generates insulin resistance and hyperinsulinemia; insulin reduces renal sodium excretion, increases sympathetic tone and alters intracellular ions, which increases vascular reactivity [19]. In the United States, almost half of HT patients are obese [20]. As a result, more than a third of the obese population in the United States has been diagnosed with hypertension, compared to fewer than a fifth of normal-weight persons [21].

Numerous pathophysiologic processes contribute to the development of HT in obese individuals, which propagates end-organ damage, such as cardiovascular disease and chronic kidney disease. Insulin resistance, inflammation, oxidative stress, adipokines (such as adiponectin and leptin), the sympathetic nervous system, and the renin-angiotensin-aldosterone system are interconnected processes [22, 23]. The association between obesity and HT is complex and intricately linked to the various comorbidities associated with obesity. Diagnosis and monitoring of HT in obese individuals are frequently hampered by the inability of these people to take their blood pressure correctly [24]. Additionally, very complex underlying pathophysiologic variables complicate the treatment of HT in obese patients [25].

On the other hand, it is indisputable that one of the most effective measures to improve HT control in obese individuals is reducing body weight. But also maintaining an adequate weight, or losing weight, can help prevent HT in non-obese individuals. Even with modest weight loss, it is possible to reduce BP and achieve a long-term health benefits [26] (Tab. 1). Furthermore, the magnitude of weight loss correlates with better results in cardiovascular risk reduction. In obese patients with metabolic syndrome, a moderate weight loss improves renal function and may lead to a 15% reduction of all-cause mortality [27]. In addition, the bariatric surgery for weight loss has the greatest potential for lowering blood pressure and preventing end-organ damage in the patient with morbid or severe obesity [28].

A prospective observational study was conducted to determine the presence of uncontrolled HT at the conclusion of a one-year follow-up period and the influence of weight gain and loss on

uncontrolled HT as a primary outcome. There were 13.631 patients who completed the one-year follow-up. Reduced BMI by at least 1 kg/m2 was linked with decreased risk of uncontrolled HT at the end of the study [men $p < 0.0001$, odds ratio (OR) = 0.586, confidence interval (CI): 0.481–0.713; women $p < 0.001$, OR = 0.732, CI: 0.611–0.876). In overweight patients, a similar relationship was identified (men $p < 0.05$, OR = 0.804, 95% CI: 0.636–0.997; women $p < 0.05$, OR = 0.730, 95% CI: 0.568–0.937). Increases in BMI of at least 1 kg/m^2 were associated with a significantly increased risk of uncontrolled HT in obese (men $p < 0.001$, OR = 1.471, CI: 1.087–1.991; women $p < 0.001$, OR = 1.422, CI: 1.104–1.833) and overweight patients (men $p < 0.0001$, OR = 1.901, 95% CI: 1.463–2.470; women $p < 0.0001$, OR = 1.647**, 95% CI** [29].

Straznicky et al. evaluated whether energy restriction could reduce BP in a group of 59 patients affected by obesity. Subjects were treated with dietary intervention or dietary intervention with moderate-intensity aerobic exercise or no treatment for 12 weeks. In both groups, Body Weight reduction was associated with a significant SBP decrease and sympathetic neural activity downregulation [30]. Besides, to maintain energy balance and achieve good control of body weight, it is also important to avoid a sedentary lifestyle. In this sense, some studies indicate that although there are no reductions in body weight, physical activity performance still reduces SBP and DBP [31].

Macronutrients

Reducing saturated fat intake is a convenient measure in controlling BP [16, 32], but the proportion of energy from different macronutrients has been questioned. In this sense, Appel et al. found that in the context of a healthy diet, the partial replacement of carbohydrates with proteins or monounsaturated fat can lower BP and reduce cardiovascular risk [32].

Diets rich in omega-3 can improve endothelial function and decrease BP [19] (Tab. 1). Omega-3 fatty acids have been shown to significantly reduce the risk for sudden death caused by cardiac arrhythmias and all-cause mortality in patients with known coronary heart disease. It's also used to treat hyperlipidemia and hypertension. There are no significant drug interactions with omega-3 fatty acids. The American Heart Association recommends consuming two servings of fish per week in people who have no history of coronary artery disease and at least one serving of fish per day in those with coronary artery disease. Modest decreases in BP have also been observed with higher intakes of omega-3 fatty acids, so consuming 1 g/day of eicosatetraenoic acid plus docosahexaenoic acid is recommended for cardioprotection [33].

An adequate protein intake seems to help control BP by increasing renal plasma flow, glomerular filtration rate, and sodium excretion. The amino acid arginine has a vasodilator action and decreases

BP [19] (Tab. 1). It has also been proven that the maternal diet in pregnancy can modulate the offspring's BP and its risk of future HT. In this sense, using regression models, adjusted according to the child's growth indicators, it is found that the protein/carbohydrate ratio is associated with the child's BP at the age of 4 years. SBP was higher when protein intake was less than 16% of energy and carbohydrate intake was > 40% of energy. These results suggest an adequate maternal macronutrient ratio may be linked to optimal neonatal blood pressure. Maternal diet, which is possibly adjustable, may significantly impact the risk of future HT in kids [34].

An adequate maternal macronutrient ratio may be linked to optimal neonatal blood pressure. A maternal diet, which is possibly adjustable, may significantly impact the risk of future HT in kids. On the other hand, in some foods of animal origin (meat, fish, dairy products, eggs), bioactive peptides could be used as ingredients in developing new functional foods useful in the treatment of HT [35].

On the other hand, higher dairy consumption has been related to a lower annual increase in SBP and DBP figures and a lower risk of suffering from HT [36]. Specifically, dairy consumption of 100-700 g/day was inversely and linearly connected with a reduced risk of HT [37]. Some prospective studies found that children who consume more dairy products early in life (18–59 months) have lower BP in childhood and adolescence [38].

Alcohol

Drinking alcohol is increasingly popular in many countries. In Asian countries, it is seen as part of the culture. Despite many reports of negative health effects of alcohol (especially cardiovascular and liver diseases) [39, 40], annual alcohol consumption per capita has steadily increased from 5.9 L (1990) to 6.65 L (2017) and is forecast to reach 7.6 L in 2030 [41]. Furthermore, in some middle-income countries (such as Vietnam, Thailand), alcohol can be easily purchased in stores without any control, including those underage drinking [42].

Many studies have shown that high alcohol intake increases the risk of HT [43, 44]. However, the mechanism by which alcohol causes hypertension remains unclear. Several mechanisms have been proposed: (1) activation of the renin-angiotensin-aldosterone system, causing an increase in renin and stimulation of angiotensin II and aldosterone production; (2) cause an imbalance of the central nervous system; (3) increases intracellular calcium concentration, stimulates endothelial release of vasoconstrictor; (4) induce oxidative damage of the endothelium leading to endothelium-dependent inhibition of nitric oxide production [45].

A study in US adults showed that moderate alcohol intake reduces all-cause mortality and the risk of cardiovascular disease [46]. A meta-analysis (36 trials, 2865 participants) found that a decrease in

alcohol intake was not associated with a decrease in blood pressure for those who drank less than two drinks per day. However, in those who drank more than six drinks per day, a reduction of about 50% was associated with a significant decrease in SBP by 5.5 mm Hg (95% CI: 4.30–6.70) and DBP by 3.97 mm Hg (95% CI: 3.25–4.70) [47]. Clearly, the risk of HT depends on the amount of alcohol consumed. Besides, gender is also an influencing factor, with alcohol consumption of 1–2 drinks/day, the risk of hypertension increased in men, whereas the risk in women was not different from those who abstain from alcohol [48].

Table 1. Influence of various factors on blood pressure control (Adapted from [19])

Dietary influence	**Strength of association with blood pressure ***	**Association address**	**Recommendation**
Bodyweight	1A	Direct	Maintain an adequate weight or lose weight if you are overweight
Protein	2A	Reverse	Take adequate amounts of protein (especially of plant origin), limit animal proteins with a lot of fat
Fats	1C	Direct-saturated Reverse-unsaturated	Reduce total and saturated fat intake and bring the intake of monounsaturated and polyunsaturated fat closer to the recommended one
Carbohydrates	2B	Direct	Eat whole-grain cereals and less sugar
Alcohol	1B	Direct	Moderate alcohol consumption to < 2 drinks/day in men and < 1 in women
Fiber	2B	Reverse	Increase the consumption of foods rich in fiber
Diet type	1A	It depends on the change	DASH diet
Sodium	1A	Direct	< 65–100 mmol/day
Potassium	1A	Reverse	Eat foods rich in potassium
Calcium	2B	Reverse	2–3 dairy/day
Magnesium	2B	Reverse	Achieve adequate magnesium intake

* he strength of association 1A is clear, consistent and strong in randomized and controlled studies; 1B: the association is clear in randomized and controlled studies, but not very consistent; 1C: clear association in observational studies; 2A: the association is not clear, but it is consistent in randomized and controlled studies; 2B: unclear and inconsistent association in randomized and controlled studies; 2C: unclear association in intervention studies.

Fiber intake

Fiber foods contain many health benefits; it helps manage gastrointestinal disorders [49], chronic constipation and irritable bowel syndrome [50]. Some types of fiber also help to lose weight [51], reduce blood glucose [52] (Tab. 1). In addition, fiber also reduces the risk of cardiovascular disease and stroke [53, 54]. There are two main types of fiber: soluble and insoluble. Soluble fiber is abundant in fruits and vegetables. Conversely, cereal and whole-grain products are high in insoluble fiber [55].

Recently, the effects of fiber on lowering blood pressure have been mentioned in several studies. Yutong Dong et al. observed that increasing dietary fiber intake significantly decreased blood pressure (6.3 and 3.7 mm Hg SBP, 5.2 and 3.0 mm Hg DBP in men and women, respectively). In addition, the results indicated that soluble fiber intake was inversely related to SBP and DBP; however, there was no association between insoluble fiber and blood pressure [56]. A meta-analysis by Khan K et al. also concluded that soluble fiber significantly reduced overall SBP and DBP at an average dose of 8.7g/day and the inclusion of soluble fiber in the daily diet may reduce the risk of cardiovascular disease [57].

On the other hand, the INTERMAP Study conducted by Aljuraiban et al. showed that insoluble fiber higher by 4.6 g/4184 kJ (4.6 g/1000 kcal) contributes to lower 1.81 mm Hg SBP. In contrast, soluble fiber was not related to blood pressure [58].

In a meta-analysis of randomized and placebo-controlled studies, it was found that fiber supplementation (with a mean dose of 11.5 g/day) was associated with a reduction in SBP of 1.13 mm Hg (95% CI: 0.23–2.49) and with a decrease in DBP of 1.26 mm Hg (95% CI: 0.48–2.04). The reductions in BP were greater in individuals over 40 years of age and in hypertensive patients than young people and normotensive patients. In general, increasing fiber intake in children as well as adults has many health benefits, contributing to the prevention of hypertension, with a recommended fiber intake of 14 g/1000 kcal [59, 60].

Sodium intake

Sodium — often simply called salt (1g sodium = 2.5g salt) — is found in almost everything you eat and drink. Sodium is an essential mineral in the body that plays a vital role in helping to control fluid balance, nerve conduction and muscle mass function. Furthermore, epidemiologic, observational and controlled clinical trials have emphasized a direct relationship between sodium intake (and sodium/potassium ratio) and increased BP [31, 61, 62]. The responsible mechanism is probably the increased sodium and fluid retention in the blood vessels; as an alternative mechanism

has been mentioned, increased vascular reactivity. Although genetics and other diet components influence blood pressure, reducing sodium intake is associated with decreased BP as a general recommendation for patients with HT [1, 31, 63] (Tab. 1).

Reducing dietary sodium lowers not only blood pressure but also reduces the risk of cardiovascular disease, all-cause mortality and other conditions [64, 65]. To determine the effect of long-term reduction in sodium intake, a Cochrane review of 34 studies found that a reduction in urinary sodium excretion in 24 h to 100 mmol (6 g/day of salt) was associated with a decrease in SBP of 5.8 mm Hg (95% CI: 2.5–9.2, $p < 0.001$) after adjusting for age, sex, ethnic group and baseline BP [66]. WHO recommended daily intake of sodium for adults is less than 2 g/day (5 g salt/day). For children, the recommended levels should be adjusted downward based on the energy requirements of children relative to those of adults [67, 68]. However, the daily sodium intake in the general population is higher than that recommended by WHO [69, 70]. The estimated mean sodium intake was 3608 (95% CI: 3414–3803) mg per day based on cross-sectional data from a 2014 sample of US adults [71]. Besides, a study carried out on a representative sample of Spanish adults showed urinary sodium excretion corresponded to a salt intake of 9.8 g/day, 88.2% of individuals with intakes that exceeded 5g/day, urinary sodium excretion is correlated with SBP and DBP ($r = 0.243$ and $r = 0.153$, respectively). In the child population, 84.5% of those ≤ 10 years old have salt intakes > 4 g/day and 66.7% of those who are 11 years old have salt intakes > 5 g/day. Furthermore, urinary sodium excretion is positively correlated with SBP and DBP ($r = 0.157$ and $r = 0.140$, respectively) [69]. Similar results were found in Mexico, where 89.4% of the population had sodium intake greater than the recommended 5 g salt/day [72].

Potassium intake

Some studies suggest that sodium is not the main conditioner of BP, but it connects with other minerals. The sodium-induced increase in BP can be enhanced by low calcium and potassium intake and increased body weight [19] (Tab. 1). In particular, the ratio of sodium-to-potassium urine is strongly associated with HT and cardiovascular diseases [73–75]. A high-salt, low-potassium diet activates the thiazide-sensitive NaCl co-transporter in the kidney, an effect that has led to sodium retention and increased blood pressure [76]. Therefore, sodium restriction or increased potassium intake effectively reduces the risk of HT in recent studies [77–80]. Geleijnse et al. observed that supplementing with 44 mmol/day of potassium (1716 mg/day) reduced SBP/DBP by 2.42/1.57 mm Hg. The reduction was higher in hypertensive individuals (3.51/2.51 mm Hg) [81]. On the other hand, potassium supplementation is considered a safe method with a significant impact on BP and is recommended as an adjunctive antihypertensive agent for hypertensive patients. Each 0.6g of

potassium per day reduced systolic blood pressure by 1.0 mm Hg and diastolic blood pressure by 0.52 mmHg. Furthermore, potassium intake of 4.7 g/day is estimated to reduce 8-15% of cerebrovascular accidents and 6–11% myocardial infarction [82]. In patients with primary hypertension, potassium supplementation significantly reduced both SBP by 4.25 mm Hg (95% CI: 2.53–5.96) and DBP by 2.53 mm Hg (95% CI: 1.02–4.05) [83]. The recommended potassium intake for hypertensive patients is 4.7–5.0 g/day and less than 1.5 g sodium/day [84].

In fact, WHO has recommended a po tassium intake of ≥90 mmol/day (3510 mg/day) for the general population [68]; actual potassium requirements will vary with individual genetics, blood pressure, and daily salt intake [85]. A ratio of sodium-to-potassium urinary approximately 1:1 is believed to be beneficial for improving long-term blood pressure control [68]. However, most people today consume a relatively high diet in salt (NaCl) and low in potassium (K+). Results from a nationally representative survey in the US (827 adults aged 20 to 69 years) showed that the mean 24-hour urinary sodium and potassium excretion was 3608 mg (95% CI: 3414–3803) and 2155 mg (95% CI: 2030–2280) respectively. The overall mean sodium-potassium molar ratio was 3.17 (95% CI: 2.91–3.43) [71]. So the actual potassium intake is approximately 2400 mg/day, although the recommended intake in the US is 4700 mg/day instead of 3510 mg/day [86]. In South Africa, 91% of adults did not meet WHO recommendation (mean 35 mmol/day), potassium intake was significantly lower in rural areas and older adults [87].

Recently, Filippini et al. conducted a systematic review and meta-analysis showed strong evidence that potassium supplementation reduced SBP and DBP. However, the exact dose-response of the association has not been well established. Moreover, they observed a U-shaped relationship between potassium intake and blood pressure levels. In this sense, both relatively low and high potassium intake can adversely affect BP levels [80]. In fact, there is no standard daily limit for potassium, but supplementing with large amounts of potassium can be dangerous, causing excess potassium, leading to hyperkalemia. Therefore, caution should be exercised when increasing potassium consumption, especially in patients with renal impairment or those taking drugs that increase renal potassium retention, such as **ACEI, ARB, DRI**, and serum aldosterone receptor antagonists [84].

Calcium intake

Calcium is the most abundant cation in the human body, with about 99% of calcium contained in the skeleton. Therefore, calcium is strongly implicated in the health and disease of both musculoskeletal and cardiovascular. A cohort study of elderly Chinese adults found that higher

dietary calcium intake (mean 600 mg/day) was associated with a reduced risk of all-cause mortality and cardiovascular mortality [88].

Several studies find an inverse association between calcium intake and BP levels, particularly in individuals with low calcium intake, an increase in calcium intake reduces blood pressure [61, 89–91]. The effect is greater with the increase in SBP associated with age and calcium from dairy products [36]. A moderate sodium intake (< 2.400 mg/day) combined with a calcium intake of more than 800 mg/day reduces the risk of HT by approximately 52%. On the other hand, individuals with well-controlled HT have significantly higher calcium intake than uncontrolled individuals [61].

Nevertheless, many other reviews and clinical trials have found that calcium supplementation has no beneficial effect on blood pressure. In randomized controlled trials (36.806 participants) with a follow-up period ranging from 15 weeks to a maximum of 7 years, no significant effect of calcium on blood pressure was detected [92]. Besides, no effect of calcium supplementation on blood pressure during pregnancy was observed in a randomized placebo-controlled trial in Gambian women [93]. In a review by Mark Houston, he believes that calcium supplementation is not recommended as an effective method to reduce BP [84].

Magnesium intake

Magnesium is an essential mineral that plays an essential role in many processes in the body. Magnesium deficiency can contribute to many diseases such as hypertension, diabetes, and stroke [94]. Dietary magnesium supplementation is believed to be beneficial in preventing and treating HT (Tab. 2) [95–97]. Numerous studies show evidence supporting an inverse relationship between dietary magnesium intake and the risk of HT [95, 98–100]. Increasing magnesium intake (per 100 mg/day increment) decreased the risk of HT by 5% (RR = 0.95; 95% CI: 0.90–1.00) [96]. Magnesium intake < 200 mg/day *vs.* >200 mg/day is associated with a higher risk of incident HT[101]. In a systematic review and meta-analysis (34 trials, 2028 participants) magnesium supplementation (mean 368 mg/day) for a median of 3 months significantly reduced SBP by 2.00 mmHg (95% CI: 0.43–3.58) and DBP by 1.78 mm Hg (95% CI: 0.73–2.82) [102].

On the other hand, magnesium supplements may enhance the effect of antihypertensive medications. In two meta-analyses by Rosanoff et al. evaluated the association of oral magnesium supplementation with a reduction in blood pressure in hypertensive subjects (mean SBP > 155 mm Hg) who were on continuous antihypertensive medication ≥ 6 months, they observed that magnesium supplementation significantly reduced SBP and DBP by 18.7 mm Hg (95% CI: 14.95–22.45) and 10.9 mm Hg (95% CI: 8.73–13,1), respectively [103, 104]. They also recently confirmed the role of magnesium supplementation in enhancing the antihypertensive effects of

antihypertensive drugs in a systematic review of 49 clinical trials [105]. Besides, in individuals with insulin resistance, prediabetes, or other chronic non-communicable diseases, magnesium supplementation reduced an average of 4.18 mm Hg SBP and 2.27 mm Hg DBP with supplemental doses ranging from 365 to 450 mg/day [106].

Nevertheless, several studies show inconsistent results on the relationship between magnesium supplementation and lowering blood pressure [107, 108]. In patients with hypertension, a study of magnesium supplementation showed no significant difference in SBP and DBP in groups with and without magnesium supplementation [109]. Different results from the meta-analyses and trials might be due to the quality of the trials included in the analysis or poorly designed trials that might also bias the results.

Table 2. Recommended daily magnesium intake (Adapted from [110])

Age	**Male [mg/day]**	**Female [mg/day]**	**Pregnancy [mg/day]**	**Lactation [mg/day]**
0–6 months	30	30		
7–2 months	75	75		
1–3 years	80	80		
4–8 years	130	130		
9–13 years	240	240		
14–18 years	410	360	400	360
19–30 years	400	310	350	310
31–50 years	420	320	360	320
51-70 years	420	320		
> 70 years	420	320		

Other nutrients

Imbalances in the supply of zinc, copper and manganese also affect BP values and HT. On the other hand, the existence of an inverse association between serum levels of vitamin D and BP has been verified. Improving the situation in this frequently inadequate vitamin seems desirable [111].

Garlic is considered one of the traditional foods, which are used almost daily with meals. Recent studies have shown that garlic is one of the most effective measures to reduce blood pressure in patients with HT [112–114]. The meta-analysis of 12 trials and 553 hypertensive participants confirmed that garlic supplements reduced blood pressure by 8.3 ± 1.9 mm Hg (SBP) and 5.5 ± 1.9 mmHg (DBP) [113]. In addition, the Garlic trial showed that Kyolic aged garlic extract was as effective in treating HT as the first-line standard antihypertensive medication [115].

Hibiscus sabdariffa is a wild tropical plant rich in organic acids, polyphenols, anthocyanins, polysaccharides, and volatile ingredients beneficial for the cardiovascular system. Hibiscus

sabdariffa beverage (hibiscus tea) is commonly used to treat arterial hypertension. A meta-analysis of RCTs showed a significant effect of H. sabdariffa in reducing both SBP and DBP [116]. Moreover, another RCTs results revealed that daily consumption of hibiscus tea, in an amount freely incorporated into the diet, reduces BP in pre-and mildly hypertensive adults and may prove an effective component of the dietary changes recommended for people with these conditions [117].

On the other hand, the Chinese discovered the antihypertensive effect of tea drinking for a long time. Currently, in both East Asia and the West, reducing blood pressure by drinking tea has been reported in population studies [118]. A meta-analysis performed by Mahdavi-Roshan et al. observed that drinking tea regularly can lower blood pressure by 3.53 mm Hg (SBP) and 0.99 mm Hg (DBP). In particular, they also found that the longer the duration of drinking tea, the higher the BP reduction [119]. Antihypertensive effects have been observed in green tea or black tea; however, green tea has a more pronounced antihypertensive effect than black tea [118–120].

Antioxidant capacity of the diet

Some studies indicate that hypertensive patients have altered antioxidant defence mechanisms; therefore, an adequate supply of antioxidants can be important in the fight against hypertension.

In a study carried out in children evaluating the antioxidant capacity of the diet (CAD), it was found that schoolchildren with normal BP figures have a significantly higher CAD than that of schoolchildren with arterial prehypertension (PHTA) and hypertension. It was also found that better CAD reduces the risk of presenting PHTA and hypertension, probably due to the greater supply of antioxidants to the body, preventing LDL's adhesion to the vascular wall [70].

To determine the relationship between the total dietary antioxidant capacity and the risk of hypertension, Paola Villaverde et al. conducted a cohort study based on the follow-up of 40,576 French women in 12.7 years. The results showed an inverse association between the risk of HT in women and the antioxidant capacity of the diet. In particular, they observed that this result was stable over time and appeared to be independent of major risk factors for HT [121].

Evidence regarding the influence of dietary patterns on the prevention and control of hypertension

Effect of dietary patterns on blood pressure and risk of hypertension

Although the effects of single nutrients on BP such as sodium, potassium, and magnesium are well known, but these nutrients are distributed in foods and foods are usually consumed as whole diets. In addition, as many interactions can occur between components of an entire diet, assessing the impact of a single nutrient on blood pressure will not be as valuable as evaluating the whole diet's

impact [122]. Furthermore, different regions and countries will have dietary patterns leading to the different prevalence of hypertension [31].

In China, the prevalence of hypertension was 23.2% [123] (results from the China Hypertension Survey, 2012–2015) and it is still increasing. Their dietary patterns may be one of the reasons for their increased risk of hypertension. A study in Hangzhou, Zhejiang Province indicated that the traditional Chinese dietary pattern (high consumption of grains, fresh fruits, vegetables, shrimp, fish, beans) was associated with a reduced risk of hypertension. In contrast, the animal food pattern (high consumption of red meat, seafood, fats/oils, alcoholic beverages) and The high-salt pattern (high consumption of pickled vegetables, processed and cooked meats, salted fish, bacon, and bean sauces) are associated with an increased risk of hypertension [124–126]. Another study of Han and multi-ethnic populations in southwestern China found that The Grassland healthy dietary pattern is associated with a lower risk of hypertension. This dietary pattern is characterized by a high intake of yogurt, soy products, and eggs, whereas the traditional diet in southern China is characterized by a high intake of fruit, poultry, pork, rice, vegetables, and aquatic products [127]. Due to the economic transition in China, the increased urbanization rate has led to large-scale lifestyle changes among young people associated with increased consumption of high-fat foods and reduced physical activity. Therefore, the prevalence of hypertension is increasing in young people [128].

On the other hand, the Japanese have the longest life expectancy globally, so there is growing global interest in the role of the Japanese dietary pattern as a possible explanation for this. Many epidemiological studies have shown that the consumption of foods according to the Japanese dietary pattern (high consumption of vegetables, seaweed, fish, fruits, soybean products, miso soup and green tea) is inversely associated with cardiovascular disease. Niu et al. observed that the Japanese dietary pattern was associated with longitudinal changes in BP in adults (both men and women) after 3 years of follow-up [129]. Another study by Htun et al. suggested that the Japanese Dietary Pattern was associated with a reduced prevalence of hypertension in men but not in women. In addition, the “Meat and fat” dietary pattern (high consumption of red meat, saturated fat, mayonnaise, wheat products) identified in their study was positively associated with the prevalence of hypertension, diabetes and hypercholesterolemia [130]. Besides, regular consumption of meat and dairy products to prevent hypertension was recommended in a study of male workers [131].

In the United States, hypertension has become a serious public health challenge, with approximately 30% of adults affected [132]. Typical dietary patterns in the United States (low in fruits, vegetables, and dairy products, high in fat) lead to an increased risk of heart disease and stroke. Appel et al. conducted a clinical trial on the effects of dietary patterns on blood pressure in 459 adults. Participants were fed a typical dietary pattern in the United States for three weeks. For eight weeks,

they were then fed a combination dietary pattern (high in fruits and vegetables, low-fat dairy products, and reduced in saturated fat and total fat); sodium intake and body weight were maintained at a constant level. The results showed that the combination dietary pattern reduced SBP by 5.5 mm Hg and DBP by 3.0 mm Hg compared with the typical dietary pattern [133].

As mentioned, sometimes in the dietary pattern, there are factors associated with a reduced risk of hypertension, such as high fruit and dairy consumption and low alcohol intake but when they were combined with other foods in the dietary pattern, resulting in the whole diet was not associated with a reduced risk of hypertension [129].

Globally recommended diets

Taking into account the importance of fighting hypertension, the Dietary Approaches to Stop Hypertension diet (DASH) was developed, based on increasing the consumption of fruits, vegetables, low-fat dairy, whole grain cereals, nuts, legumes and seeds, with low consumption of meat, sodium, added sugar and saturated fat. The DASH diet has yielded favourable results in BP control [15, 31, 63, 134] (Tab. 1), particularly effective for older adults and hypertensive persons [135]. A meta-analysis (24 trials, 23.858 participants) by Gay et al. showed that following the DASH diet reduced blood pressure by 7.62 mm Hg (SBP) and 4.22 mm Hg (DBP) [63]. Besides, the meta-analysis of Filippou et al. had a similar conclusion, the DASH diet reduced SBP by 3.2 mmHg (95% CI: 2.3–4.2; $p < 0.001$) and DBP by 2.5 mm Hg (95% CI: 1.5–3.5; $p< 0.001$). In particular, HT did not alter the BP-lowering effect [136].

Similar to the DASH diet, the Mediterranean diet (MD) is also recommended for improving cardiovascular health and lower blood pressure. This diet is characterized by the high consumption of fish/seafood, olive oil, vegetables, fruits, whole grains, legumes, nuts; moderate consumption of eggs, poultry, dairy, wine and limit consumption of red meat, sweets [137]. A meta-analysis by Nissensohn et al. showed that the adoption of the MD for at least 1 year reduced SBP (–1.44 mm Hg) and DBP (–0.70 mm Hg) in individuals with normal blood pressure or mild hypertension; however, the reduction in blood pressure was small in all cases [138]. One study in older adults (65-79 years of age) found that a MD significantly reduced systolic blood pressure (−5.5 mm Hg; 95% CI, −10.7 to −0.4; $p = 0.03$) in men but not in women [139]. Another meta-analysis performed by Filippou et al. showed that the MD reduced SBP by 1.5 mm Hg (95% CI: 0.1–2.8) and 0.9 mm Hg DBP (95% CI,: 0.3–1.5) compared with the usual diet. Moreover, the MD resulted in a greater reduction in DBP in trials in which individuals had baseline SBP ≥ 130 [140].

On the other hand, the beneficial effects of a vegetarian diet on blood pressure control have been reported in many studies [141, 142]. Kai Wei Lee et al. observe that a vegetarian diet significantly

reduced SBP by 2.66 mm Hg (95% CI: 1.55–3.76, $p < 0.001$) and DBP by 1.69 (95% CI: 0.41–2.97, $p < 0.001$) compared with an omnivorous diet. In particular, the vegan diet showed a greater effect on reducing SBP than the lacto-ovo vegetarian diet (which allows for the consumption of eggs and dairy) [141].

We must also consider that the simultaneous implementation of several guidelines (reduction in weight, sodium and alcohol, increased activity, and following the DASH diet) may have a more significant benefit than following a single measure [15, 16, 135]. As indicated by Chobanian et al., the factors with the most significant impact on BP reduction were the implementation of the DASH diet and weight control [143].

Conclusion

HT is a serious problem with an increasing incidence, parallel with inadequate and frequent diagnosis, and poorly controlled. Good blood pressure control can prevent adverse cardiovascular events caused by hypertension, prolong life expectancy and improve quality of life. Adjusting the intake of nutritional factors greatly influences the prevention and control of hypertension, such as a diet rich in omega-3, reducing sodium, increasing potassium and magnesium, reducing alcohol consumption. In addition, the application of a diet such as the DASH diet, the MD diet or the Vegetarian diet, along with increased physical activity also has a significant impact on the control and prevention of hypertension.

Author contributions

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Conflict of interest

The authors declare no conflict of interest.

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Ethical consideration

No known conflict of interest was associated with this publication. This manuscript was read and approved by all named authors, and there are no other persons who satisfied the criteria for authorship but are not listed. The order of authors listed in the manuscript has been approved by all the contributors. The authors have nothing to declare.

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