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REVIEW ARTICLE

Non-pharmacological management of hypertension: in the light of current research

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Abstract
Hypertension is a major risk factor for a number of cardiovascular diseases. Proper management of hypertension may require both pharmacological and non-pharmacological interventions. Non-pharmacological interventions help reduce the daily dose of antihypertensive medication and delay the progression from prehypertension to hypertension stage. Non-pharmacological interventions include lifestyle modifications like dietary modifications, exercise, avoiding stress, and minimizing alcohol consumption. Nutritional requirements of hypertensive individuals can be addressed through adopting either the DASH diet or through traditional Mediterranean diet. These dietary guidelines promote the consumption of fruits, vegetables, grains, dairy products, and food rich in K^+, Mg^{+2}, Ca^{+2}, and phosphorus. Restriction of Na^+ intake has the greatest role in lowering the blood pressure. The DASH diet alone has the effect equal to that of a single drug therapy. After dietary modifications, exercise and weight loss are the second major intervention for hypertension management. Avoiding stressful lifestyle, depression, and anxiety also help to reduce elevated blood pressure. Minimizing alcohol intake also favors the blood pressure reduction. However, lifestyle modification is a dynamic process and requires continuous adherence. It is a multi-factorial approach targeting more than one intervention. However, 6–12-month lifestyle modifications can be attempted in stage-1 hypertensive patients without any cardiovascular complication, in the hope that they may be sufficiently effective to make it unnecessary to use medicines.

Keywords DASH diet · Exercise · Hypertension · Lifestyle modifications · Low salt diet · Non-pharmacological management

Introduction

Hypertension is a major risk factor for cardiovascular diseases leading to morbidity and mortality. Hypertension alone is responsible for 14% of deaths globally. The rate of hypertension has increased from 13,307/100,000 in 1990 to 20,525/100,000 in the year 2015 [1]. The prevalence of hypertension in adults ranges from 30 to 45% in different countries of the world [2]. Unhealthy eating habits, decreased physical activity, obesity, smoking, and alcohol consumption are the key factors for development of hypertension. Proper management of hypertension is necessary in order to prevent its complications and to improve the quality of life of the patient. Hypertension management involves both pharmacological and non-pharmacological interventions for effective control. Despite the availability of very effective medications, the

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blood pressure cannot be controlled in about 70% of patients who receive only pharmacological treatment for hypertension [3]. The non-pharmacological interventions can be utilized alone before starting the pharmacological therapy or in combination after. The lifestyle modifications can help reduce the use of medications. So far, several studies have been conducted to find out correlation between different non-pharmacological interventions and hypertension. A study was conducted on 6779 hypertensive patients, and the changes achieved in SBP were 5.4 mmHg reduction for behavioral counseling, 3.5 mmHg reduction for dietary modifications, 11.4 mmHg reduction for improved physical activity, and 6.4 mmHg reduction for multiple interventions [4]. This study proved that lifestyle directly affects the level of blood pressure. These lifestyle changes include increased physical activity, better diet, healthy weight, avoiding smoking, and limiting alcohol consumption.

Nevertheless, a multi-factorial approach is required to control hypertension through non-pharmacological interventions. In this article, the following non-pharmacological interventions will be reviewed: (1) dietary modifications, (2) dietary sodium restriction, (3) potassium and magnesium supplementation, (4) increased Ca^{+2} intake, (5) minimizing alcohol intake, (6) body weight and exercise, (7) combined effect of weight loss and Na^{+} restriction, and (8) reduced physiological stress and anxiety.

The main purpose of this review is to emphasize the significance of non-pharmacological interventions for hypertension control and to provide the most recent research evidence on the success of these interventions in effective management of hypertension.

Search strategy

Search was carried out in Medline, Scopus, CINHAL, PubMed, Cochrane Database, and Google Scholar. The syntax used for literature search was Hypertension AND Non-pharmacological Management AND DASH Diet AND Lifestyle Modifications AND Potassium & Magnesium supplementation AND Alcohol Intake AND Low Salt Diet AND Exercise. The titles, abstracts, study protocols, and the contents of study were scrutinized through our inclusion exclusion criteria. Any reservation regarding the selection of study was resolved through consensus. The data extraction sheet was created through Microsoft Excel© for the extraction of data. We excluded all studies that did not reported consistent data. The studies published in language other than English were also not included. Since this is a narrative review, hence, no ethical permission was required.

On the basis of available literature, the effectiveness of each intervention for hypertension management is discussed one by one as follows:

1. Dietary modifications: Dietary habits are directly linked to hypertension. The research studies proved that a diet rich in fiber and dairy products, low in Na^{+}, rich in K^{+} and Mg^{+2}, and high in polyunsaturated fatty acids is beneficial for the prevention and management of hypertension. Current clinical guidelines recommend the lifestyle modifications, as an initial treatment in prehypertension stage and in combination with pharmacological treatments in all other stages of hypertension for better management of hypertension [5, 6]. Despite of all the positive findings for the beneficial effects of dietary modifications, the healthcare practitioners are still not clear as which dietary approach to recommend. It has been observed that individuals on vegetarian diet are less likely to develop hypertension and other cardiovascular diseases [7]. The "Dietary Approach to Stop Hypertension (DASH)" and "Traditional Mediterranean Diet" are the highly recommended dietary approaches for the prevention and management of hypertension.

- The DASH diet: DASH diet was designed for the prevention and effective management of hypertension. It is now considered as diet of choice for the prevention and treatment of hypertension. The effectiveness of DASH diet has been established through DASH trials conducted in different parts of the world [8]. In an 08-week DASH trial, 459 participants were randomly distributed in the following three groups: (a) control diet, (b) diet rich in fruits and vegetables, (c) combination diet, i.e., diet rich in fruits and vegetables, low-fat dairy products, and reduced in saturated fats (DASH-combination diet) the salt intake was kept constant in all three groups. At the end of trial, it was observed that in the combination diet group, the reduction in both systolic and diastolic blood pressure was greater in black population where the reduction in blood pressure was 6.9/3.7 mmHg as compared to 3.3/2.4 mmHg in white population. It was also observed that combination diet lowered systolic blood pressure more in hypertensive patients 11.4 mmHg than in normotensive individuals 3.4 mmHg [9]. In another 08-week DASH trial, 459 participants were randomly distributed in the following three groups: (a) control diet, (b) diet rich in fruits and vegetables, (c) combination diet, i.e., diet rich in fruits and vegetables and reduced in saturated fats and low-fat dairy products (DASH-combination diet), the salt intake was kept constant in all three groups. At the end of trial, it was observed that the reduction in both systolic and diastolic blood pressure was greater in the combination diet group where the reduction in blood pressure was 5.5/3.0 mmHg more as compared to control diet. Similarly, a fruits and vegetables diet reduced both systolic and diastolic blood pressure by 2.8/1.1 mmHg more than control diet. The combination diet lowered both systolic and diastolic blood pressure more in hypertensive patients 11.4/5.5 mmHg than in normotensive individuals 3.5/2.1 mmHg [10]. In a more recent meta-analysis of 24 studies involving 23,858 participants, it was reported that strict compliance to DASH diet resulted in substantial reduction in both systolic and diastolic blood pressure SBP 7.62 mmHg/4.22 mmHg respectively [11]. A recent OMNIHEART Trial (Optimal Macronutrients Intake to Prevent Heart Disease Trial) conducted on 2195 participants reported the additional benefit of replacing the carbohydrate content of DASH diet either with proteins or monounsaturated fats (preferably from vegetable source). OMNIHEART-like diet resulted in BP reduction of 3.9/2.2 mmHg Pr (difference ≤ 0) 0.98/0.96 [12]. Another OMNIHEART Trial involving 164 participants revealed that two versions of DASH diet with reduced carbohydrate content (high in proteins and monounsaturated fats) resulted in reduction of BP by 1.4/1.2 mmHg and 1.3/0.8 mmHg respectively when compared with normal DASH diet (high-carbohydrate content) [13]. To determine the combined effect of DASH diet and exercise, a 16-week ENCORE Trial was conducted on 144 overweight hypertensive individuals randomized in three groups: (a) DASH diet alone, (b) DASH diet plus behavioral weight management, and (c) usual diet control group. The blood pressure reduction of 16.1/9.9 mmHg was observed in DASH diet + weight management group compared to 11.2/7.5 mmHg reduction in DASH diet alone and 3.4/3.8 mmHg reduction in usual diet control group [14] (see Table 1).

Traditional Mediterranean diet

A study conducted in the Mediterranean region in 1950 reported that the people living in this region live longer and have less CVS diseases as compared to other European regions. This finding prompted further research on the lifestyle and dietary habits of the people living there. The main features of Mediterranean diet are (1) increase intake of fruits, vegetables, and pulses, (2) high consumption of monounsaturated fatty acids and polyunsaturated fatty acids, (3) less consumption of red meat, and (4) restricted intake of alcohol [15]. A 06-year follow-up study involving 9408 males and females reported that strict implementation of a Mediterranean diet resulted in reduction in SBP by 3.1 mmHg and DBP by 1.9 mmHg. On the other hand, moderate compliance resulted in 2.4 mmHg reduction in SBP and 1.3 mmHg reduction in DBP [16]. Christiana Maria Kastorini et al. in a meta-analysis of 50 clinical trials found that a traditional Mediterranean diet associated with 2.35 mmHg reduction in SBP and 1.58 mmHg reduction in DBP [17]. (see Table 1)

2. Sodium restriction: Sodium plays an important role in pathophysiology of hypertension. A high salt diet leads to profibrotic changes in vascular smooth muscles through induction of collagen synthesis. This collagen deposition in blood vessels leads to arterial stiffness [18]. Daily Na^+ intake of 2400 mg/24 h is considered as normal/beneficial. Whereas further reduction to 1500 mg/24 h recommended in the persons who are at increased risk of hypertension or stroke [19]. There are several clinical trials to evaluate the effect of high Na^+ on hypertension including Trial of Hypertension Prevention Phase-1 (TOHP-1) and DASH-Sodium Trial. The TOHP-1 is the largest randomized control trial to evaluate seven non-pharmacological interventions on 744 pre hypertensive individuals. Four hundred seventeen in the control group and 327 in an intervention group. The intervention group received counseling with aim to reduce Na^+ intake to 1400 mg/24 h while the control group received no such intervention. After 18 months, 44 mmol/24 h reduction from baseline in urinary Na^+ was observed. This reduction in urinary Na^+ was more prominent in white women as compared to African-American population. The larger systolic BP reduction effect was observed in women than men (−4.4 mmHg vs −1.2 mmHg, $p = 0.02$). The net reduction in both systolic and diastolic blood pressure in "Restricted Na^+ Intake Group" was 2.1 mmHg SBP and 1.2 mmHg DBP as compared to "Control Group." It was further observed for every 100 mmol/24 h reduction in urinary Na^+ that there is a reduction of 1.4/0.9 mmHg in blood pressure [5]. A 15-year follow-up study revealed that dietary Na^+ restriction decreases the risk of long-term cardiovascular events by 25% [20]. Similarly, in DASH-Sodium Trial 412, participants with or without hypertension were randomly assigned to either "Control Diet Group" (typical US diet) or "DASH Diet Group." Each diet group consumed high, intermediate, or low Na^+ food for 30 consecutive days in random fashion. The results of study revealed that reducing the Na^+ intake from high to intermediate level resulted in systolic blood pressure reduction of 2.1 mmHg in "Control Diet Group" and 1.3 mmHg in "DASH Diet Group." Similarly, the reduction from intermediate to low level Na^+ intake resulted in further reduction of 4.6 mmHg in "Control Diet Group" and 1.7 mmHg reduction in "DASH Diet Group." The DASH diet was associated with significantly lower blood pressure at each Na^+ intake level. In comparison to Control Diet with high Na^+ intake, the DASH diet with low Na^+ content led to systolic BP reduction of 11.5 mmHg in hypertensive individuals which is equal

Table 1 Effect of dietary modifications and Na^+ restriction on blood pressure

Sr. #	Investigator	Study design	Population (*n*)	Mean age (years)	Intervention details	Duration	Gender ratio	Racial profile	Overall BP reduction (mmHg)
1	Laura P. Svetkey et al.	DASH trial (a randomized controlled trial)	459	45 ± 10.6	(a) Combination DASH diet group vs control group (b) Fruit and vegetable-rich diet group vs control group	08 weeks	51% male	60% Black 40% White	(a) − 3.3 mmHg SBP (W)[a] − 2.4 mmHg DBP (W)[a] − 6.9 mmHg SBP (B)[b] − 3.7 mmHg DBP (B)[b] (b) − 0.9 mmHg SBP (W)[a] − 0.3 mmHg DBP (W)[a] 3.5 mmHg SBP (B)[b] − 1.4 mmHg DBP (B)[b]
2	Lawrence J. Appel et al.	DASH trial (a randomized controlled trial)	459	44 ± 11	(a) Combination DASH diet group vs control group (b) Fruit and vegetable-rich diet group vs control group	08 weeks	49% male	31% White 62% Black 7% others	(a) − 5.5 mmHg SBP − 3.0 mmHg DBP (b) − 2.8 mmHg SBP − 1.1 mmHg DBP
3	Hawkins C. Gay et al.	Meta-analysis of 24 randomized controlled trials	23,858	45 ± 8.4	Net BP lowering effect of DASH diet vs control group	06 to 48 months	80% male	Not reported	7.62 mmHg SBP − 4.22 mmHg DBP
4	John Molitor et al.	Observational study	2195	40–59 (years)	To compare the effect of OMNIHEART diet with typical US diet	03-year survey	50% male	Not reported	− 3.9 mmHg SBP − 2.2 mmHg DBP
5	Lawrence J. Appel et al.	OMNIHEART Trial (a randomized controlled trial)	164	53.6 ± 10.9	(a) DASH diet with high protein content vs normal DASH diet (b) DASH diet with high unsaturated fat content vs normal DASH diet (c) Normal DASH diet group (high in carbohydrates)	06 weeks	55% male	55% Black 40% White 5% others	(a) − 1.4 mmHg SBP − 1.2 mmHg DBP (b) − 1.3 mmHg SBP − 0.8 mmHg DBP (c) − 0.1 mmHg SBP − 0.4 mmHg DBP
6	James A. Blumenthal et al.	ENCORE Trial (a randomized controlled trial)	144	52 ± 10	(a) DASH + weight management group (b) DASH diet alone group (c) Control group	04 months	33% male	60% White 39% Black 1% Asian	(a) − 16.1 mmHg SBP − 9.9 mmHg DBP (b) − 11.2 mmHg SBP − 7.5 mmHg DBP (c) − 3.4 mmHg SBP − 3.8 mmHg DBP
7	Nunez- Cardoba et al.	SUN Study (a 6-year follow-up study)	9408	36.7 ± 10.5	To evaluate association between adherence to traditional Mediterranean diet and incidents of hypertension	06 years	38% male	Not reported	− 3.1 mmHg SBP − 1.9 mmHg DBP
8	Christiana Maria Kastorini et al.	Meta-analysis of 35 clinical trials, 02 prospective and 13 cross-sectional studies	534,906	54 ± 9.4	To evaluate association between consumption of traditional Mediterranean diet and incidents of hypertension	03 months to 01 year	Not reported	Not reported	− 2.35 mmHg SBP − 1.58 mmHg DBP

Table 1 (continued)

Sr. #	Investigator	Study design	Population (*n*)	Mean age (years)	Intervention details	Duration	Gender ratio	Racial profile	Overall BP reduction (mmHg)
9	Paul K. Whelton et al.	TOHP-I Trial	744	43 ± 6.5	Na^+ restriction group vs control group	18 months	70% male	82% White 18% Black	− 2.1 mmHg SBP 1.2 mmHg DBP
10	Frank M. Sacks et al.	DASH-Sodium Trial (a randomized controlled trial)	412	47 ± 10	(a) DASH diet + low Na^+ vs controlled diet + low Na^+. (b) DASH diet + intermediate Na^+ vs controlled diet + intermediate Na^+ (c) DASH diet + high Na^+ vs controlled diet + high Na^+	30 days	41% male	43% White 57% Black	(a) − 2.2 mmHg SBP − 1.1 mmHg DBP (b) − 5.0 mmHg SBP − 2.5 mmHg DBP (c) −5.9 mmHg SBP − 2.9 mmHg DBP

Abbreviations: *BP*, blood pressure; *SBP*, systolic blood pressure; *DBP*, diastolic blood pressure; *DASH*, Dietary Approach to Stop Hypertension; *OMNIHEART*, Optimal Macronutrient Intake Trial to Prevent Heart Disease; *ENCORE*, Exercise and Nutrition Interventions for Cardiovascular Health; *SUN*, Seguimiento Universidad de Navarra

[a] White race

[b] Black race

to the BP lowering effect of a single drug therapy [21] (see Table 1).

3. Potassium and magnesium supplementation: Potassium intake has an inverse correlation with hypertension. Recent research showed that K^+ consumption has an important role in salt-sensitive hypertension especially in black population [22]. Salt loading increases mean arterial blood pressure by 6.8 mmHg in African/Black population vs 1.9 mmHg in white population when given low K^+ diet. This hypertensive effect was reduced by 4.9/3.3 mmHg in black population vs 2.5/1.9 mmHg in white population when given high K^+ diet to the participants, i.e., 70 mmol.day [23]. In a meta-analysis of 33 randomized control trials involving 2609 (1560 hypertensive + 1005 normotensive) individuals, the K^+ supplementation was associated with 4.4/2.4 mmHg reduction in both systolic and diastolic blood pressure. This effect of K^+ appeared to be enhanced with concurrent use of high Na^+ intake [24]. In a metaregression analysis of 27 potassium trials that had at least 44 mmol of potassium supplementation/day leads to 2.4/1.57 mmHg reduction in both systolic and diastolic blood pressure [25]. It is important to mention here that long-term data to confirm the role of K^+ in lowering the blood pressure is not conclusive. However, it becomes clinically relevant in racial perspective especially in black population as observed in some epidemiological studies [23]. INTERSALT trial involving 287 participants revealed that participants receiving 96 mmol K^+ supplementation/day resulted in more systolic and diastolic blood pressure reduction, i.e., 1.9/0.6 mmHg respectively as compared to placebo [26]. Alberto Ascherio et al., in a 04-year prospective study involving 30,681 individuals, reported that K^+ and Mg^{+2} had an inverse correlation with baseline systolic and diastolic blood pressure [27].

Like potassium, magnesium also has an inverse correlation with hypertension. Mg^{+2} is found rich in fruits and vegetables that are studied for beneficial effects against hypertension. A meta-analysis of 34 trials involving 2028 normotensive and hypertensive participants showed a positive effect for Mg^{+2} intake (368 mg/day) for 3 months in lowering blood pressure to 2.0 mmHg SBP and 1.78 mmHg DBP [28]. In an another study, the relative risk of hypertension for Mg^{+2} intake > 300 mg/day compared to intake < 200 mg/day was 0.78 [27, 29]. T. Dykner et al. reported that Mg^{+2} supplementation reduced blood pressure by 12 mmHg SBP and 8 mmHg DBP [30] on contrary to Lind et al., who found no effect of Mg^{+2} supplementation on hypertension [31]. Despite of compelling epidemiological data in favor of hypotensive effects of food containing high Mg^{+2} content, results of clinical studies are conflicting. Heterogeneity still exists between the results of different studies. Hence, further studies are required to investigate the effects of K^{+} and Mg^{+2} on hypertension management (see Table 2).

4. Increased calcium and vitamin D supplementation: There are contradictory evidences on the role of Ca^{+2} in lowering blood pressure. Mierlo et al. in a meta-analysis reported the blood pressure lowering effect of Ca^{+2} supplementation [32]. On contrary, Shusuke Yagi et al. in a retrospective study reported that prevalence of hypertension was higher in patients with hypercalcemia [33]. Korean National Health and Nutrition Survey III also showed the beneficial effects of Ca^{+2} in lowering the elevated blood pressure [34]. A Cochrane review on 15,000 pregnant women revealed that high Ca^{+2} intake decrease the risk of hypertension during pregnancy [35]. On the other hand, a few epidemiological studies that suggest that vitamin D deficiency may lead to development of hypertension [36, 37]. Several clinical studies have been carried to examine the antihypertensive effect of vitamin D supplementation. To date, most of randomized control trials do not support the use of vitamin D or its analogues to treat hypertension. However, there are few observational studies that suggest the antihypertensive effect of Vitamin D supplementation in patients with chronic kidney disease and diabetes [38–41]. Miles D. Witham et al. in a 06-month randomized controlled trial conducted on 68 white participants revealed that vitamin D has no association with blood pressure reduction [42]. Similarly, Robert Scragg et al. in an 18-month randomized controlled trial on 322 predominantly white participants observed no significant decrease in either systolic or diastolic blood pressure [43]. John P. Forman et al. in a 03-month randomized controlled trial involving 283 black participants revealed that for each 1 ng/ml increase in plasma 25, hydroxyvitamin D, there was 2.0 mmHg reduction in systolic blood pressure; on the other hand, there was no effect on diastolic blood pressure [44]. A meta-analysis of 46 randomized control trials also revealed that vitamin D supplementation has no effect on either systolic or diastolic blood pressure (see Table 3).

5. Minimizing alcohol intake: Reduction of alcohol intake is one of the recommendations in JNC-8 guidelines. Excess alcohol consumption is responsible for 5–30% of all hypertension cases [45]. Alcohol intake is directly correlated with elevated blood pressure. The reduction in weekly alcohol from 452 to 64 ml was found to be associated with 5/3 mmHg reduction in blood pressure in 3 weeks [46]. A meta-analysis of 15 randomized control trials involving 2234 individuals revealed that alcohol reduction was associated with 3.3/2.04 mmHg reduction in blood pressure [47]. A Japanese study conducted on 539 participants revealed that increase in blood pressure is directly related to alcohol consumption. In mild drinkers, systolic and diastolic blood pressure was 2.1/1.7 mmHg higher than that in non-drinkers; in moderate drinkers, systolic and diastolic blood pressure was 3.0/2.9 mmHg higher than in non-drinkers; similarly, in heavy drinkers, systolic and diastolic blood pressure was 2.3/2.0 mmHg higher than in non-drinkers [48]. Abramson et al. also revealed that chronic alcohol consumption is associated with elevated blood pressure [49]. A meta-analysis of 36 studies involving 2865 participants revealed that reduction in alcohol intake from 06 drinks/week to 03 drinks per week resulted in 5.5 mmHg reduction in SBP and 3.97 mmHg in DBP [50]. Peter D. Arkwright et al. in a 05-month randomized controlled trial involving 491 participants revealed that individuals who consume ≥ 350 ml alcohol/week had their systolic and diastolic blood pressure 5.8/2.9 mmHg higher than non-drinkers, individuals who consumed 160–349 ml alcohol/per week had their systolic and diastolic blood pressure 4.5/2.2 mmHg higher than non-drinkers, similarly, the individuals who consumed less than 160 ml alcohol per week had their systolic and diastolic blood pressure 3.7/5.2 mmHg higher than non-drinkers [51]. NHANES-III study conducted on women revealed that the average systolic blood pressure was higher in women who consumed 30 mg more alcohol than those who consumed moderate/less alcohol and use of contraceptives increased the hypertensive effect of alcohol in women [52]. Although there are some studies which have found no correlation between alcohol consumption and hypertension [53], but still more than 60 studies conducted in different parts of the world have observed the positive correlation between increased alcohol consumption and hypertension [54] (see Table 4).

6. Body weight and exercise: Physical activity is the major lifestyle modification for the management of hypertension. There are a number of studies that support the relationship between physical activity and hypertension. Individuals with a higher fitness level have lesser chances to develop hypertension [55]. A meta-analysis of 54 randomized controlled trials involving 2419 participants revealed that ≥ 150 min exercise/week resulted in decrease in both systolic and diastolic blood pressure by 5.13/2.78 mmHg, respectively, 121–149 min/week exercise resulted in 4.67/2.11 mmHg reduction in both systolic and diastolic blood pressure, and ≤

Table 2 Effect of Mg^{+} and K^{+} supplementation on blood pressure

Sr. #	Investigator	Study design	Population (*n*)	Mean age (years)	Intervention details	Duration	Gender ratio	Racial details	Overall BP reduction (mmHg)
1	Morris et al.	Observational study	38	38.5	70 mmol/day K^{+} supplementation 120 mmol/day K^{+} supplementation	14 days		24 Black 14 White	− 7.7 mmHg SBP − 5.2 mmHg DBP
2	Whelton et al.	Meta-analysis of 33 randomized control trials	1560 hypertensive 1005 normotensive		Either 60 or 100 mmol of K^{+}/day (intervention group) Either placebo or no potassium (control group)	04 days to 03 years		197 Black 2282 White	− 4.4 mmHg SBP − 2.45 mmHg DBP
3	Geleijnse et al.	Metaregression analysis of 27 randomized control trials	N/A	45 ± 12	44 mmol of K/day^{+} supplementation	02 weeks to 02 years	60% male	N/A	− 2.42 mmHg SBP − 1.57 mmHg DBP
4	Richard H. Grim Jr. et al.	INTERSALT Trial Randomized controlled trial	287	57.8 ± 6.2	96 mmol of K^{+}/day supplementation	2.2 years	100% male	284 White 03 Black	− 1.9 mmHg SBP − 0.6 mmHg DBP
6	Ascherio et al.	Observational study	30,681	N/A	Association between blood pressure and daily intake of K^{+}, Mg^{+2}, and Ca^{+2} was observed	04 years	100% male	Predominantly White	• Ca^{+2} was associated with lower incidences of hypertension only in lean men • K^{+1} and Mg^{+2} had an inverse correlation with baseline SBP and DBP
7	T. Dykner et al.	Randomized controlled trials	39	62.2 ± 4.2	20 received active Mg^{+2} treatment (15 mmol/day) Controlled group received no treatment	06 months	20% male		− 12.0 mmHg SBP − 8.0 mmHg DBP
8	Lind et al.	Double-blind placebo controlled studies	71	60 ± 9.4	49 received active Mg^{+2} treatment (15 mmol/day) 22 received placebo	06 months	49% male		+1.0 mmHg SBP − 2.7 mmHg DBP

Abbreviations: *BP*, blood pressure; *SBP*, systolic blood pressure; *DBP*, diastolic blood pressure

Table 3 Effect Ca^{+2} and vitamin D supplementation on blood pressure

Sr. #	Investigator	Study design	Population (n)	Mean age (years)	Intervention details	Duration	Gender ratio	Racial details	Overall BP reduction (mmHg)
1	Mierlo et al.	Meta-analysis of 40 randomized control trials	2492	43.7 ± 14.3	1200 mg Ca^{+2} supplementation/day	03 to 208 weeks	47% male	31 studies Whites 09 studies non-Whites	− 1.86 mmHg SBP − 0.99 mmHg DBP
2	Shusuke Yagi et al.	A retrospective observational study	114	57 ± 15	Association between serum Ca^{+2} level and hypertension was observed	N/A	32% male	100% Japanese	The prevalence of hypertension was higher in patients with hypercalcemia
3	Korean Health and Nutrition Survey III	Community health survey	2761	40.21 years	Association between blood pressure and daily intake of K^{+} and Ca^{+2} was observed	N/A	51.5% male	Korean	• No association of K^{+} was found with both SBP and DBP • Ca^{+2} was inversely associated with both SBP and DBP
4	Miles D. Witham et al.	Randomized control trial	68	63 ± 11	Either 100,000 IU vitamin D_3 or placebo every 02 months for 06 months	06 months	65% male	100% White	No reduction in blood pressure was observed after 06 months vitamin D_3 therapy
5	Robert Scragg et al.	Randomized control trial	322	48 ± 9.7	(a) 200,000 IU Vitamin D_3 for 02 months followed by 100,000 IU vitamin D_3 for 18 months. vs placebo	18 months	25% male	92% White	− 0.6 mmHg SBP − 05 mmHg DBP
6	John P. Forman et al.	Randomized control trial	283	51 ± 08	(a) 1000 IU vitamin D3/day (b) 2000 IU vitamin D3/day (c) 4000 IU vitamin D3/day (d) Placebo	03 months	35% male	100% Black	(a) − 0.66 mmHg SBP (b) − 3.44 mmHg SBP (c) − 4.0 mmHg SBP (d) + 1.7 mmHg SBP No reduction of DBP was observed for any group
7	Louise A. Beveridge et al.	Meta-analysis of 46 randomized control trials	4541	Not reported	Active or inactive forms of vitamin D or vitamin D analogues vs placebo	04 weeks to 02 years	Not reported	4327 White 214 Black	No effect of Vitamin D was observed on either SBP or DBP

Abbreviations: *BP*, blood pressure; *SBP*, systolic blood pressure; *DBP*, diastolic blood pressure

Table 4 Effect of minimizing alcohol intake on blood pressure

Sr. #	Investigator	Study design	Population (n)	Mean age	Intervention details	Alcohol consumption detail	Duration	Gender ratio	Racial profile	Overall change in BP (mmHg)
1	Xui Xin Jiang He et al.	Meta-analysis of 15 randomized controlled trials	2234	43 ± 8.5	Meta-analysis to evaluate the effect of minimizing alcohol intake on systolic and diastolic blood pressure	Overall 66% reduction	01 to 104 weeks	97% male	Not reported	− 3.31 mmHg SBP − 2.04 mmHg DBP
2	Tetsuya Ohira et al.	Randomized controlled trials	539	50 ± 7.8	(a) Light drinkers vs non-drinkers (b) Moderate drinkers vs non-drinkers (c) Heavy drinkers vs non-drinkers	(a) ≤ 22 g/day (b) 23-45 g/day (c) ≥ 46 g/day	24 h	100% male	Japanese	(a) + 2.1 mmHg SBP + 1.7 mmHg DBP (b) + 3.0 mmHg SBP + 2.9 mmHg DBP (c) + 2.3 mmHg SBP + 2.0 mmHg DBP
3	Jerom L. Abramson et al.	An observational study	157	43. ± 7.8	On normotensive individuals (a) 0 drinks per week (b) 1–2 drinks per week (c) ≥ 3 drinks per week	N/A	24 h	34% male	61% White 27% Black 12% others	24 h average BP (a) 112.2 mmHg SBP 71.3 mmHg DBP (b) 115.2 mmHg SBP 72.6 mmHg DBP (c) 116.6 mmHg SBP 74.6 mmHg DBP
4	Michael Roerecke et al.	Meta-analysis of 36 clinical trials	2865	49.5 ± 10	Meta-analysis to evaluate the effect of reducing alcohol intake from 06 to 03 drinks/day on both systolic and diastolic blood pressure	Overall 50% Reduction	01 week to 02 years	86% male	Not reported	− 5.50 mmHg SBP − 3.97 mmHg DBP
5	Peter D. Arkwright et al.	Randomized controlled trial	491	31 ± 6.7	(a) ≥ 350 ml/week vs non-drinkers (b) 161–350 ml/week vs non-drinkers (c) 1–160 ml/week vs non-drinkers	N/A	05 months	100% male	82% White 06% Black 12%	(a) + 5.8 mmHg SBP + 2.9 mmHg DBP (b) + 4.5 mmHg SBP + 2.2 mmHg DBP (c) + 3.7 mmHg SBP + 5.2 mmHg DBP

Abbreviations: *BP*, blood pressure; *SBP*, systolic blood pressure; *DBP*, diastolic blood pressure

120 min/week exercise resulted in 2.82/2.19 mmHg reduction in both systolic and diastolic blood pressure. This hypotensive effect was found equal in normal BMI and BP group as well as high BMI and BP group [56]. Meta-analysis of 28 randomized controlled trials involving 1012 individuals divided in 33 subgroups revealed that dynamic resistance training exercise resulted in reduction of both systolic and diastolic blood pressure by 2.6/3.11 mmHg respectively as compared to a non-training control group; similarly, isometric handgrip training resulted in 11.8/5.8 mmHg reduction in both systolic and diastolic blood pressure as compared to the non-training control group [57]. Meta-analysis of 23 clinical trials involving 22 hypertensive and 12 normotensive groups revealed that dynamic exercise in hypertensive group resulted in 3.6/1.8 mmHg additional reduction in both systolic and diastolic blood pressure as compared to normotensive group [58]. Another meta-analysis of 11 exercise trials on 320 normotensive and hypertensive individuals using exercise as the only intervention for the duration of 04 weeks reported the systolic blood pressure reduction of 3.0 mmHg and diastolic blood pressure reduction of 3.0 mmHg [59]. A recently conducted research study reported that aerobic exercise induced 20% increase in NO release from vascular endothelial cell and 10% decrease in blood pressure [60]. Since acute exercise results in an increase blood pressure, the blood pressure of an individual should be controlled before starting the exercise (see Table 5).

7. Combined effect of weight loss and Na^+ restriction: A randomized control trial of non-pharmacological interventions in the elderly (TONE) was conducted to find out the combined effect of Na^+ restriction and weight loss on the blood pressure. In this trial, 975 participants were divided into one of four subgroups, dietary sodium restriction alone ($n = 340$), weight loss alone ($n = 147$), combination of both ($n = 147$), and usual care group ($n = 341$). The follow-up period was 15 to 36 months. The TONE results revealed 3.4 mmHg reduction in SBP and 1.9 mmHg DBP reduction in dietary Na^+ restriction alone group, 4.0 mmHg SBP, and 1.1 mmHg DBP reduction in weight loss alone group, while 5.3 mmHg reduction SBP and 3.4 mmHg DBP reduction in combine Na^+ restriction and weight loss group as compared to 0.8 mmHg SBP and 0.8 mmHg DBP reduction in the usual care group [61]. Similarly, in the second phase of TOHP-II trial, 2382 participants were also randomized in four subgroups: Na^+ restriction alone, weight loss alone, combination of both Na^+ restriction and weight loss, and usual care group. The intervention aimed at achieving daily Na^+ consumption, 80 mmol/day, and weight loss ≥ 4.5 Kg. After 6 months, average weight loss in both weight loss group and combination group was 4.1 to 4.4 Kg and weight loss in Na^+ reduction group was 1.2 Kg less than usual care group. However, after 36 months, the participants regained weight in both weight loss group and combination groups close to baseline. Similarly, the Na^+ restriction was also reduced to as low as 48 mmol/day, well short of target value, i.e., 80 mmol/day. TOHP-II results have shown 3.7 mmHg reduction in SBP and 2.7 mmHg reduction in DBP in weight loss group, 2.9 mmHg reduction in SBP, and 1.6 mmHg reduction in low Na^+ group; similarly, combination group shown 4.0 mmHg reduction in SBP and 2.8 mmHg reduction in blood pressure as compared to control group after 6 months. However, after 36 months, BP reductions were attenuated and remained statistically significant only for SBP and DBP in weight loss group and for SBP in low Na^+ group. Furthermore, the long-term maintenance of weight loss was less successful as compared to dietary Na^+ reduction [62]. US national guidelines recommend DASH diet, weight loss, and aerobic exercise for the prevention and control of hypertension. Diet Exercise Weight Intervention Trial (DEW-IT) was conducted to simultaneously assess the efficacy of DASH diet, aerobic exercise, and weight loss intervention for the treatment of hypertension. In the DEW-IT trial, 44 hypertensive obese individuals with BP of 130–170/80100 mmHg previously on single blood pressure medication were randomized into lifestyle group and control group for 9 weeks. The lifestyle group was given a hypo-caloric DASH diet that provided 100 mmol of Na^+ per day and 30–45-min moderate intensity exercise three times a week. The control group received no intervention. At the end of trial, the mean weight loss in the lifestyle group was 4.9 Kg. Similarly, the net mean BP reduction in the lifestyle group was 9.5 mmHg SBP ($p < 0.001$) and 5.3 mmHg DBP ($p < 0.002$). Corresponding changes in daytime systolic and diastolic blood pressure were 12.1 and 6.6 mmHg respectively ($p < 0.001$) [63]. The PREMIER trial also assessed the effect of diet, exercise, and weight loss simultaneously on hypertension. In the PREMIER trial, 810 stage-I hypertensive patients who were not receiving any hypertensive medication were randomized into three groups, i.e., (a) established, behavioral intervention implementing established recommendations ($n = 268$), (b) established plus DASH diet group ($n = 269$), and (c) advise only/control group. In comparison to the advice only group, the net mean reduction in SBP was 3.7 mmHg in established group and 4.3 mmHg in

Table 5 Effect of weight reduction and exercise on blood pressure

Sr. #	Investigator	Study design	Mean age	Population (n)	Intervention details	Duration	Gender ratio	Racial profile	Overall BP reduction (mmHg)
1	Seamus P. Whelton et al.	Meta-analysis of 54 randomized controlled trials	21 to 75 years	2419	(a) ≤ 120 min/week vs control (b) 121–150 min/week vs control (c) > 150 min/week vs control	03 weeks to 02 years	> 80% men in 10 trials > 80% women in 17 trials Mix ratio in remaining 24 trials	62% White 16% Asian 11% Black	(a) − 2.82 mmHg SBP − 2.19 mmHg DBP (b) − 4.67 mmHg SBP − 2.11 mmHg DBP (c) − 5.13 mmHg SBP − 2.78 mmHg DBP
2	Veronique A. Cornelissen et al.	Meta-analysis of 24 randomized controlled trials	53.6 ± 9.4	1012	(a) Dynamic resistance training [a] vs non-training control group (b) Isometric handgrip [b] vs non-training control group	06 to 52 weeks	Not reported	Not reported	(a) − 2.6 mmHg SBP − 3.1 mmHg DBP (b) − 11.8 mmHg SBP − 5.8 mmHg DBP
3	Linda S. Pescatello et al.	Meta-analysis of 23 clinical trials	43.9 ± 1.5	34 groups (22 hypertensive + 12 normotensive)	Dynamic exercise by hypertensive vs dynamic exercise by normotensive 39.3 ± 2.0 min per session	18.4 ± 3.4 weeks	Not reported	Predominantly Non-Hispanic White	− 3.6 mmHg SBP − 1.8 mmHg DBP
4	Kelley et al.	Meta-analysis of 12 randomized controlled trials	47.2 ± 20.9	320	Exercise group vs control group 38.0 ± 14.0 min per session	06 to 30 weeks	50 ± 42% male	Predominantly White	− 3.0 mmHg SBP − 3.0 mmHg DBP

Abbreviations: *BP*, blood pressure; *SBP*, systolic blood pressure; *DBP*, diastolic blood pressure

[a] Dynamic resistance training involves concentric and/or eccentric contraction of muscles while both the length and tension of muscles change

[b] Isometric handgrip training involved 4 × 2-min bilateral or unilateral contractions with rest period of 3, respectively, 1 min between contractions

Table 6 Combined effect of weight loss and Na^+ restriction on blood pressure

Sr. #	Investigator	Study design	Population (*n*)	Mean age	Intervention details	Duration	Gender ratio	Racial profile	Overall BP reduction (mmHg)
1	Paul K. Whelton et al.	TONE Trial	975	66.3 ± 4.5	(a) Na^+ reduction alone group (b) Weight loss alone group (c) Combined Na^+ reduction and weight loss group (d) Usual care group	03 years	52% male	75% White 25% Black	(a) − 3.4 mmHg SBP − 1.9 mmHg DBP (b) − 4.0 mmHg SBP − 1.1 mmHg DBP (c) − 5.3 mmHg SBP − 3.4 mmHg DBP (d) − 0.8 mmHg SBP − 0.8 mmHg DBP
2	Paul K. Whelton et al.	TOHP-I Trial	2182	43 ± 6.5	(a) Weight loss group vs control group (b) Na^+ restriction group vs control group	18 months	70% male	82% White 18% Black	(a) − 2.9 mmHg SBP − 2.4 mmHg DBP (b) − 2.1 mmHg SBP − 1.2 mmHg DBP
3	Paul K. Whelton et al.	TOHP-II Trial	2382	43 ± 6.1	(a) Weight loss group vs control group (b) Na^+ restriction group (c) Combination of both vs control group	36 months	66% male	79% White 21% Black	(a) − 3.7 mmHg SBP − 2.7 mmHg DBP (b) − 2.9 mmHg SBP − 1.6 mmHg DBP (c) − 4.0 mmHg SBP − 2.8 mmHg DBP
4	Edgar R. Miller et al.	DEW-IT Trial	44	54 ± 9	(a) Lifestyle group (b) Control group	09 weeks	38% male	38% White 62% Black	(a) − 9.5 mmHg SBP − 5.3 mmHg DBP (b) − 1.1 mmHg SBP − 0.6 mmHg DBP
5	Lawrence J. Appel et al.	PREMIER Trial	810	50 ± 8.9	(a) Behavioral interventions only group (b) Behavioral interventions + DASH diet group (c) Advice only or control group	06 months	38% male	66% White 34% Black	(a) − 3.7 mmHg SBP − 1.7 mmHg DBP (b) − 4.3 mmHg SBP − 2.6 mmHg DBP (c) − 0.6 mmHg SBP − 0.9 mmHg DBP

Abbreviations: *BP*, blood pressure; *SBP*, systolic blood pressure; *DBP*, diastolic blood pressure; *TONE*, Trial of Non-Pharmacological Interventions in Elderly; *TOHP-I*, Trial of Hypertension Prevention Phase-I; *TOHP-II*, Trial of Hypertension Prevention Phase-II; *DEW-IT*, Diet, Exercise, and Weight Loss Intervention Trial established plus DASH diet group. Similarly, the net mean reduction in DBP was 1.7 mmHg for the established group and 2.6 mmHg for the established plus DASH diet group. The addition of DASH diet in established behavioral intervention only provided an incremental 1.7 mmHg SBP and1.6 mmHg DBP reduction. In comparison to the baseline hypertension prevalence of 38%, the prevalence of hypertension was 17% in the established group, 12% in the established plus DASH diet group, and 26% in advice only group. Similarly, 30% participants in the established group, 35% in the established plus DASH diet group, and 19% in the advice only group had optimal blood pressure, i.e., < 120 mmHg SBP and < 80 mmHg DBP [64] (see Table 6).

8. Reduced physiological stress and anxiety: Transient elevation in blood pressure occurs in response to physiological stress and anxiety. The episodes of stress and anxiety may lead to persistently elevated blood pressure [65]. According to a research study, individuals who were lonely in either childhood or early adulthood had more chances to develop hypertension in later part of life [66]. US nurses' health study reported that victims of childhood abuse were associated with hypertension [67]. There are numerous studies that link depression with cardiovascular diseases. Stressful events like sorrow, disappointment, disasters, and fear are positively associated with hypertension [68–70]. Stress and anxiety lead to enhanced sympathetic activity through the release of epinephrine into the blood, resulting in elevated blood pressure. Secondly, stress results in an increase in cortisol release in the body leading to hypertension [71]. On contrary, there are some studies that do not see any significant relationship between anxiety and hypertension. A study that conducted on 58 outpatients in neurology department did not correlate hypertension with depression and anxiety [72]. All these studies suggest that anxiety and depression are directly associated with hypertension and alleviation of depression and anxiety is necessary for the proper management of hypertension.

Conclusion

Proper management of hypertension requires both pharmacological and non-pharmacological interventions. Both pharmacological and non-pharmacological approaches have additive effect in proper management of hypertension. According to American Society of Hypertension guidelines, 6–12-month lifestyle modifications can be attempted in stage-1 hypertensive patients without any cardiovascular disease, in the hope that they may be sufficiently effective to make it unnecessary to use medicines [73]. Non-pharmacological interventions for hypertension mostly include lifestyle modifications. Recent studies reported the positive effects of lifestyle modifications on hypertension management. These lifestyle modifications include dietary modifications, Na^+ restriction, increase consumption of K^+, weight control, daily exercise, minimizing alcohol consumption, and living a stress-free life. The dietary modifications include increased consumption of fruits, vegetables, and grains along with increased intake of monounsaturated fatty acids and polyunsaturated fatty acids, decreased consumption of high Na^+ content diet, and minimizing alcohol intake. Nutritional requirements of hypertensive individuals can be addressed through adopting either the DASH diet or through traditional Mediterranean diet. Both these diets have proven effectiveness in management of hypertension. High Na^+ intake is another problem that needs to be addressed. In processed food, the additional Na^+ is added as a preservative. It has been observed in a number of studies that the greatest BP lowering effect was observed when Na^+ intake was reduced. A research study reported that processed food contributes to 77% of total Na^+ intake while cooking and table salt contributes 11.3% of total Na^+ intake and maximum BP lowering effect was observed when Na^+ was reduced to less than 50 mmol/day [74]. Similarly, increase in dietary K^+ and phosphorus intake is necessary for the management of hypertension. The DASH diet and traditional Mediterranean diet provide a higher amount of these beneficial ions. Weight control and exercise is the second most effective method for the management of hypertension. A daily brisk walk for at least 40 min can help reduce the blood pressure. Minimizing the alcohol consumption and stress management is also necessary for the management of hypertension.

Non-pharmacological interventions are extremely important in pre hypertensive stage as they retard the progression from prehypertension stage to hypertension stage. Lifestyle modification is a dynamic process and requires continuous adherence to the guidelines rather than a short-term approach. Hence, it requires continuous motivation and education. It is a multi-factorial approach targeting at more than one intervention. Nobody can achieve the effective blood pressure control by just assuming a single intervention but by the adoption of set of interventions simultaneously.

Limitations and future perspective

Although this review contains all major non-pharmacological interventions for hypertension management, however for future reviews, minor interventions for hypertension management like increased intake of omega-3, garlic, onion, cocoa flavanol-rich food, decreased caffeine intake, and smoking cessation should also be considered. At present, limited literature and smaller clinical trials are available on these interventions, requiring further research to prove their effectiveness in hypertension management.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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