Discover Food

Review

Effects of dietary approaches to prevent hypertension and enhance cardiovascular health

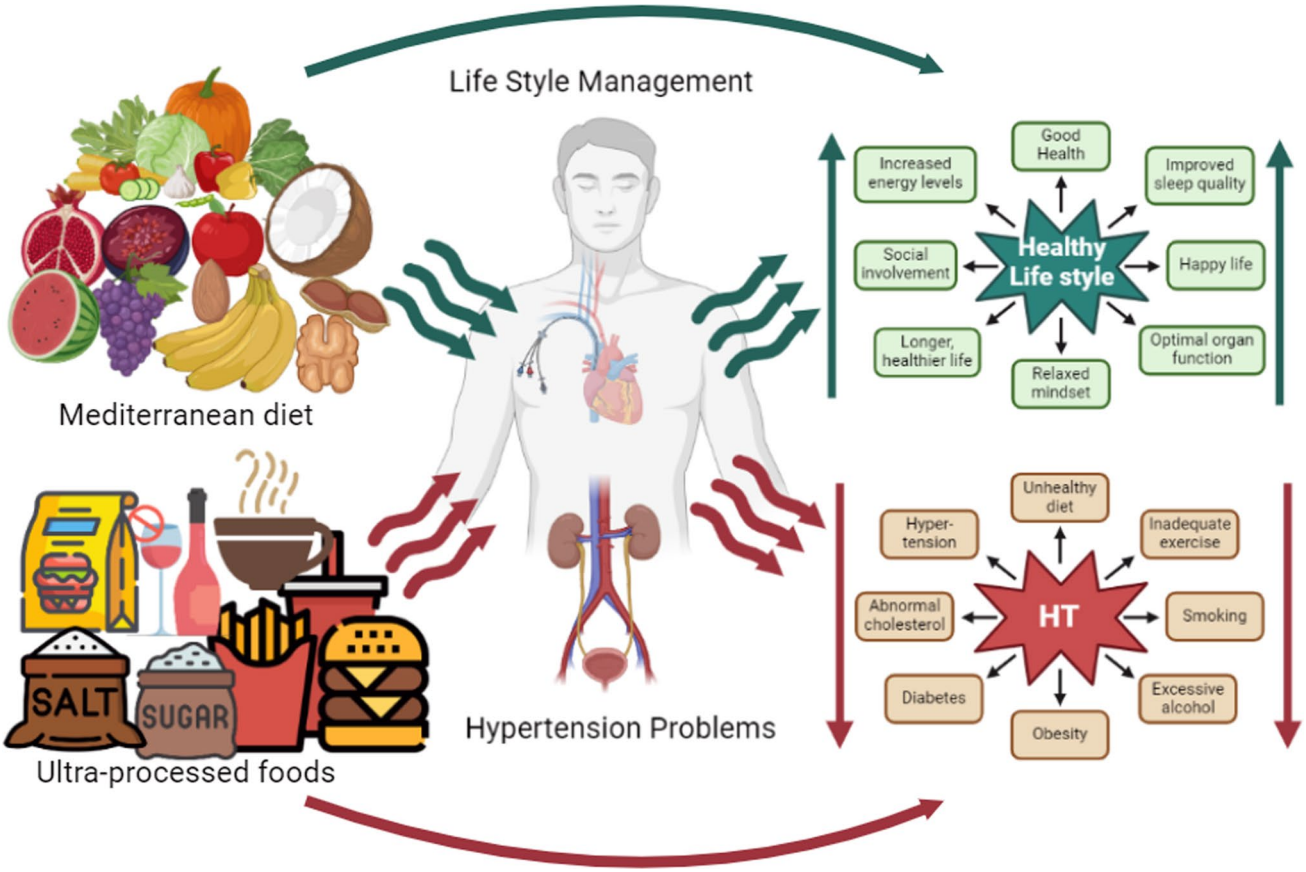
Arumugam Vignesh[1] · Thomas Cheeran Amal[2] · Aravindan Shanmugam[2,3] · Krishnan Vasanth[4] · Subramaniam Selvakumar[5]

Received: 4 September 2024 / Accepted: 7 January 2025
Published online: 11 January 2025

Abstract
Hypertension (HT) significantly impacts cardiovascular health (CVH) by exerting chronic stress on arteries and the heart, leading to severe health complications. This review explores the intricate relationship between dietary choices and high blood pressure (BP). Dietary choices are crucial in both the development and management of high BP. Excessive sodium intake is a well-documented risk factor for HT, and strategies to reduce salt consumption can mitigate its adverse effects. Processed and packaged foods also pose severe risks due to hidden sodium and other unhealthy ingredients, making healthier alternatives essential. Potassium plays a vital role in managing BP, with potassium-rich foods supporting a balanced diet. Saturated and trans fats contribute to elevated BP, and healthier fat alternatives are recommended. Excessive sugar consumption negatively affects BP, with hidden sugars in popular foods requiring practical strategies for reduction. Alcohol and caffeine also influence BP, and moderate consumption is advised to avoid potential risks. The Mediterranean diet offers a holistic, evidence-based approach to enhancing CVH, with practical advice and meal plans for a flavourful and health-promoting dietary regimen.

✉ Arumugam Vignesh, arumugamvignesh@ngmc.org; Thomas Cheeran Amal, amaltc.tc@gmail.com; Aravindan Shanmugam, ashanmugam1996@gmail.com; Krishnan Vasanth, vasanthlabbu@gmail.com; Subramaniam Selvakumar, selvs20@yahoo.com | [1]Department of Botany, Nallamuthu Gounder Mahalingam College (Autonomous), Tamil Nadu, Pollachi 642 001, India. [2]ICAR - Central Institute for Cotton Research, RS, Tamil Nadu, Coimbatore 641 003, India. [3]Advanced Plant Technology, Clemson University, Clemson, SC 29634, USA. [4]Department of Botany, Bharathiar University, Tamil Nadu, Coimbatore 641 046, India. [5]Department of Biochemistry, Bharathiar University, Tamil Nadu, Coimbatore 641 046, India.

Graphical abstract



Highlights

- Dietary choices critically impact blood pressure (BP) management and prevention.
- Excess sodium and unhealthy fats are linked to elevated BP and cardiovascular disease.
- Potassium-rich foods and healthy fats support BP regulation.
- Moderate alcohol intake may benefit cardiovascular health.
- • Mediterranean diet effectively lowers BP and cardiovascular risk.

Keywords Functional food · Blood pressure · Gut health · Cardiovascular health · Hypertension

Abbreviations

AHA	American Heart Association
AT	Angiotensin
ATP	Adenosine Triphosphate
BMI	Body Mass Index
BP	Blood Pressure
CTSs	Cardiotonic Steroids
CV	Cardiovascular
CVD	Cardiovascular Diseases
CVH	Cardiovascular Health
HDL	High Density Lipoprotein

HFCS	High Fructose Corn Syrup
HT	Hypertension
K^+	Potassium
LDL	Low Density Lipoprotein
MBG	Marinobufagenin
mg	Milligrams
Na^+	Sodium
$Na\ Cl_2$	Sodium Chloride
$Na\ NO_3$	Sodium Nitrate
RAAS	Renin-Angiotensin-Aldosterone System
ROS	Secondary Metabolism
SNS	Sympathetic Nervous System
WHO	World Health Organization

1 Introduction

High blood pressure (BP) or persistent hypertension (HT) is defined by a systolic/diastolic BP exceeding 140/90 mm Hg, with slight variations based on factors such as age, sex, race, and other medical conditions [1]. Affecting millions worldwide, hypertension often remains unnoticed until its severe consequences, such as heart attack and stroke, become apparent [2]. The World Health Organization (WHO) reports that approximately 50% of the global adult population is affected by HT, with projections suggesting an increase to 60% by 2025 [3]. This rise is driven by rapid urbanization, lifestyle changes, and low awareness of hypertension's risks, impacting both developing and developed nations [4]. HT is primarily categorized into primary or essential HT (90–95%), where the cause is unknown but is influenced by factors such as diet, lack of exercise, and family history. Secondary HT (5–10%) results from specific conditions, including thyroid disorders or kidney issues [5]. Alarmingly, 40–50% of individuals with HT are unaware of their condition, posing significant risks. Despite often being asymptomatic, HT damages blood vessels and the heart, leading to complications such as heart disease, strokes, and kidney problems. Early detection and management are crucial to prevent these severe outcomes [6].

Managing HT traditionally involves a multifaceted approach, combining pharmaceutical interventions with lifestyle modifications [7]. Within this framework, dietary choices play a pivotal, yet often underestimated, role in regulating BP. The foods consumed daily significantly impact overall health, and BP control, highlighting the importance of understanding this relationship [8]. Beyond the conventional advice to reduce salt intake, various dietary components may subtly contribute to elevated BP levels. A comprehensive examination of the interplay between HT and diet is essential to understanding the complex network of influences on BP regulation [9]. This investigation underscores the need for a nuanced perspective on dietary components and their implications for public health. While pharmaceutical interventions are crucial, the impact of dietary habits on managing and preventing HT should not be overlooked [3]. Effective preventive and therapeutic strategies require a balanced approach that integrates both medical treatments and lifestyle modifications.

Cardiovascular disease (CVD) is an umbrella term that encompasses diseases affecting the heart and blood vessels. There are several potential risk factors that lead to the development of CVD, including high blood pressure, atherosclerosis, and type 2 diabetes mellitus (T2DM) [10]. Considering these health and economic burdens, diet-related illnesses are among the leading priorities of our time. There is evidence that nearly one-third of individuals with T2DM have established CVD, and a similar proportion have atherosclerotic cardiovascular disease (ASCVD) [11]. In 2010, after decades of declining cardiovascular disease (CVD) death rates, the American Heart Association (AHA) expanded its focus from treating existing CVD to promoting overall health at both individual and population levels. Central to this shift was a new definition of cardiovascular health (CVH), initially outlined by "Life's Simple 7" seven health metrics: dietary quality, physical activity, smoking status, body mass index, fasting blood glucose, cholesterol levels, and blood pressure. Each metric was classified as poor, intermediate, or ideal, with ideal CVH defined by all metrics at optimal levels. Extensive research since 2010 has highlighted strengths and limitations in this approach, prompting the AHA to update its CVH metrics. This advisory introduces "Life's Essential 8," an enhanced framework including updated measures of diet, physical activity, nicotine exposure, blood lipids, and blood glucose, as well as new metrics for sleep health [12].

This review explores the intricate relationship between dietary choices and high blood pressure (BP), aiming to provide valuable insights into how specific dietary components can influence CVH. While the impact of excessive salt intake on

HT is well documented [13–15], there is growing interest in understanding how other dietary factors contribute to BP regulation. Dietary elements such as potassium, magnesium, and calcium play significant roles in managing BP [16]. For instance, potassium helps counteract the effects of sodium, potentially lowering BP when consumed in sufficient amounts through foods like bananas and leafy greens. Research also indicates that magnesium and calcium contribute to lower BP levels, with studies suggesting that their intake can reduce HT risk [17]. Additionally, bioactive compounds found in fruits and vegetables, such as flavonoids, have been associated with beneficial effects on BP [18]. This review delves into the roles of various macronutrients, micronutrients, and bioactive compounds in BP regulation, and examines how dietary patterns, such as the Mediterranean diet, which includes a variety of fruits, vegetables, whole grains, and healthy fats, can support BP management [19]. Connecting broad dietary patterns with specific nutrients, this review aims to enhance our understanding of how food choices impact BP, thus informing more effective strategies for HT prevention and management. Ultimately, this review seeks to shift the focus from solely pharmaceutical interventions to a more comprehensive approach that incorporates dietary modifications. The goal is to empower individuals with knowledge to make proactive dietary choices and to influence public health policies towards more holistic strategies for managing high BP.

2 Methodology

Electronic databases viz. Google Scholar, the Willey online library, Scopus, Science Direct, ACS publications, PubMed, Springer Link, Nature Communication, and PLoS One were explored extensively using keywords including "Nutraceutical", "functional food", "food supplement", "hypertension", "mediterranean diet", "alcohol", "caffeine", "renin angiotensin aldosterone system", "sodium chloride", "ultra processed foods", "human Gut", "potassium", "body mass index", "blood pressure", "cardiovascular diseases", "high density lipoprotein", "cardiovascular health", "low density lipoprotein" and "metabolic pathway". Eventually, 150 relevant literature published before October, 2024 were collected, curated, and critically evaluated to extract necessary information.

3 Mechanisms and implications of high blood pressure

Understanding the mechanisms underlying BP is crucial before examining the role of dietary factors. HT is characterized by elevated pressure in the arteries, the blood vessels responsible for transporting blood from the heart to the rest of the body [20]. This condition arises when the force of blood against arterial walls remains consistently high, placing undue strain on both the arteries and the heart and potentially leading to a range of health issues [21]. To visualize, think of arteries as highways that deliver blood throughout the body. When pressure within these arteries is elevated, it is akin to a constant surge of traffic, which causes wear and tear on the arterial walls [22]. Over time, this persistent strain can damage the arteries, reducing their flexibility and increasing the risk of atherosclerosis characterized by the hardening and narrowing of the arteries [23]. The heart, acting as the central pump, must work harder to push blood against this elevated pressure and this increased workload can lead to thickening of the heart muscle and various heart related issues [24]. Consequently, the combined impact on the arteries and the heart significantly raises the risk of severe health events, such as heart attacks and strokes [25].

Lifestyle factors, including diet, play a pivotal role in both the development and management of HT. While genetics and age contribute to BP levels, dietary choices are modifiable factors that can significantly influence BP [26]. For example, a diet high in sodium can lead to fluid retention, increasing blood volume and pressure on the arterial walls [15]. Conversely, a diet rich in potassium, found in fruits and vegetables, can help balance sodium levels and support healthy BP. Mechanisms behind high BP are multifaceted, involving several physiological processes. The diameter of the arteries is regulated by the contraction and relaxation of smooth muscle in their walls. Contraction leads to vasoconstriction, decreasing arterial diameter and increasing resistance to blood flow. This heightened resistance requires the heart to pump with greater force to maintain circulation, resulting in elevated BP [27]. Fluid balance also plays a significant role in BP regulation. Excess sodium in the bloodstream can cause fluid retention, increasing blood volume and subsequently, the pressure on arterial walls [15]. Cardiac output, which is the product of heart rate and stroke volume (the amount of blood pumped per heartbeat), influences BP as well. An increased heart rate or stroke volume elevates cardiac output, thereby raising BP [28]. The endothelium, the inner lining of blood vessels, produces nitric oxide, which helps relax and dilate blood vessels. Endothelial dysfunction, often associated with conditions like

obesity and diabetes, reduces nitric oxide production, leading to increased arterial stiffness and higher BP [29]. Stress and other stimuli can activate the sympathetic nervous system, resulting in the release of adrenaline. This response increases heart rate, constricts blood vessels, and raises BP as part of the body's "fight-or-flight" mechanism [30]. Genetic factors also play a role in BP regulation. Certain gene variants may influence how the body manages sodium, responds to stress, or regulates blood vessel diameter, thus contributing to HT [31].

The renin–angiotensin–aldosterone system (RAAS) is another critical hormonal system in BP regulation (Fig. 1). A decrease in blood flow to the kidneys triggers the release of renin, which sets off a chain of events leading to the production of angiotensin II (AT-II). This hormone causes blood vessels to constrict and stimulates the retention of sodium and water, both of which raise BP. Prolonged excessive activation of angiotensin II, as part of the RAAS, results in sustained high BP by continuously constricting blood vessels, increasing resistance in peripheral blood vessels, and promoting sodium and water retention, all of which contribute to further increases in BP. Chronic alterations in the RAAS, particularly involving angiotensin II and aldosterone, have been directly linked to HT [32, 33]. These alterations disrupt normal blood pressure regulation, demonstrating the complex interplay between these hormones and Table 1 showed the categorisation of the stages of HT. Effective management of HT involves not only understanding these underlying mechanisms but also implementing lifestyle changes, such as a balanced diet, regular physical activity, and stress management. Pharmacological interventions may also be necessary, tailored to address the specific mechanisms contributing to an individual's HT. By targeting these mechanisms, healthcare professionals can develop more effective strategies for controlling BP and reducing the risk of related complications.

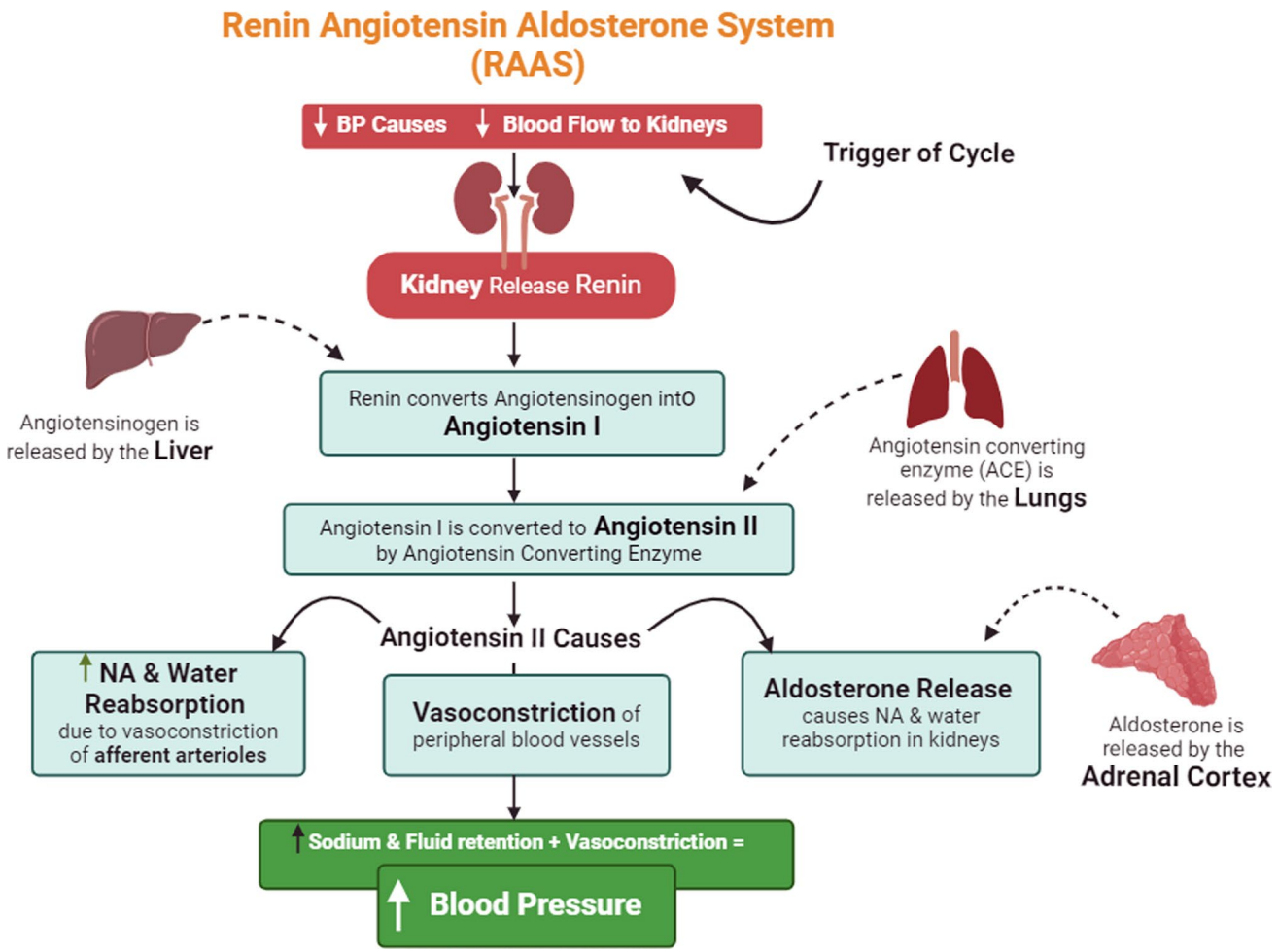


Fig. 1 Depicts the Renin–Angiotensin–Aldosterone System mechanism during the hypotensive condition

Table 1 Categorisation of the stages of hypertension

Classification	Systolic BP (mm Hg)	Diastolic BP (mm Hg)	Management	Reference
Normal	Less than 120	Less than 85	–	[25, 26, 34]
Elevated	120–129	Less than 80	Lifestyle-Diet Modification	
Stage-I HT	130–139	80–89	Lifestyle and diet measures BP lowering drug/s CVD risk factor assessment and management	
Stage-II HT	140 or higher	90 or higher		
HT Crisis	Higher than 180	Higher than 120	Consult doctor immediately	

4 The sodium conundrum: navigating the impact of salt on blood pressure (BP)

Excessive sodium intake, a primary dietary factor contributing to high blood pressure (BP), poses a significant CVH risk. Sodium, an essential component of salt, is ubiquitous in processed and restaurant foods, often leading individuals to consume amounts that exceed recommended limits [15]. Understanding the intricate relationship between sodium and HT is crucial for promoting CVH. High sodium intake stimulates the brain to release endogenous cardiotonic steroids (CTSs), such as ouabain and marinobufagenin (MBG), through the sympathetic nervous system [35]. These CTSs can inhibit the Na^+/K^+ pump and alter the RAAS, leading to increased sodium retention by suppressing natriuresis [36]. MBG, in particular, acts as a vasoconstrictor, increasing vascular resistance and contributing to elevated BP and vascular damage. Moreover, an overactive RAAS, influenced by the WNK signalling pathway, impairs renal sodium excretion, increasing blood volume and BP [7]. This process leads to the production of reactive oxygen species (ROS), causing renal and vascular damage, and triggering inflammatory responses through T cells and macrophages, which produce pro-inflammatory cytokines [37]. The combined effects of increased inflammation and blood volume elevate vascular resistance, resulting in high BP and HT (Fig. 2).

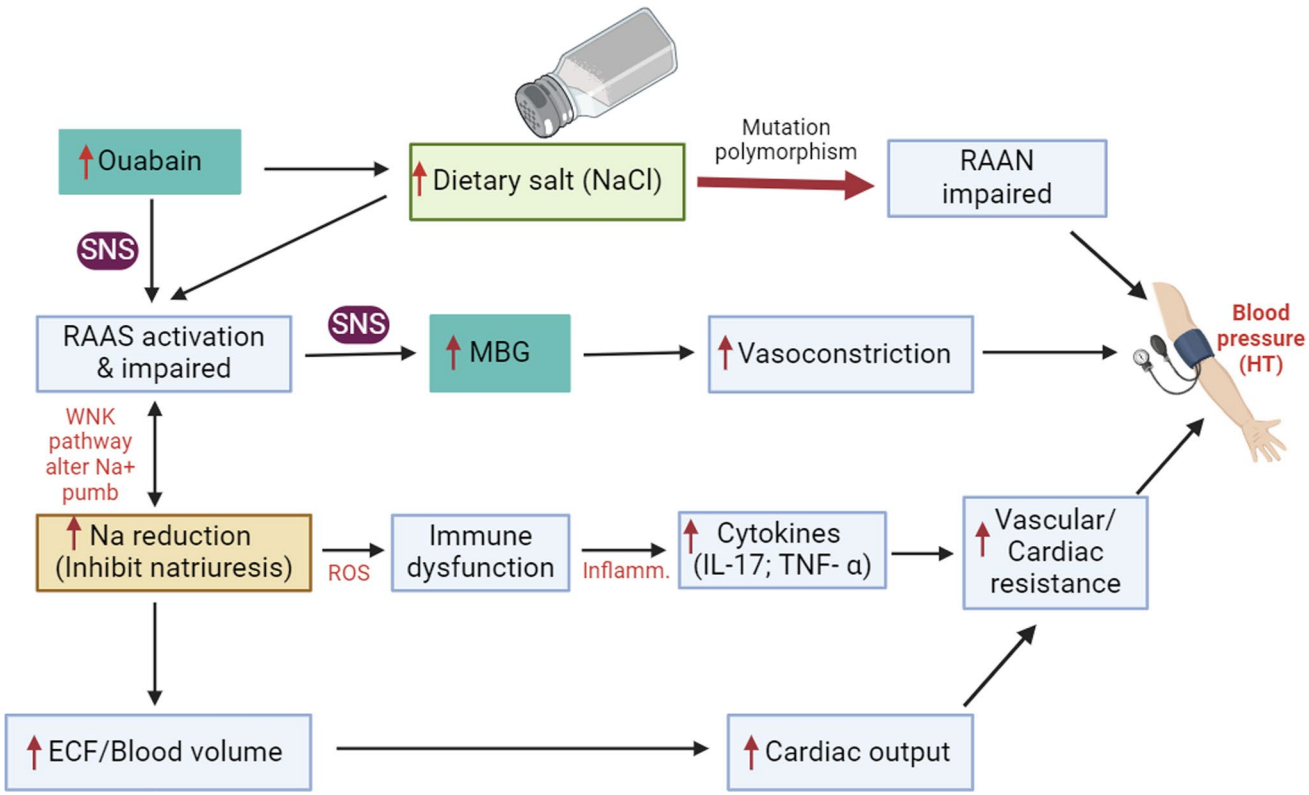


Fig. 2 A brief mechanism of dietary salt-induced hypertension. CTS: Cardiotonic Steroids; MBG: Marinobufagenin

Sodium plays a critical role in fluid balance, nerve function, and muscle contractions, but excessive intake disrupts this balance and results in elevated BP [38]. The most common source of sodium is table salt; however, processed and restaurant foods significantly contribute to high sodium intake. Canned soups, frozen meals, snacks, and condiments often contain hidden sodium, complicating efforts to manage intake [39]. The WHO and the American Heart Association (AHA) recommend limiting daily sodium intake to less than 2300 mg (mg), approximately one teaspoon of salt (Felder et al. 2022). For individuals with HT, older adults, and those with certain chronic conditions, the recommended limit is even lower, at 1500 mg/day [40]. To mitigate the impact of sodium on BP, proactive measures are essential. Start by reading food labels carefully to understand sodium content and make informed choices [41]. Opting for fresh, whole foods and preparing meals at home allows for better control over sodium intake and reduces reliance on processed foods [14]. Experiment with alternative seasonings such as fresh herbs, spices, citrus, and vinegar to enhance flavour without adding extra salt [42]. Many products also offer low-sodium or sodium-free versions. Addressing the sodium conundrum is vital for managing and preventing HT. By becoming aware of sodium's effects, adhering to recommended intake limits, and adopting strategies to reduce consumption, individuals can significantly enhance their CVH and mitigate the risk of HT related complications.

5 Risks of processed and packaged foods

In the modern era, dietary habits have undergone a significant transformation, with a marked increase in the consumption of processed and packaged foods. Although these options are convenient and flavorful, they often contain excessive amounts of sodium, posing a significant risk to CVH [43]. Sodium is commonly used in these foods as a preservative and flavor enhancer, making it a hidden threat that can substantially elevate BP [44]. The true danger lies in the often-overlooked sodium content in packaged foods. While the salt shaker is an obvious source of sodium, the hidden sodium in processed items contributes significantly to health risks [45]. These foods, marketed for their convenience and taste, can undermine CVH, to make informed dietary choices, it's crucial to scrutinize food labels. The "Nutrition Facts" panel provides essential information about sodium content per serving, and understanding terms like sodium chloride (NaCl), monosodium glutamate (MSG), and sodium nitrate ($NaNO_3$) can help identify hidden sources of sodium [43]. To mitigate these risks, adopting alternative options and healthier choices is essential. Shifting towards fresh produce, whole grains, and minimally processed foods can help reduce sodium intake and support better CVH. Making these dietary adjustments, individuals can significantly improve their health and manage their sodium consumption effectively.

Incorporating fresh fruits and vegetables into the diet offers essential nutrients without the added burden of excessive sodium [15]. These natural, unprocessed foods not only contribute to overall health but also support cardiovascular well-being. Opting for whole grains like quinoa, brown rice, and whole wheat bread over processed counterparts ensures higher nutritional value and lower sodium content [46]. Rich in fiber, vitamins, and minerals, these grains are a healthier choice and choosing lean protein sources such as poultry, fish, tofu, and legumes helps avoid the high sodium levels often found in processed meats and pre-packaged protein products [47]. Cooking meals at home allows for better control over ingredients and seasoning, reducing reliance on sodium-heavy processed foods [48]. Making soups, sauces, and condiments from scratch, individuals can significantly lower their salt intake. While the convenience of processed foods is appealing, the long-term benefits of choosing whole, minimally processed options far outweigh their temporary allure. Given the prevalence of sodium in modern diets, a critical examination of food labels is essential for making informed dietary choices. Embracing alternative options and healthier choices can help break free from the sodium dilemma associated with processed foods, fostering a dietary environment that promotes optimal CVH and overall well-being.

Ultra-processed foods (UPF) are heterogeneous group of products that typically contain a combination of ingredients not commonly found in home cooking. These foods often contain excessive calories, added sugars, sodium, and unhealthy fats, all of which are linked to an increased risk of CVD [48]. In the United States, UPF account for 57.0% of the energy intake of the adult population, which may contribute to the development of CVD [49]. The biological pathways through which ultra-processed foods affect CVH involve myriad of mechanisms. The interactions among numerous compounds and characteristics of these foods that are not yet fully understood. For example, UPF can cause different alterations in glucose metabolism, which may activate specific inflammatory pathways that contribute to CVD [50]. The immune factors present in UPF may engage in bidirectional interactions with gut microbiota, Additionally, many cardiovascular risk factors contribute to the onset of endothelial dysfunction and injury, creating a prothrombotic and proinflammatory molecular environment. These factors, along with a complex network of molecular feedback loops, lead to the escalation and persistence of atherogenesis, ultimately resulting in various cardiovascular events [51]. Understanding these

mechanisms highlights the importance of dietary choices and the potential health risks associated with ultra-processed foods. Focusing on whole, minimally processed foods, individuals can better support their cardiovascular health.

6 Hidden impact of sugar on blood pressure

In the realm of dietary discussions surrounding HT, sodium often takes center stage as a well-known adversary. However, the significant yet often overlooked role of sugar in BP regulation deserves equal attention [52]. This review explores the complex relationship between excessive sugar consumption and HT, revealing the hidden sugars present in common foods and beverages [53]. It also provides practical tips for reducing sugar intake without sacrificing taste, offering valuable insights for those aiming to maintain optimal CVH. While sugar intake is commonly linked to weight gain and conditions like diabetes, its direct connection to HT is frequently underestimated [54].

Sucrose, commonly known as table sugar, is a disaccharide composed of glucose and fructose. Although it is widely used in processed foods, its role is less prominent compared to high-fructose corn syrup (HFCS) [55]. Unlike sucrose, which has equal parts glucose and fructose, HFCS contains a higher percentage of fructose (about 55%) compared to glucose (45%), making it the predominant sweetener in processed foods and beverages such as fruit drinks and sodas [56]. Consumption of sucrose and HFCS triggers the sympathetic nervous system (SNS), leading to increased heart rate, renin secretion, renal sodium retention, and vascular resistance-factors that collectively contribute to elevated blood pressure [57]. Additionally, fructose intake induces insulin resistance, which is a broader metabolic dysfunction linked to HT. Sugar and HFCS impact BP through mechanisms such as hyperleptinemia, increased methylglyoxal levels, and reduced ATP levels [58]. Figure 3 outlines how fructose, present in both sucrose and HFCS, may contribute to HT. High fructose intake specifically impacts insulin sensitivity in adipose tissue, leading to hyperinsulinemia a condition more closely associated with fructose than glucose [59]. Elevated insulin levels stimulate the SNS, further exacerbating BP issues. Moreover, fructose-induced metabolic changes can lead to inflammatory processes that reduce blood vessel flexibility and increase resistance to blood flow [60]. The hidden sugars in our diets often come from less obvious sources,

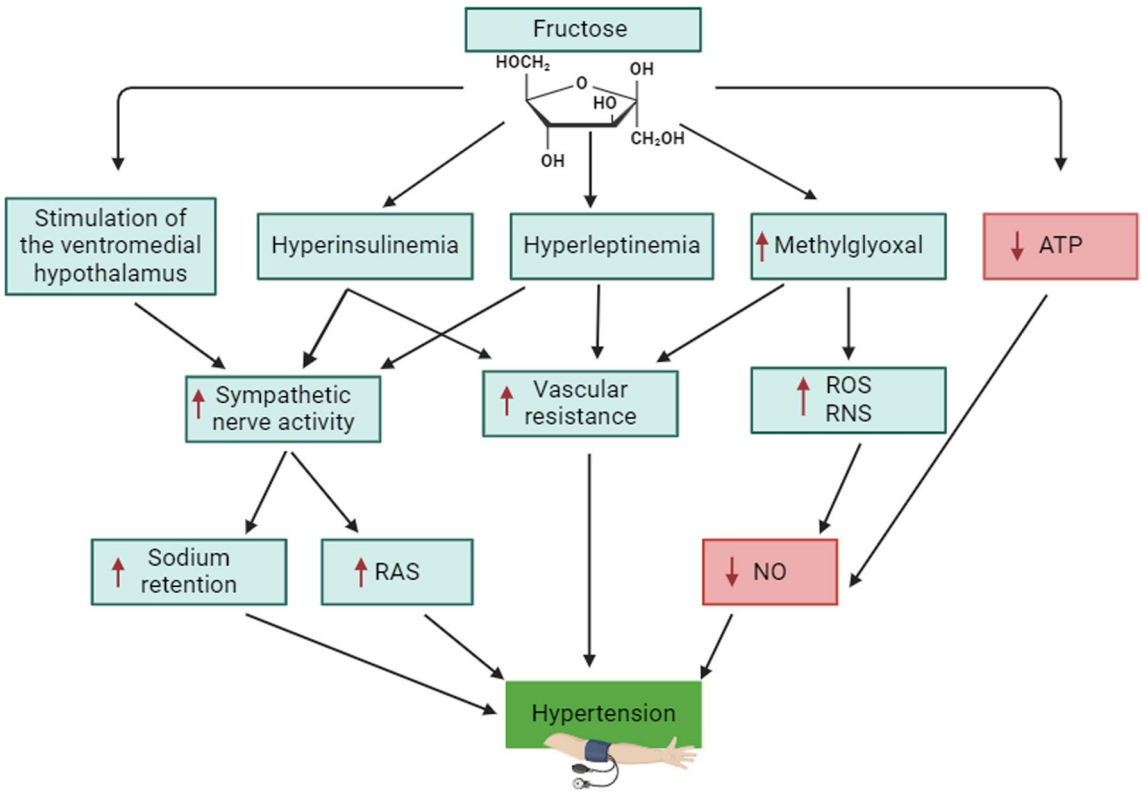


Fig. 3 Hypertensive mechanisms of sucrose. Arrows represent direct effects, or indirect effects through intermediates, which is not shown for simplicity. NO, nitric oxide; RAS, renin-angiotensin system; RNS, reactive nitrogen species; ROS, reactive oxygen species

making it challenging to manage intake. Popular items like soft drinks, energy drinks, and fruit-flavored beverages can contain alarming amounts of added sugars. Even seemingly healthier options, such as sweetened iced teas, contribute significantly to daily sugar intake [61]. Processed and packaged foods, including cereals, granola bars, and flavored yogurts, frequently harbor hidden sugars [62].

Sauces like ketchup and barbecue sauce can also contain surprising amounts of added sugars. To combat excessive sugar consumption, adopting practical strategies is essential. Reading nutrition labels diligently helps identify hidden sugars and choose products with minimal added sugars. Opting for water, herbal teas, or infused water instead of sugary beverages is an effective way to reduce sugar intake. Gradually adjusting recipes to lower sweetness levels allows taste buds to adapt over time. Using natural sweeteners like honey, maple syrup, or agave in moderation can provide alternatives to refined sugars. Understanding the dual impact of sodium and sugar on HT underscores the need for a comprehensive approach to CVH. Recognizing the hidden sugars in popular foods and beverages and implementing strategies to reduce sugar consumption, individuals can make informed dietary choices that support optimal cardiovascular well-being. This holistic approach empowers individuals to manage their BP effectively without compromising on taste or satisfaction.

Artificial sweeteners are synthetic sugar substitutes commonly used in food and beverages to provide sweetness without the calories of regular sugar. Compared to sucrose, it has a distinctive intense sweetness that when added in small amounts to increase acceptance [63]. Popular types include aspartame, sucralose, saccharin, acesulfame potassium (Ace-K), and cyclamate. Some artificial sweeteners are derived from naturally occurring substances like amino acids, while others are purely synthetic. There have been ongoing health concerns about the use of artificial sweeteners in food and drink. This had led to the discovery of steviol glycosides, a natural sweetener found in the *Stevia rebaudiana*. Diterpene steviol glycosides are found in higher concentrations in leaves and are 250–300 times sweeter than sucrose, but have a bitter taste than rebaudiosides A and C [64]. Clinical trials conducted on patients with mild to moderate hypertension showed that long-term stevioside use (250 mg) has no effect on normal glucose levels or blood pressure [65]. Long-term clinical trials showed that taking 750 mg of stevioside daily for a year lowers both systolic and diastolic blood pressure without alterations in left ventricular mass index, according to follow-up trials conducted for up to 2 years at an increased dose of 1500 mg/day [66]. Isosteviol synthesized from stevioside has significantly reduced arterial blood pressure in spontaneously hypertensive rats through intraperitoneal injection. The antihypertensive effect is due to isosteviol inhibition of calcium influx in vascular smooth muscle cells, independent of the endothelium or nitric oxide pathways [67].

7 Impact of dietary fats on cardiovascular health (CVH)

In the intricate tapestry of CVH, the types of fats consumed play a crucial role, extending beyond the well-discussed effects of sodium and sugar. Saturated and trans fats, prevalent in fried and processed foods, have a substantial impact on BP and overall cardiovascular well-being. The main sources of saturated fats are animal-based foods including meat, dairy, and some types of oil [68]. These fats are solid at room temperature and are associated with elevated levels of low-density lipoprotein (LDL) cholesterol, a recognized risk factor for cardiovascular disease (CVD) and HT [11]. Trans fats, although naturally present in small amounts in some animal products, are predominantly created through hydrogenation, a process that turns liquid oils into solid fats for use in many processed and packaged foods [69]. Trans fats increase the risk of cardiovascular problems by lowering high-density lipoprotein (HDL) cholesterol and raising LDL cholesterol [70].

Both saturated and trans fats contribute to arterial stiffness, a condition where arteries lose their elasticity and struggle to accommodate blood flow, leading to increased BP [71]. Chronic inflammation, exacerbated by the consumption of these unhealthy fats, further damages blood vessels and increases the risk of elevated BP [72]. Additionally, these fats are implicated in the development of insulin resistance, which is associated with heightened risk for H and other cardiovascular problems [73]. In contrast, monounsaturated fats found in olive oil, avocados, and certain nuts offer cardiovascular benefits by improving cholesterol levels and supporting heart health [74]. Polyunsaturated fats, including those from fatty fish, flaxseeds, and walnuts, are especially beneficial for BP regulation, with omega-3 fatty acids being particularly effective [75].

To reduce intake of saturated and trans fats, opting for whole foods over processed and fried options is essential. Incorporating fresh fruits, vegetables, lean proteins, and whole grains into the diet supports heart health. Lean protein sources such as poultry, fish, tofu, and legumes provide essential nutrients without the saturated fats found in red and processed meats [76]. Using plant-based oils like olive and canola oil in cooking and salad dressings can also promote cardiovascular health. Nuts and seeds, such as almonds, walnuts, chia seeds, and flaxseeds, are excellent sources of

heart-healthy fats that add flavor and texture while benefiting cardiovascular well-being [77]. Beyond the pervasive concerns of sodium and sugar, understanding the impact of dietary fats on BP is crucial for cardiovascular health. By making conscious dietary choices and opting for healthier fat sources, individuals can foster a heart-friendly diet and promote optimal cardiovascular well-being. This comprehensive awareness empowers individuals to make informed choices, taking a proactive approach to heart health.

8 Cardiovascular health and diet

The relationship between cardiovascular health and diet is evolving, as dietary choices play a central role in influencing heart health by affecting blood pressure, cholesterol levels, blood sugar, and body weight. In contrast, balanced diets rich in whole foods like fruits, vegetables, whole grains, nuts, seeds, lean proteins, and healthy fats have been shown to reduce cardiovascular risk. For instance, the Mediterranean diet is widely regarded as one of the most effective and recommended diets for promoting cardiovascular health [78]. Following this, the DASH diet is recommended for the prevention and management of hypertension. The Mediterranean diet, which emphasizes olive oil, fish, and plant-based foods, supports cardiovascular health by providing anti-inflammatory and antioxidant nutrients. The DASH diet, specifically designed to lower blood pressure, focuses on fruits, vegetables, lean protein, and low-fat dairy, helping to control hypertension, a significant contributor to heart disease [79].

Functional foods are designed to improve health by including bioactive compounds that can impact lipid metabolism, vascular function, microbiome composition and activity, as well as digestive and inflammatory systems [80]. Certain peptides, fatty acids, phenolics, vitamins, dietary fibers, probiotics, prebiotics, and plant sterols/stanols are some examples of these substances. In research including both humans and animals, some of these bioactive ingredients have demonstrated impacts on cardiovascular risk pathways; their effects on blood lipid levels have received special attention. However, functional foods on clinical outcomes remains largely unestablished and warrants further research. Functional foods containing plant sterols and stanols are specifically formulated to help lower cholesterol levels, which can reduce the risk of cardiovascular disease [81]. Plant sterols and stanols are naturally occurring compounds found in small amounts in fruits, vegetables, nuts, and seeds. They can compete with cholesterol for absorption in the digestive tract because of their structural similarity. This competition reduces the amount of cholesterol absorbed, helping to lower blood LDL cholesterol levels. Research shows that a daily intake of around 2–3 g of plant sterols/stanols can effectively lower LDL cholesterol by about 7–12% within a few weeks [82]. However, it's best to consume these functional foods as part of a balanced diet.

The three major macronutrients such as fats, carbohydrates, and proteins, provide energy to maintain regular biological activities. However, it has been known that reducing fats or carbohydrates can impact health outcomes. Low-fat diets restrict fat intake, especially saturated fats, leading to potential weight loss when calories are controlled, though they may be challenging to sustain due to reduced satiety. These diets can improve cholesterol and cardiovascular health but require the inclusion of healthy fats to avoid lowering HDL [83]. In contrast, low-carb diets reduce carbohydrates, which lowers insulin levels and promotes fat burning, often resulting in greater initial weight loss compared to low-fat diets. Low-carb diets can also enhance cardiovascular markers like HDL and triglycerides, though high saturated fat intake could raise LDL [84]. Additionally, low-carb diets may improve blood sugar control and insulin sensitivity, which is beneficial for those with insulin resistance or type 2 diabetes. However, these diets can initially cause fatigue or headaches as the body adjusts. Both diet types offer advantages: low-fat diets are generally easier to follow and align with heart health recommendations, while low-carb diets provide greater satiety through higher protein and fat intake. Ultimately, the choice depends on individual health goals, dietary preferences, and sustainability, and consulting with a healthcare provider can help determine the most suitable approach.

9 The potassium paradox

In the complex landscape of BP regulation and CVH, potassium stands out as a crucial yet often underutilized mineral. The "potassium paradox" highlights the essential role of potassium in maintaining optimal BP while addressing the widespread issue of insufficient intake among many individuals [85]. Potassium, an essential mineral and electrolyte, plays a fundamental role in various physiological functions. It helps balance sodium levels, which is vital for regulating fluid balance and supporting optimal BP [86]. Despite its importance, a significant number of people fail to meet the

recommended daily intake of potassium [87]. This paradox arises from the contrast between potassium's benefits and it's under consumption. Potassium counteracts the adverse effects of sodium by promoting vasodilation and relaxing the walls of blood vessels, which helps lower BP and reduce cardiovascular strain [88]. It also maintains the delicate balance of electrolytes essential for nerve transmission, muscle contraction, and overall cellular function [89].

Adequate potassium intake is linked to a reduced risk of CVD, including stroke and heart attack, and supports the prevention of arrhythmias [90]. Additionally, potassium helps prevent kidney stones and supports overall kidney function. One mechanism through which potassium influences BP involves its role in renal function. High dietary potassium intake promotes natriuresis and kaliuresis, processes associated with the reduction of the renal Na^+/Cl^- co transporter (NCC) activity. This reduction increases the driving force for distal tubular epithelial Na^+ channel (ENaC)-dependent potassium secretion, thus contributing to lower BP (Fig. 4). Foods rich in potassium, such as certain fruits, vegetables, and fortified products, can help achieve these beneficial effects (Table 2). To address the potassium paradox, incorporating potassium-rich foods into a balanced diet is essential. Foods like bananas, oranges, potatoes, spinach, and beans are excellent sources of potassium. Additionally, some breakfast cereals and energy bars are fortified with potassium [91]. Adopting a mindful approach to meal planning and focusing on potassium-rich options, individuals can bridge the gap highlighted by the potassium paradox and enhance their overall cardiovascular health. The multifaceted benefits of potassium extend beyond BP regulation, impacting various vital functions throughout the body. Embracing the nourishing power of potassium through informed dietary choices can support optimal heart health and overall well-being.

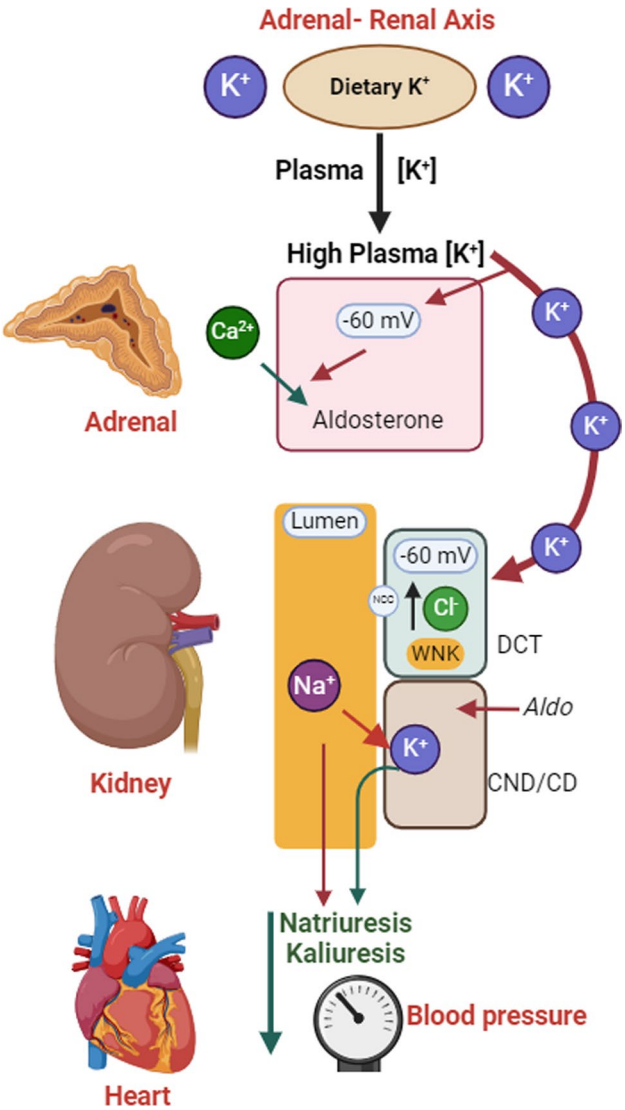


Fig. 4 The role of dietary potassium in hypertension

Table 2 The potassium rich food and smart food choices reduced the blood pressure level

S. No	Potassium rich food	Smart food choices reduced the blood pressure level	References
1.	Bananas	Perhaps the most well-known source of potassium, bananas are convenient and versatile. They can be enjoyed on their own, added to smoothies, or incorporated into various dishes	[92]
2.	Oranges	Citrus fruits, including oranges, provide a refreshing source of potassium. Freshly squeezed orange juice or whole oranges are excellent additives for a potassium-rich diet	[93]
3.	Sweet Potatoes	These nutrient-dense tubers not only are rich in potassium but also contain a myriad of vitamins and fibres. Baked or mashed sweet potatoes are delicious and nutritious choices	[94]
4.	Spinach	Leafy greens, particularly spinach, are excellent sources of potassium. Incorporating spinach into salads, smoothies, or cooked dishes enhances potassium intake	[95]
5.	Kidney Beans	Kidney beans are notably high in potassium. They can be included in soups, stews, or salads for a wholesome potassium boost	[96]
6.	Lentils	These legumes are versatile and can be incorporated into various dishes, such as soups, curries, and salads, providing a substantial potassium contribution	[97]
7.	Yogurt	Greek yogurt and other varieties of yogurt not only are delicious but are also rich in potassium. Adding yogurt to breakfast or enjoying it as a snack can enhance potassium intake	[98]
8.	Almond Milk	For those seeking dairy alternatives, almond milk fortified with potassium can be a suitable option	[99]
9.	Fish	Fatty fish, like salmon, not only provide heart-healthy omega-3 fatty acids but also contribute to potassium intake. Grilled or baked salmon are nutritious choices	[100]
10.	Pistachios	Nuts, particularly pistachios, offer a potassium-packed snack. They can be enjoyed on their own or added to salads and dishes for a delightful crunch	[101]

The DASH (Dietary Approaches to Stop Hypertension) diet is designed to reduce blood pressure by focusing on foods high in potassium, calcium, magnesium, and fiber, while limiting sodium, saturated fats, and added sugars [102]. Its effectiveness in lowering blood pressure partly comes from its high potassium content, but the concept of a "potassium paradox" in the DASH diet reflects a curious aspect of potassium's role in regulating blood pressure. The association between potassium excretion and lower blood pressure reinforces the diet's effectiveness, supporting the role of potassium in managing hypertension through pathways such as sodium excretion enhancement and vascular relaxation [103]. Metabolites derived from gut microbial activity appear to mediate the blood pressure-lowering effects of both potassium intake and DASH adherence, highlighting a complex interaction between diet, microbiota, and host metabolism. This overlap of potassium-BP and DASH-BP related metabolites implies that a portion of the DASH diet's blood pressure-lowering effects may be attributed to potassium-driven microbial pathways. These findings underscore the multifaceted nature of DASH in blood pressure regulation and suggest that DASH-specific metabolites may provide novel targets for future dietary interventions or therapies for hypertension. The 1988 observational INTERSALT study examined the relationship between 24-h urinary potassium (K^+) excretion, used as an indicator of dietary potassium intake, and blood pressure. After adjusting for confounding factors, this study, which included over 10,000 men and women from 32 countries, demonstrated a significant inverse relationship between blood pressure and urinary potassium excretion. Data from the DASH trial, along with findings from several other studies, suggest that the blood pressure-lowering effect of dietary potassium (K^+) is especially pronounced in individuals with high sodium (Na^+) intake [104].

10 Alcohol and caffeine

The impact of alcohol and caffeine on BP regulation is a subject of considerable debate in CVH. Although moderate alcohol consumption and caffeine intake are linked to various effects, their nuanced influences on HT warrant careful consideration [105]. Moderate alcohol consumption, particularly of red wine, is associated with potential cardiovascular benefits. Polyphenols in red wine, such as resveratrol, may improve CVH [106, 107]. In moderation, alcohol may exert a vasodilatory effect, potentially leading to a slight reduction in BP. The American Heart Association (AHA) defines moderate alcohol consumption as up to one drink per day for women and up to two drinks per day for men, with a standard drink containing approximately 14 g of pure alcohol [108]. However, excessive alcohol intake is linked to HT, heart failure, and an increased risk of stroke [109, 110]. Individual responses to alcohol vary due to factors such as age, genetics, and overall health.

Caffeine, found in coffee, tea, energy drinks, and chocolate, acts as a central nervous system stimulant and can lead to increased heart rate and temporary BP elevation [111]. While caffeine can cause short-term BP increases, habitual consumers often develop tolerance, leading to less pronounced BP effects [112]. Despite the generally mild acute effects, high caffeine intake may contribute to sustained HT in sensitive individuals [113]. Most adults can safely consume up to 400 mg of caffeine per day, roughly equivalent to four 8-oz cups of brewed coffee [114]. Nonetheless, individuals should be mindful of their tolerance and sensitivity to caffeine. Understanding and adhering to recommended limits for alcohol and caffeine consumption are crucial. Monitoring standard drink sizes and caffeine content helps manage intake effectively [106]. Regular BP monitoring and awareness of how alcohol and caffeine affect BP are essential, especially for individuals with HT or those at risk. Staying hydrated is also important, particularly when consuming these substances, as balancing fluid intake can mitigate adverse BP effects [107]. Consulting healthcare professionals for personalized advice can further tailor recommendations based on individual health profiles. Overall, practicing moderation and being informed about guidelines can help navigate the complex relationship between alcohol, caffeine, and BP.

11 The mediterranean diet: a holistic approach to heart health

Shifting the narrative from an exclusive focus on foods to avoid, the Mediterranean diet emerges as a holistic and heart-healthy approach to nutrition. Grounded in extensive research, this dietary pattern emphasizes whole foods, lean proteins, and heart-healthy fats [77]. Here, we explore the principles of the Mediterranean diet, highlight its proven benefits, and provide practical tips and meal plans to guide readers in adopting this wholesome and sustainable dietary lifestyle [115]. The Mediterranean diet is characterized by a generous intake of fruits and vegetables. These colorful, nutrient-dense foods provide essential vitamins, minerals, antioxidants, and fiber, all of which contribute to overall CVH

[116]. Whole grains, such as brown rice, quinoa, and whole wheat, form a staple part of the Mediterranean diet, offering complex carbohydrates and fiber that promote satiety and stable blood sugar levels [75].

Healthy fats, primarily from sources such as olive oil, nuts, and seeds, are emphasized in the Mediterranean diet. These fats, rich in monounsaturated and polyunsaturated fatty acids, are associated with a reduced risk of heart disease [117]. Lean proteins, including fish, poultry, legumes, and beans, are also prominent. Fish high in omega-3 fatty acids, such as salmon and mackerel, are particularly beneficial for CVH [100]. Moderate consumption of dairy products, especially yogurt and cheese, provides calcium and additional protein while aligning with the Mediterranean principles [115]. Additionally, the use of herbs and spices enhances flavor and adds antioxidant-rich elements to meals [118]. Studies have demonstrated the Mediterranean diet's positive impact on heart health [34, 119, 120]. This diet has been linked to a decreased risk of CVD, including heart attack and stroke. It promotes favorable changes in lipid profiles, such as increased HDL cholesterol and reduced LDL cholesterol levels [11]. The emphasis on whole foods rich in potassium and magnesium contributes to BP regulation, potentially lowering the risk of hypertension [16]. Moreover, the inclusion of anti-inflammatory foods like olive oil and fatty fish may help reduce inflammation, a factor associated with various chronic diseases, including CV issues [34].

Incorporating legumes, such as lentils, chickpeas, and beans, provides additional benefits due to their high fiber content and plant-based protein [46]. Regular consumption of legumes has been associated with improved glycemic control and lower LDL cholesterol levels [121]. Furthermore, the Mediterranean diet's focus on seasonal and locally sourced foods not only supports environmental sustainability but also maximizes nutrient density and flavor [122]. The Mediterranean diet also supports weight management and a healthy body mass index (BMI), thanks to its nutrient-dense and satisfying food options. Embracing the Mediterranean tradition of savoring meals with family and friends fosters a healthier relationship with food. Eating mindfully and paying attention to hunger and fullness cues can further enhance well-being. The Mediterranean diet represents a holistic and evidence-based approach to promoting heart health. Centered around whole foods, lean proteins, and heart-healthy fats, this dietary pattern offers numerous benefits, from improved lipid profiles to reduced risk of CVD. Practical tips and meal plans provide actionable steps for individuals seeking to adopt this enriching lifestyle, making the Mediterranean diet not just a path to better heart health but also a flavorful journey toward a sustainable and fulfilling way of eating.

12 Conclusion

Dietary choices have a profound impact on the management and prevention of high BP and CVH. Excessive sodium intake is strongly linked to elevated BP and CVD, making it essential to reduce salt consumption. In contrast, potassium-rich foods, such as bananas, oranges, and spinach, help counteract sodium's effects and support BP regulation. Unhealthy fats, specifically saturated and trans fats, contribute to increased LDL cholesterol and arterial stiffness, exacerbating BP issues, at the same time healthy fats, including those found in olive oil, avocados, and nuts, can improve cholesterol levels and reduce inflammation, benefiting CVH. Excessive sugar consumption, particularly from processed foods and sugary drinks, contributes to insulin resistance and HT risk. While moderate alcohol use, as measured by BMI, may have some CV advantages, excessive consumption is linked to elevated BP and an increased risk of heart disease. Moreover, caffeine, found in coffee and energy drinks, can cause short-term BP increases, especially in individuals who are sensitive to it, though regular consumers may develop tolerance. The Mediterranean diet, characterized by high intake of fruits, vegetables, whole grains, lean proteins, and healthy fats, has been shown to reduce BP and lower CVD risk. Future research should explore the intricate interactions between these dietary factors (functional foods) and BP, and public health strategies should emphasize education and support for sustainable dietary changes is crucial for mitigating HT and enhancing overall CVH.

Acknowledgements Not applicable

Author contributions AV: Conceptualization, supervision, data curation, methodology, project administration, investigation and writing—original draft. TCA and AS: Formal analysis, Writing—review and editing and validation. KV and SS: Formal analysis, Writing—review and editing and editing the manuscript. All authors read and approved the final manuscript. "All the data were generated in-house, and no paper mill was used. All authors agree to be accountable for all aspects of work ensuring integrity and accuracy.

Funding Not applicable.

Data availability No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate Not applicable.

Informed consent for publication Not applicable.

Competing interests The authors declare that they have no conflict of interest or competing financial interest.

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