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REVIEW

# Systematic Review of the Effects of Sparkling Water Consumption on Blood Pressure

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**Purpose of review** At present, almost all national health agencies and professional societies recommend reducing dietary sodium to lower blood pressure and prevent cardiovascular disease and stroke. The scientific community has questioned these recommendations multiple times. However, the institutions have clarified that the evidence supporting the reduction of sodium intake remains strong. This review is an examination of the literature on the impact of carbonated water consumption on the blood pressure of hypertensive patients

**Recent findings** Current literature focuses on the act of ingestion and the immediate post-consumption periods, highlighting the significant role of the nervous system on blood pressure increase. This differs from earlier literature, which predominantly focused on hypotheses surrounding the nutritional components responsible for elevated blood pressure

**Summary** Research findings remains uncertainty regarding whether hypertensive patients should avoid the consumption of sparkling water. To contextualize these results, we discuss potential physiological mechanisms, recommendations from relevant organizations, and variations in methodologies and study designs. In conclusion, the question of whether hypertensive patients should steer clear of sparkling water remains unanswered.

**Keywords** Carbonated water · Sparkling water · Blood pressure · Sodium

## Introduction

Water intake is recognized as essential for maintaining health. Water balance is achieved through individual intake variations depending on environmental temperature, physical activity and renal regulation [1, 2]. In addition to the amount of water, the composition of the water must also be considered, as it is directly related to the organic processes of the human body.

Knowledge about the salutary properties of certain waters dates back to Hippocrates, with many of these waters having been employed for therapeutic purposes since ancient times. Currently, the consumption of carbonated water has lost interest in the conventional scientific community.

Concerning the relationship between water and hypertension, its consumption has been associated with an elevation in blood pressure. This phenomenon can be elucidated by the augmentation of sympathetic nervous system activity via reflex mechanisms triggered by gastric distension [3].

Data studying the impact of salt in water dates back to the twentieth century. During this period, a positive correlation was established between stroke mortality and the acidity of river water [4–6].

However, the influence of minerals on health has aroused interest [4–7]. Water intake favors the digestive solubility of food and improves intestinal physiology. Nevertheless, the results vary depending on the water mineralization type. In this sense, water rich in calcium and magnesium has shown evidence in the protection of bone health [4, 6]. Sodium and potassium participate in the active transport of many substances through the ATPase system and acid–base buffer [8]. Moreover, there has been a body of evidence linking the use of mineral waters with a reduction in certain cardiovascular risk factors [9].

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Mineral or artificial carbonated water typically includes supplemental micronutrients such as calcium, potassium, sodium in different forms (potassium citrate or sodium bicarbonate), which may have implications for an individual's health.

Over the past few decades, a range of health concerns has emerged concerning carbonated beverages, with varying degrees of significance. There have been apprehensions that the consumption of carbonated beverages might be associated with reduced bone density, dental erosion or gastrointestinal reflux disease has led to the conclusion that while they may induce a transient reduction in lower oesophageal sphincter pressure, they do not, on the whole, exacerbate or promote gastrointestinal reflux disease [10]. Considering the presence of sodium in these waters and the current concern about the influence of this cation on hypertension, it is interesting to study its effects on this disease.

At present, almost all national health agencies and professional societies recommend reducing dietary sodium as a means to lower blood pressure and prevent cardiovascular disease and stroke. The European Society of Hypertension and Cardiology suggests a daily intake of 5–6 g of salt for the general population [11, 12]. This salt restriction may reduce the number and doses of antihypertensive drugs [11].

Similarly, the American Heart Association (AHA) currently recommends a sodium intake of less than 1500 mg/d for the entire US population [13]. The AHA reported on observational studies and a meta-analysis that stirred controversy about recommendations for reduced sodium intake. Nevertheless, the institution clarified that the evidence regarding the reduction of sodium intake remains robust [14].

Currently, still water is the type of water most consumed in Spanish homes. However, the consumption of sparkling water accelerates more rapidly; in 2021 consumption rises to 113 million kilos [15], 42.6% of the Spanish adult population aged $\geq$ 18 years is hypertensive [16]. In that sense, a low-sodium diet is one of the main recommendations used by health professionals once the disease starts.

The objective of this systematic review is to demonstrate the effects of consuming sparkling water on blood pressure in hypertensive patients. Answering the clinical question: Should hypertensive patients avoid sparkling water?

## Materials and Methods

The inclusion criteria were follows:

- Presence of carbonic acid (H2CO3) in the chemical composition of studied waters.
- Longitudinal studies.
- Blood pressure determination before and after the ingestion of sparkling water.
- Publication date from January 1, 2000, up to the commencement date of the search.

The exclusion criteria used were as follows:

- Not be written in English or Spanish.
- Intervention on an animal sample.

The search strategy used was composed of the MeSH term "hypertension" which was related by the Boolean "AND" to the MeSH term "carbonated" and the free term "sparkling water". The final strategy was the following: "hypertension" AND ("Carbonated water" OR "Sparkling Water"). No filters or limits were applied to searches.

The authors searched the following databases using the search strategy: Epistemonikos (last searched: 18/10/2022), CINAHL (last searched: 19/10/2022), Embase (last searched: 19/10/2022), Cochrane (last searched: 22/10/2022), Scopus (last searched: 22/10/2022), WOS (last searched: 24/10/2022) and PubMed (last searched: 28/10/2022).

To decide if the articles met the inclusion criteria, a title reading was first performed, discarding those that did not focus on the intake of carbonated waters. Then an abstract reading was carried out to screen the articles that did not take blood pressure measurements and apply the exclusion criteria referring to the language. Finally, the reading of the entire body of research was carried out, in which the presence of H2CO3 in the water composition was determined and the determination of blood pressure was taken into account. This process was carried out by both authors simultaneously, and at the end of the filtering process, the articles that matched the selection criteria of both authors were chosen.

As a result of the systematic review three studies were included. Due to the shortage of results, María del Pilar Vaquero Rodrigo was contacted for advice on research with potential to be included in the study. Through that collaboration, 12 studies were submitted and subsequently subjected by both authors to an abstract evaluation, and a comprehensive examination of the complete documents.

For the extraction of the data of interest, the blood pressure determinations in every study and the factors that could be related to them were taken: moment of measurement after the intake of carbonated water and measurements made on the hormone aldosterone.

## Results

As shown in Fig. 1, the use of the search strategy in different databases yielded 435 results, out of which 3 were excluded due to not meeting the language exclusion criteria, and 13 were removed as duplicates. Subsequently, 419 articles underwent screening through title and abstract

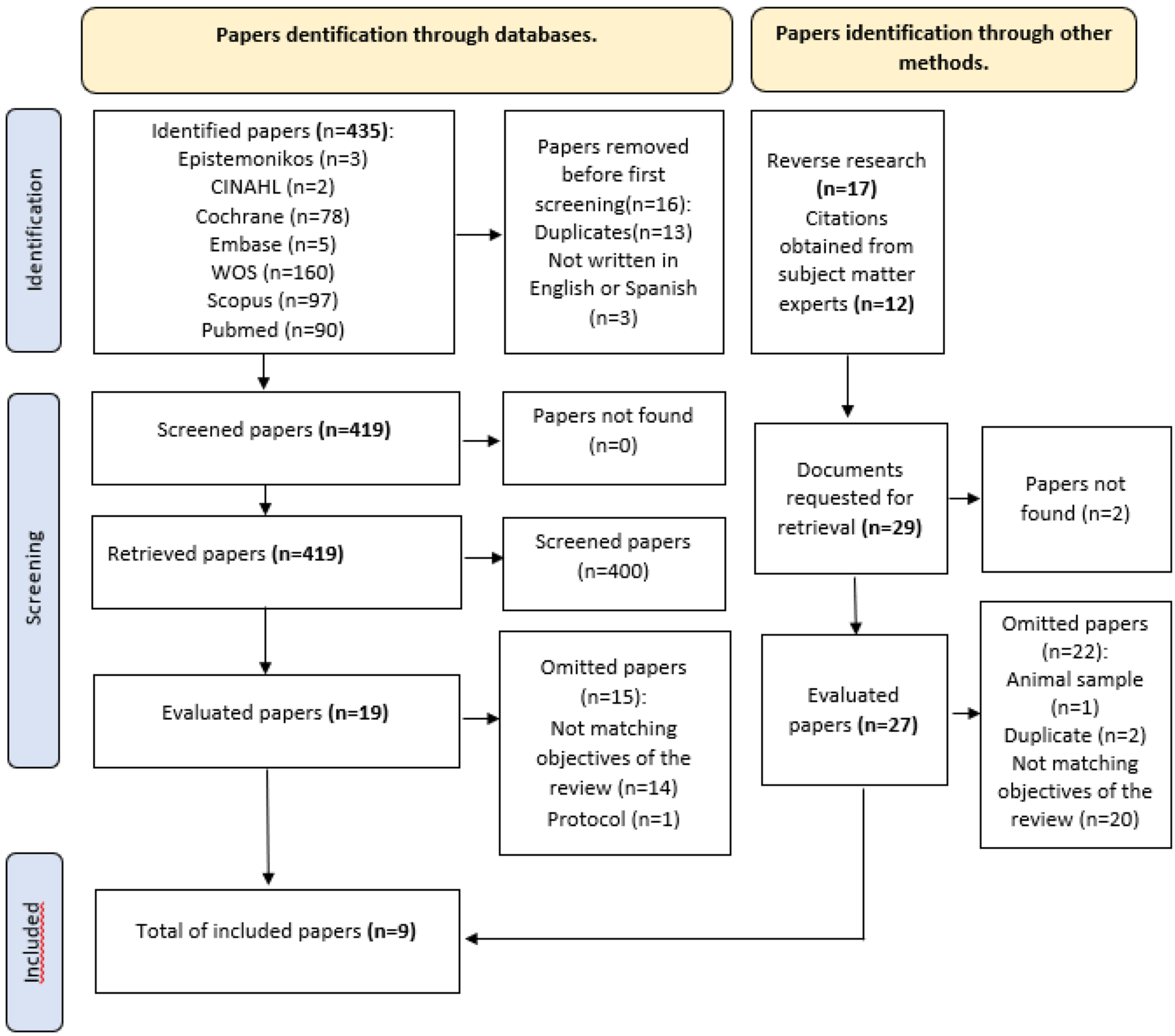


**Fig. 1** Process of identifying evidence

reading, leading to the elimination of 400 references. Consequently, 19 studies underwent critical appraisal, and 16 were excluded for not meeting the inclusion criteria. The systematic search process resulted in 3 studies that fulfilled both the inclusion and exclusion criteria.

Additionally, 29 studies were identified through backward search and expert recommendations in the field. Among them, 2 studies were not found, and 23 did not meet the inclusion criteria after their abstracts and full-texts were reviewed. Therefore, from this identification phase, 4 investigations were extracted, which, combined with the 3 studies identified through the systematic search, resulted in a total of 9 studies included in the results.

As depicted in Table 1, this study identified 4 trials and 3 nonrandomized before-after quasi-experimental studies. No retrospective or observational research was identified. Main characteristics of each analyzed studies are delineated in Tables 2 and 3 below.

The analyzed findings exhibit variability in the outcomes. Two of the investigations demonstrate a noteworthy increase in certain parameters of blood pressure subsequent to the consumption of carbonated water as opposed to noncarbonated water [24, 25]. Conversely, five of the studies reveal the absence of statistically significant disparities in blood pressure measurements following the consumption of carbonated water with mineralization compared to noncarbonated water with lower mineral content [17, 18, 20, 22, 23]. Only one of the examined research endeavors documented a statistically significant reduction in systolic blood pressure subsequent to the consumption of carbonated water compared to

**Table 1** Main characteristics of the identified studies

| Title | Objective | Design (sample size) |
|---|---|---|
| Sodium-rich carbonated natural mineral water ingestion and blood pressure [17] | To assess the effect of ingesting sodium-rich mineral water on blood pressure in normotensive individuals | Randomized, two-way crossover trial.(17) |
| The therapeutic effect of carbogaseous natural mineral waters in the metabolic syndrome [18] | To assess the effect of Borsec mineral sparkling water on people suffering metabolic syndrome | Randomized clinical trial.(45) |
| Aldosterone changes after consumption of a sodium-bicarbonated mineral water in humans. A four-way randomized controlled trial [19] | To measure the effect of sparkling mineral water consumption on aldosterone levels in healthy adults by comparing them with the control water | 4way randomized, crossover clinical trial (individually randomized in sequences, not clusters)(21) |
| An intervention with mineral water decreases cardiometabolic risk biomarkers. A crossover, randomise, controlled trial with two mineral waters in moderately hypercholesterolaemic adults [20] | To examine the effects of a mineral water intervention on cardiometabolic markers and compare it with regular water in terms of benefits on the markers mentioned | Randomized and crossover clinical trial. Simple blind of the researcher.(64) |
| Reduction in cardiovascular risk by sodium-bicarbonated mineral water in moderately hypercholesterolemic young adults [21] | To study the effects of drinking sodium-bicarbonate mineral water on cardiovascular risk (CVR) in young patients with moderate CVR | Nonrandomized before-after quasi-experimental study.(18) |
| Bone remodelling is nor affected by consumption of a sodium-rich carbonated mineral water in healthy postmenopausal women [22] | To investigate the effects of consuming sodium-rich mineral water on bone remodeling and urinary mineral excretion in postmenopausal women | Nonrandomized before-after quasi-experimental study. (18) |
| A sodium-rich carbonated mineral water reduces cardiovascular risk in postmenopausal women [23] | To investigate the effects of consuming sodium-rich carbonated mineral water on lipoprotein metabolism | Before-after quasi-experimental study(18) |
| The pressor response to the drinking of cold water and cold carbonated water in healthy younger and older adults [24] | To investigate whether drinking water with a cold or carbonation stimulus would cause a more effective pressor response, and whether it would be greater in older than in younger adults | Before-after quasi-experimental study (22) |
| Ingestion of carbonated water increases middle cerebral artery blood velocity and improves mood states in resting humans exposed to ambient heat stress [25] | To investigate whether carbonated water ingestion influences blood pressure, cerebral blood flow index, perspiration, and if it positively influences thermal perceptions and mood in resting humans exposed to ambient heat | Before-after quasi-experimental study (17) |

**Table 2** Trials analysis

| Title | Method | Results | Measurements | Water |
|---|---|---|---|---|
| Sodium-rich carbonated natural mineral water ingestion and blood pressure [17] | 7 weeks of exclusive ingestion of carbonated water followed by another 7 weeks of ingestion of noncarbonated water. A 6 week washout period was implemented between study arms. Measurements of blood pressure and urine samples were taken prior to the initiation of the intervention phase following each study arm | No significant differences between carbonated and control water on blood pressure and sodium or potassium excretion | 0 and 7 weeks of each arm | Non carbonated Vitalis or carbonated water Agua das pedras |
| The therapeutic effect of carbogaseous natural mineral waters in the metabolic syndrome [18] | Three randomized groups were assigned to receive either carbonated mineralized water, low mineralization water, or nonbottled water. Each participant consumed 2 L of the assigned water daily for 4 weeks | No significant differences in blood pressure among the three groups | 0 and 4 weeks | Non carbonated mineral water, tap water or carbonated water Borsec |
| Aldosterone changes after consumption of a sodium-bicarbonated mineral water in humans. A four-way randomized controlled trial [19] | On different days, the same group of participants consumed either high-mineralization carbonated water or low-mineralization water while in a fed or fasting state. Blood samples were collected at 30, 60, and 120 min after the completion of ingestion | Serum aldosterone level significantly decreases with the consumption of mineralized (carbonated) water | 0, 30, 60, 120 min after ingestion | Vichy Catalan control or carbonated water |
| An intervention with mineral water decreases cardiometabolic risk biomarkers. A crossover, randomise, controlled trial with two mineral waters in moderately hypercholesterolaemic adults [20] | Two groups of moderately hypercholesterolemic individuals consumed 1 L of bicarbonated water (carbonated water) or low-mineralization water. The interventions were then crossed over with an intermediate 8 week washout period. Blood pressure and serum aldosterone measurements were conducted | No significant differences between carbonated and control water regarding their effects on blood pressure and serum aldosterone levels | 0,4 and 8 weeks of each arm | Vichy Catalan control or carbonated water |
| The pressor response to the drinking of cold water and cold carbonated water in healthy younger and older adults [24] | The participants drank 200 mL of cold, cold carbonated, and room temperature water. Blood pressure was monitored using a volume-clamp method. The measurement protocol consisted of 10 min of control,1 min of ingestion, and 20 min of recovery. The interventions were then crossed on different days in randomized order | Drinking cold carbonated water significantly raised blood pressure in comparation with cold water | Mean values for 1 min drinking period and 0–5, 5–10, 10–15, and 15–20 min of the recovery period | Non carbonated Oishii Mizu or carbonated water Wilkinson, Asahi |

**Table 2** (continued)

| Title | Method | Results | Measurements | Water |
|---|---|---|---|---|
| Ingestion of carbonated water increases middle cerebral artery blood velocity and improves mood states in resting humans exposed to ambient heat stress [25] | The participants rested in a 37ºC ambient room for 60 min. The baseline measurements were obtained for 10 min. Next, participants ingested either noncarbonated water or carbonated water at 4ºC within 30 s, followed by a 15 min rest period during which measurements were collected every 5 s. Participants ingested both the drinks twice. The order of the four arms was randomized | Drinking carbonated water significantly raised blood pressure in comparation with control water | 0,1,6 and 12 min post ingestion | Non carbonated Oishii Mizu or carbonated water Wilkinson, Asahi |

measurements obtained after the ingestion of noncarbonated water [21]. Furthermore, investigations examining 24 h urine samples did not observe any notable discrepancies in sodium cation (Na) excretion following the consumption of sparkling water compared to the results obtained from the ingestion of noncarbonated demineralized water [17, 22].

One of the studies consulted revealed a substantial decrease in serum aldosterone concentration at 30, 60, and 120 min after the consumption of carbonated bicarbonate water in the absence of food, in comparison to the consumption of still water under similar conditions. Additionally, a significant reduction in aldosterone concentration was found 120 min after consuming both types of water when accompanied by food [19].

## Discussion

Authorities such as the American Heart Association [14] and the European Society of Hypertension and Cardiology [12], among others, advocate reducing sodium intake as a preventive measure against hypertension.

Despite the high sodium concentration found in the waters examined in the studies included in this review [17, 21, 23], the results obtained in this review demonstrate that the consumption of carbonated water did not exhibit statistically significant alterations in blood pressure readings when compared to control waters during observation periods exceeding 30 min following consumption [17, 18, 20–23].

For the justification of these results, much of the literature consulted argues that healthy individuals are able to maintain their hydrosaline balance. A high salt intake implies the inhibition of the renin–angiotensin–aldosterone system which serves as a critical regulator in maintaining the balance of sodium and potassium and plays a pivotal role in regulating extracellular volume [11].

The results of studies examining postprandial aldosterone concentration are in accordance with these findings. Specifically, serum aldosterone levels decreased 120 min after consuming carbonated water compared to control water [19]. Similar results were observed in another study involving postmenopausal women [22]. These findings are consistent with the results obtained from a specific study that investigated postprandial sodium excretion [18, 21].

It is noteworthy that the studies which observed an increase in blood pressure employed the volume clamp method coupled with finger photoplethysmography [24, 25]. The remaining studies utilized an automated digital oscillometric device. Additionally, the ambient temperature in one of the studies was higher than in the rest of the review research [25].

**Table 3** Before-after quasi-experimental studies analysis

| Title | Method | Results | Measurements | Water |
|---|---|---|---|---|
| Reduction in cardiovascular risk by sodium-bicarbonated mineral water in moderately hypercholesterolemic young adults [21] | They maintained a consumption of 1L of low mineralization water for 8 weeks, followed by a subsequent 8 week period in which they consumed 1L of carbonated bicarbonate water. Measurements were taken at 4 weeks and 8 weeks after the initiation of each intervention arm | After the period of consuming carbonated water, a statistically significant reduction in SBP was observed compared to control water. However, there were no significant differences between the measurements taken at 4 weeks and 8 weeks of carbonated water consumption | 0,4 and 8 weeks of each arm | Vichy Catalan control or carbonated water |
| Bone remodelling is not affected by consumption of a sodium-rich carbonated mineral water in healthy postmenopausal women [22] | The sample maintained a 1L daily intake of low mineralization water for 8 weeks. Subsequently, they switched to a 1L daily intake of carbonated bicarbonate water for another 8 weeks. Blood pressure measurements were recorded at the beginning of the intervention and at the end of each phase. Additionally, 24 h urine samples were collected at the end of each phase | No significant differences were found in blood pressure levels. Furthermore, there were no significant differences in the 24 h sodium excretion between the intervention involving carbonated water and the intervention involving low mineralization water | 0 and 2 months | Vichy Catalan control or carbonated water |
| A sodium-rich carbonated mineral water reduces cardiovascular risk in postmenopausal women [23] | Participants maintained the intake of 1L of low mineralization water for an initial period of 8 weeks, after which they sequentially transitioned to ingesting 1L of bicarbonated water (carbonated) for another 8 weeks. Blood pressure measurements were taken at the onset of the intervention period and upon completion of each phase of the study | No statistically significant alterations in participant´s blood pressure was observed across the different stages of the study | 0 and 2 months | Vichy Catalan control or carbonated water |

In this review, studies that conducted measurements during or shortly after the consumption of carbonated water (up to 20 min) demonstrated a significant increase in certain components of blood pressure when compared to the results obtained with the consumption of noncarbonated water [24, 25].

In order to account for the significant rise of blood pressure following the consumption of carbonated water in comparison to noncarbonated water, researchers hypothesize several potential factors: nociceptive stimulation of the trigeminal nerve after carbonated water consumption, the utilization of cold water, which leads to an increase in plasma noradrenaline and blood pressure as a response to the decline in core temperature, and the elevation of vasopressin due to the activation of TRPV1 receptors in the larynx [26, 27].

Consequently, it is suggested that the inhibition of aldosterone may serve as a short-term homeostatic mechanism to prevent increases in blood pressure [19]. However, the findings indicate that carbonated water elevates blood pressure in the initial minutes following ingestion, prior to the influence of aldosterone, due to the stimuli generated within the nervous system [24, 25].

The studies consulted also provide justification for the limited effect of sodium in raising blood pressure in the participants. They highlight that sodium chloride (NaCl) has a much greater capacity to increase extracellular volume compared to other sodium salts without chloride. Despite the waters used in the study designs being rich in sodium, the presence of chloride is in lower doses [17, 20, 21].

One of the main limitations of this review is the scarcity of available evidence, which could be attributed to the predominant emphasis on sodium restriction in hypertension management. This widespread focus, advocated by influential health organizations, may have deterred further research and limited the body of evidence on alternative interventions.

The quasi-experimental studies analyzed did not implement the intervention by groups; instead, they chose to subject the same group to two intervention periods with different types of water [21–23].

For the investigations that utilized randomized groups, it was observed that only one of the studies applied blinding to the researchers responsible for data analysis [19]. The remaining studies did not apply any form of blinding [17, 18, 20, 24, 25]. It is essential to emphasize that blinding of the researcher would be the only feasible approach due to the noticeable texture differences between still water and sparkling water.

Additionally, the included studies exhibit heterogeneity in their designs and small sample sizes, likely stemming from the complex nature of the intervention protocols employed. These factors contribute to challenges in achieving larger, more uniform sample sizes and study designs, limiting the generalizability of the findings.

Another noteworthy limitation is the lack of explicit investigation into the potential health effects of water carbonation. Although all the studied waters were carbonated, the reviewed documents primarily concentrate on the influence of mineral composition or the post-ingestion effects rather than the gasification process itself.

One notable limitation is the potential for publication bias, as the search was confined to published literature and did not encompass grey or commercial literature databases. This exclusion may have inadvertently omitted valuable studies and introduced a bias towards published findings.

Additionally, human bias should be acknowledged, as a considerable portion of the literature examined originated from the research group led by Dr. María del Pilar Vaquero Rodrigo. The involvement of a specific research group in a substantial proportion of the reviewed studies raises the possibility of subjective interpretations and inherent biases, which may have influenced the conclusions drawn in this work.

Given these considerations, it is important to interpret the results of this review within the context of the aforementioned biases and limitations, while acknowledging the need for further research to address these potential sources of bias and enhance the robustness of future investigations.

## Conclusion

Drawing from the outcomes of this systematic review, it remains uncertain whether hypertensive patients should avoid consuming sparkling water. Most of the evidence presented in this review did not specifically include hypertensive patients in their interventions.

Nevertheless, these findings necessitate a reconsideration of the prolonged effects of carbonated water on blood pressure. Furthermore, they underscore the significance of aldosterone and raise questions regarding the current sodium restriction recommendations for hypertension prevention.

Future studies should endeavor to implement methodologies involving continuous blood pressure monitoring from the point of consumption, extending over more protracted periods to facilitate the assessment of aldosterone's role. Additionally, the inclusion of hypertensive patients within the study cohorts is imperative. This approach will contribute to a more comprehensive understanding of the potential risks and benefits associated with carbonated water consumption within this specific population.

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

## Compliance with Ethical Standards

**Conflict of Interests** The authors declare no conflict of interests.

**Human and Animal Rights and Informed Consent** This article does not contain any studies with human or animal subjects performed by any of the authors.

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