



## The Effect Using Of Sodium Bicarbonate Supplements In Increasing Endurance: A Literature Review

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### Abstract

#### Background

In recent years, sodium bicarbonate ( $\text{NaHCO}_3$ ) has been increasingly used as an ergogenic supplement due to its ability to improve body performance, delay muscle fatigue, and support athlete performance during high-intensity exercise.

#### Objectives

This systematic review examines the effectiveness of sodium bicarbonate ( $\text{NaHCO}_3$ ) supplementation in improving athlete physical performance, especially regarding muscle endurance during exercise.

#### Methods

This study used the Systematic Literature Review (SLR) method with PRISMA (Preferred Reporting Items for Systematic Reviews) guidelines and data collection criteria techniques using PICO. Articles were searched in international databases such as Scopus, ScienceDirect, Web of Science (WOS), and PubMed. The keywords used include "Sodium Bicarbonate," "Endurance," "Performance," and Muscle Fatigue. 9 studies were selected based on their relevance to the effectiveness of sodium bicarbonate supplementation in improving athlete performance.

#### Results

The results of the study showed that the use of sodium bicarbonate ( $\text{NaHCO}_3$ ) supplementation is not universal but somewhat highly dependent on contextual variables such as the type of sport, duration, and intensity of activity, athlete training level, and supplementation approach (dose and time of administration). However, most of the existing studies still use general designs and involve limited populations, thus limiting the generalizability of the findings.

#### Conclusion

The research findings show that sodium bicarbonate supplementation has improved sports performance, especially in high-intensity and short-medium duration activities. However, its effectiveness highly depends on the type of sport, athlete's fitness level, dose, and the proper administration time. An individualized approach and further research are needed to optimize its benefits specifically.

**Keywords:** Sodium Bicarbonate, Endurance, Performance, Muscle Fatigue

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## INTRODUCTION

In the world of sports, it is necessary to have optimal levels of strength, endurance, speed, and recovery ability to achieve the best performance (Apollaro et al., 2023; Islam, et al., 2024; Naimah et al., 2022). Physical endurance is one indicator that determines an athlete (Stepanyan & Lalayan, 2023; Yolanda et al., 2025). Athletes with good and optimal endurance can maintain performance at high intensity (Fadilah & Widodo, 2023; Kim & Nam, 2021; Kristiono et al., 2024). Increasing physical endurance is one component determining an athlete's performance (Apollaro et al., 2023; Islam, et al., 2024; Jurić et al., 2019).

High exercise intensity can cause the body to produce lactic acid due to anaerobic metabolism (Bachero-Mena & González-Badillo, 2021; Hadjarati & Massa, 2023; Islam et al., 2025). This is influenced by changes in the concentration of intracellular and extracellular ions in the muscles, which causes decreased contractile performance (Cairns & Renaud, 2023; Kreutzer et al., 2022; Nubatonis et al., 2024).

This accumulation of lactic acid can cause decreased performance, muscle fatigue, and muscle burning, which inhibits the athlete's ability to maintain high intensity (Ariyadi et al., 2024; Gholami et al., 2022; Rini & Purnomo, 2021). During matches and training, energy metabolism increases drastically, which can lead to the accumulation of metabolites such as hydrogen ions ( $H^+$ ) and inorganic phosphate (Malone et al., 2021; Raeder et al., 2024). This accumulation can lead to neuromuscular fatigue, a temporary decrease in the muscle's capacity to produce force, thus affecting the athlete's performance (Abadi et al., 2025; Pethick & Tallent, 2022).

Due to the high metabolic demands during competition and training, the accumulation of detrimental metabolites (such as  $H^+$  and  $P_i$ ) can reduce the muscle's capacity to produce force (Abdulkader et al., 2024; Sundberg et al., 2018). This is referred to as neuromuscular fatigue, which is defined as a temporary decrease in the muscle's capacity to produce force due to exercise with the underlying mechanism originating from the periphery or center (Badaruddin et al., 2023; Dalton et al., 2024). This will undoubtedly hinder the athlete's performance because the muscle's ability to work optimally is disrupted in muscle contraction efficiency.

In recent years, supplements to increase endurance have become increasingly popular (Katmawanti et al., 2022; Miguel-Ortega et al., 2024). Sodium bicarbonate has become one of the supplements widely used by athletes to improve performance, especially in high-intensity training involving anaerobic metabolism (Gurton et al., 2024; Varovic et al., 2023). In this case, sodium bicarbonate is a buffer to help neutralize lactic acid, increasing the athlete's ability to train or compete longer at high intensity (Hanada et al., 2023). This supplement helps reduce the accumulation of lactic acid in the body by functioning as a buffer that neutralizes hydrogen ions ( $H^+$ ), thereby preventing a decrease in muscle pH that can inhibit athlete performance after exercise (Insam & Chidley, 2024; Ragone et al., 2020).

This supplement increases blood pH and decreases hydrogen ion concentration, slowing muscle fatigue during high-intensity activity (Kreutzer et al., 2022). Sodium bicarbonate is also known to increase the diffusion of  $H^+$  ions from muscles to blood plasma, which allows muscles to maintain contractions during high-intensity exercise (Grgic et al., 2021). Studies have shown that sodium bicarbonate can improve performance in high-intensity exercises such as repeated sprints, explosive training, and long intervals (Insam & Chidley, 2024). In addition, sodium bicarbonate has also been shown to have a positive effect in extending endurance to fatigue in various sports, both individual sports and team sports (Lopes-Silva & Franchini, 2021). Based on the background of the problems above, this study aims to explore the effectiveness of sodium bicarbonate supplements in increasing muscle endurance based on various previous studies.

## METHOD

### Research Design.

This study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The analytical framework was adapted from previous bibliometric studies on various topics. This study used the PICO method to identify relevant articles. PICO is a research strategy that utilizes multiple academic sources, including books and scientific journals, to explore the subject of the study. This review focuses on academic literature on the use of sodium bicarbonate supplements in improving muscle endurance.

### Search and Selection Strategy

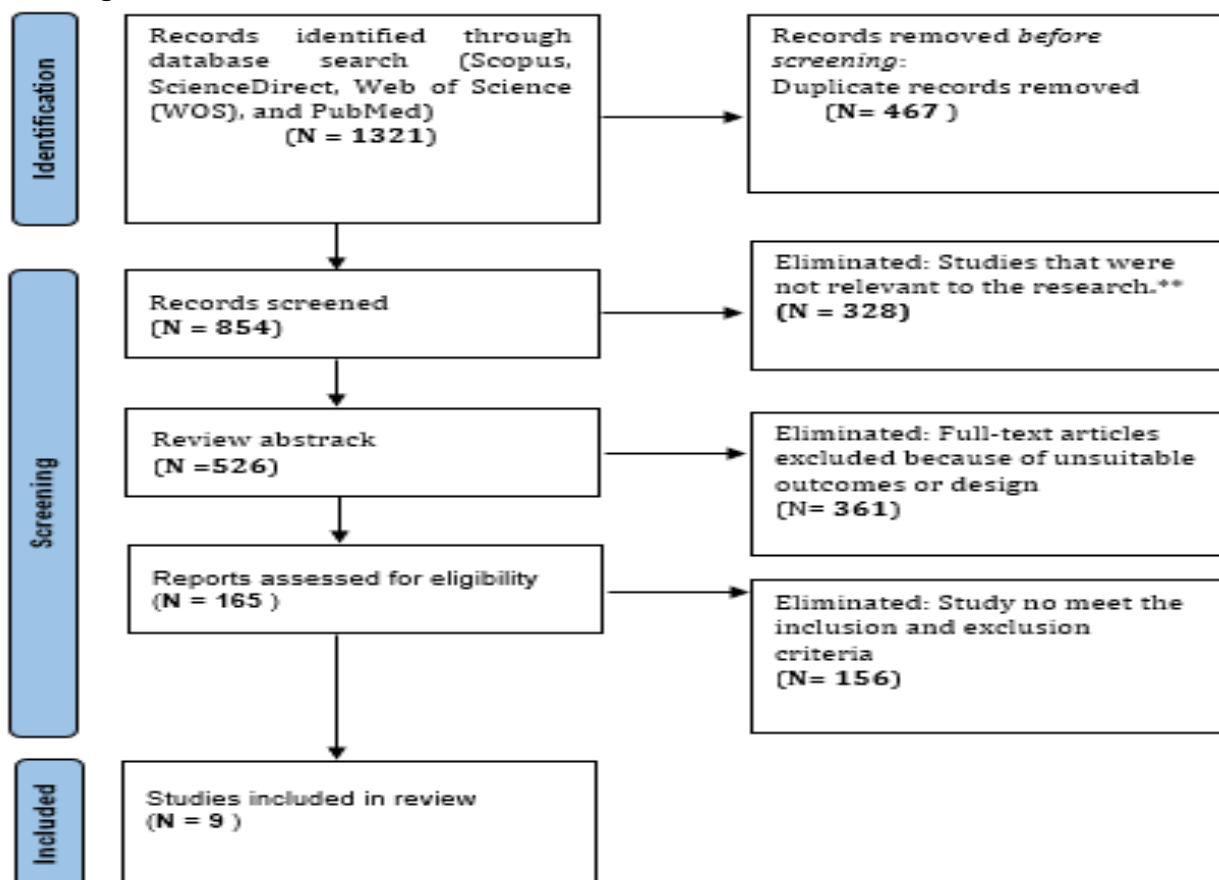
The databases used in this study include Scopus, ScienceDirect, Web of Science (WOS), and PubMed. The keywords used in the search were sodium bicarbonate, muscle endurance, fatigue, and performance. The inclusion criteria in this study were journal articles discussing using sodium bicarbonate, increasing muscle endurance, reducing fatigue, and performance. Reference management software (Mendeley) was used to organize citations, screen titles, and abstracts and evaluate full-text articles based on PICO selection criteria.

**Table 1. PICO Scale**

PICO	Inclusion Criteria	Exclusion Criteria
Population	Athletes or physically active individuals aged 18–40 years	Elderly or individuals with certain medical conditions
Interventions	Sodium bicarbonate supplementation at certain doses before or during physical activity	Non-sodium bicarbonate interventions (e.g., caffeine, creatine, or other supplements)
Comparison	Control group, placebo, or other type of intervention compared with sodium bicarbonate	Studies without a comparison group or that do not mention the control method
Outcome	Muscle endurance performance, decreased fatigue, increased exercise capacity	Results unrelated to muscle performance or endurance

### Inclusion and Exclusion Criteria

The search and selection process used electronic databases, including Scopus, ScienceDirect, Web of Science (WOS), and PubMed. The analytical framework applied in this study is consistent with previous studies in the same field. Overall, 1321 articles published between 2018 and 2025 were selected. Reference management software (Mendeley) was used to organize records, screen titles, and abstracts and to review full-text articles on food intake and eating behavior published during the period. Articles were excluded from the study if (1) they only contained abstracts without access to the full text, (2) they were not published in a peer-reviewed scientific journal, (3) they did not open access, or (4) they did not meet at least one of the inclusion criteria. Only journals that met all inclusion criteria were selected for evaluation. The selection process based on the PRISMA guidelines can be seen in Figure 1.

**Figure 1. PRISMA Research Flowchar**

## RESULTS AND DISCUSSION

Table 2. Research findings

Author	Characteristics of the sample	Study Design	Exercise Tes	Supplementation (Type/Doses)	Result
Aktitiz et al., (2024)	12 recreational male cyclists (age: 31.17 ± 4.91 years)	Double-blind, placebo-controlled crossover design	Cycling exercise, in which participants pedaled an ergometer at 95% of a predetermined anaerobic threshold for 30 minutes	acute sodium bicarbonate intake (ASB, 0.2 g kg <sup>-1</sup> SB)	Acute, multi-day low-dose sodium bicarbonate administration did not significantly improve high-intensity endurance performance in male recreational cyclists despite increasing blood bicarbonate concentrations, suggesting limited efficacy for enhancing muscular endurance.
Silva de Souza et al., (2024)	17 participants (mean ± SD, age 29 ± 5 years)	Double-blind, placebo-controlled crossover design	Fran Benchmark Test, a CrossFit® exercise consisting of a combination of thrusters and pull-ups with 21-15-9 repetitions, to measure muscle speed and strength. Second, a 500-meter rowing test using a Concept2® ergometer to measure cardiorespiratory endurance.	Consuming 0.3 g/kg body weight of NaHCO <sub>3</sub> in capsule form.	Sodium bicarbonate supplementation improved performance in the CrossFit® Fran benchmark, indicating increased muscular endurance. However, it did not significantly affect subsequent 500 m rowing performance, suggesting the benefit may be specific to certain high-intensity exercises rather than all endurance activities.
Newbury et al., (2024)	six highly trained female swimmers (age: 18 ± 1 years)	Double-blind, placebo-controlled crossover design	6 × 75-meter repeated sprint swimming test, followed by a 200-meter maximum time trial after 30 minutes of active recovery	Consuming 0.3 g/kg body weight of NaHCO <sub>3</sub> in capsule form.	Consuming sodium bicarbonate (NaHCO <sub>3</sub> ) did not improve performance in highly trained female swimmers, showing no significant improvement in mean 75 m swim time or maximal 200 m swim time, regardless of the consumption strategy used.
Varovic et al., (2023)	Nineteen men who had experience in resistance training	Double-blind Crossover	The training protocol involved three sets of bench press and biceps curl exercises at an intensity of 70% of 1 repetition maximum (1RM) to muscle failure..	Consuming 0.3 g/kg body weight of NaHCO <sub>3</sub> in capsule form.	Sodium bicarbonate consumption increased muscular endurance in resistance-trained men, specifically increasing repetitions in the third set and total repetitions in the bench press exercise. This suggests that sodium bicarbonate reduces the effects of acidosis, increasing muscle contractility during resistance training.
LEACH et al., (2023)	Ten trained male cyclists (age, 31.1 ± 9 years)	Double-blind, placebo-controlled crossover design	Participants then performed simulated 16.1-km time trials	Consuming 0.3 g/kg body weight of NaHCO <sub>3</sub> in capsule form.	Sodium bicarbonate ingestion before a 16.1 km cycling time trial significantly improved performance times in trained male cyclists, demonstrating its potential as an effective ergogenic aid to enhance endurance during prolonged high-

						intensity exercise.
Lassen et al., (2021)	Twenty-one Danish male and female elite orienteers (age = 25.2 ± 3.6 years)	Double-blind, placebo-controlled crossover design	The athletes also performed two 3.5 km time-trial runs (TT-runs)	Consuming 0.3 g/kg body weight of NaHCO <sub>3</sub> in capsule form.	Individualized sodium bicarbonate (NaHCO <sub>3</sub> ) supplementation followed by a warm-up resulted in varying degrees of alkalosis in each athlete, with peak times ranging from 60 to 180 minutes. Supplementation increased alkalosis levels before and after a 3.5 km run and improved athlete performance by an average of 6 seconds, especially in the latter part of the run.	
Durkalec-Michalski et al., (2020)	Twenty-four trained male field hockey players	Double-blind, placebo-controlled crossover design	two separate Wingate anaerobic tests (WAnTs).	Acute consumption of sodium bicarbonate (ASB, 0.2 g kg <sup>-1</sup> SB)	Sodium bicarbonate supplementation, both progressive-chronic and acute, positively influences anaerobic capacity and discipline-specific performance in athletes, especially in field hockey, increasing power indices and buffering capacity during high-intensity efforts, thereby supporting overall athletic performance.	
Wang et al., (2019)	Twenty healthy college-age male	Double-blind, placebo-controlled crossover design	The first 3 weeks were at low intensity, and the next 3 weeks were at higher intensity. Blood samples were taken 5 minutes before and 30 minutes after the following HIIT training sessions: week 1 session 1, week 3 session 3, and week 6 session 3.	Consuming 0.3 g/kg body weight of NaHCO <sub>3</sub> in capsule form.	Sodium bicarbonate supplementation improves anaerobic performance in athletes by increasing serum HCO <sub>3</sub> <sup>-</sup> levels, increasing peak power, and accelerating lactate clearance rates during high-intensity interval training.	
Delextrat et al., (2018)	Fifteen female university basketball players (23.3 ± 3.4 years)	Double-blind Crossover	Basketball practice test	Consuming 0.4 g/kg body weight of NaHCO <sub>3</sub> in capsule form.	Sodium bicarbonate supplementation significantly improves athlete sprint and repeated jump performance, as demonstrated in female basketball players. It increases mean sprint and circuit times and jump height and reduces performance decline without causing gastrointestinal side effects.	

The use of sodium bicarbonate (NaHCO<sub>3</sub>) supplementation has long been known as one of the ergogenic agents used to improve sports performance, especially in activities involving the contribution of anaerobic lactate metabolism, where the accumulation of hydrogen ions (H<sup>+</sup>) causes a decrease in intramuscular pH which has an impact on muscle fatigue. A review of the various studies in this table reveals that, although there is a consensus regarding the potential of NaHCO<sub>3</sub>, the results of its application are still diverse and highly dependent on the activity context, protocol design, and individual characteristics of the athlete. One interesting finding emerged from the study of Aktitiz et al. (2024), where acute and multi-day NaHCO<sub>3</sub> supplementation in recreational cyclists did not

significantly impact high-intensity endurance performance despite increasing blood bicarbonate concentrations. This highlights that increasing bicarbonate concentrations is not always directly proportional to increased performance, mainly when the activity is carried out in an intensity zone still dominated by aerobic metabolism. Additionally, the fact that participants were recreational cyclists suggests that individual training level and physiological capacity may be important variables in determining the effectiveness of supplementation.

In contrast to these findings, studies by Varovic et al. (2023) and Silva de Souza et al. (2024) showed that in high-intensity, explosive activities such as resistance training and CrossFit®, NaHCO<sub>3</sub> supplementation resulted in significant improvements in muscular endurance and final set performance. These findings reinforce the notion that NaHCO<sub>3</sub> is most effective when used under conditions that cause high metabolic stress, such as repetitions to muscle failure or short intervals with limited rest. The effects also tend to be more pronounced in the final set or repetition, where H<sup>+</sup> ion accumulation is highest.

A study by Delextrat et al. (2018) extended this evidence to the context of team sports such as basketball, where NaHCO<sub>3</sub> was shown to improve sprint and repeated jump performance. These effects occurred without significant gastrointestinal side effects, an important consideration considering that GI complaints are a major limitation of NaHCO<sub>3</sub> use, especially at high doses. However, not all studies have shown significant benefits. Newbury et al. (2024) reported that NaHCO<sub>3</sub> did not improve 6×75 m sprint or 200 m time trial performance in elite female swimmers. These findings highlight the variability in response between individuals and the possibility of gender-, sport- or administration-specific responses, which need further exploration. Similarly, Lassen et al. (2021) showed that peak alkalosis occurred at a highly variable time window (60–180 min), highlighting the need for an individualized approach to supplementation timing. In the context of high-intensity repetitive training (HIIT).

studies by Wang et al. (2019) and Durkalec-Michalski et al. (2020) showed that NaHCO<sub>3</sub> increases anaerobic capacity, peak power, and accelerates lactate clearance, which is particularly relevant for athletes who rely on the glycolytic system. These results support its use in sports such as field hockey and HIIT programs, where performance is determined by the ability to sustain high outputs for short, repeated periods. The findings of Leach et al. (2023) provide strong evidence that NaHCO<sub>3</sub> can improve high-intensity endurance performance in trained male cyclists. This highlights that the response to supplementation is also highly dependent on the population studied, with athletes with higher levels of training likely showing better efficacy due to their more optimal metabolic capacity to exploit the alkalotic environment.

It can be concluded that this review confirms that the benefits of NaHCO<sub>3</sub> supplementation are not universal but somewhat highly dependent on contextual variables such as type of sport, duration, and intensity of activity, level of training, and supplementation approach (dose and time of administration). However, most studies still use generic designs and limited populations, which limit the generalizability of the findings. In addition, there is still a lack of understanding of physiological biomarkers that can predict the response to NaHCO<sub>3</sub> and how they affect training adaptation in the long term. Aspects such as individual buffering capacity, hydration status, and basic nutritional profiles of athletes have also not been widely studied as modulators of the effects of this supplement. Given the differences in results and the complexity of the variables, further research needs to focus on the individualization of supplementation strategies, both in terms of time of administration (peak alkalosis time) and adaptive doses based on gastrointestinal tolerance and body weight. Testing the long-term effects of periodic NaHCO<sub>3</sub> use in a structured training program. Evaluation of the effects of NaHCO<sub>3</sub> in sports with mixed metabolic characteristics, such as soccer, futsal, or boxing. Exploration of the interaction between NaHCO<sub>3</sub> with other supplements, such as beta-alanine or creatine, which also function as buffers.

## CONCLUSION

Provide a statement that what is expected, as stated in the "Introduction" chapter can ultimately result in "Results and Discussion" chapter, so there is compatibility. Moreover, it can also be added to the prospect of the development of research results and application prospects of further studies into the next (based on result and discussion).

## ACKNOWLEDGMENT

Theium bicarbonate supplementation has been proven to improve sports performance, especially in high-intensity and short-medium duration activities. However, its effectiveness highly depends on the type of sport, the athlete's fitness level, the dose, and the proper administration time. An individualized approach and further research are needed to optimize its benefits specifically.

## AUTHOR CONTRIBUTION STATEMENT

MH and RK were responsible for designing and conceptualizing the study, collecting data, and drafting the initial manuscript. UAA, GGM, and ADRA were involved in data collection, results interpretation, and the manuscript's critical revision. SI also acted as the corresponding author, handling all communications and revisions related to the publication.

## CONFLICT OF INTEREST AND FUNDING

There is no conflict of interest

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