Ergogenic Effects of Sodium Bicarbonate Supplementation on Middle-, But Not Short-Distance Swimming Tests: A Meta-Analysis

Ergogenic effects of sodium bicarbonate supplementation on middle, but not short-distance swimming tests: a meta-analysis

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Abstract

This meta-analysis explored the effects of sodium bicarbonate supplementation on swimming performance. Seven databases were searched to find relevant studies. A random-effects meta-analysis of standardized mean differences (SMD) was performed to analyze the data. Nine studies were included in the review. There was no significant difference between placebo and sodium bicarbonate when considering data from all included studies (SMD: –0.10; $p = 0.208$) or in the subgroup analysis for 91.4-m and 100-m swimming tests (SMD: 0.11; $p = 0.261$). In the subgroup analysis for 200-m and 400-m swimming tests, there was a significant ergogenic effect of sodium bicarbonate (SMD: –0.22; $p < 0.001$; –1.3%). Overall, these results suggest that sodium bicarbonate ingestion improves performance in 200-m and 400-m swimming events. The ergogenic effects of this supplement were small, but they may also be of substantial practical importance given that placings in swimming competitions are commonly determined by narrow margins.

Keywords: ergogenic aid; data synthesis; NaHCO3; alkalosis

Introduction

Competitive swimming is a single-bout event. It involves swimming at a varied distance using different techniques. As is the case with many sports, placings in competitive swimming are often determined by narrow margins. This is likely best illustrated by the 100-m butterfly finales race results at the 2008 Beijing Olympics, where the difference between the first and second place was only one-hundredth of a second (i.e., 50.58 seconds vs. 50.59 seconds). Given the small differences in placings commonly seen in competitive swimming, the use of ergogenic aids in this sport may be of substantial practical importance.

One popular ergogenic aid is sodium bicarbonate (McNaughton, Gough, Deb, Bentley, & Sparks, 2016). The effects of sodium bicarbonate on exercise performance have been explored since the 1930s (Dennig, Talbott, Edwards, & Dill, 1931). Currently, sodium bicarbonate is considered a supplement with good evidence supporting its ergogenic effect on exercise performance (Maughan et al., 2018). Sodium bicarbonate primarily acts by increasing blood pH and bicarbonate levels, leading to an increased efflux of H^+ from muscles active during exercise into circulation (Heibel, Perim, Oliveira, McNaughton, & Saunders, 2018; Lancha Junior, de Salles Painelli, Saunders, & Artioli, 2015). The increase in H^+ removal during high-intensity exercise contributes to intramuscular pH maintenance, a delay in fatigue, and performance improvements (Heibel et al., 2018; Lancha Junior et al., 2015).

Even though sodium bicarbonate supplementation is commonly recommended for swimmers, there is no consensus regarding its ergogenic effects on swimming performance (Domínguez et al., 2017; Mujika, Stellingwerff, & Tipton, 2014). Several studies explored the effects of sodium bicarbonate on swimming performance, but the results reported in primary studies are conflicting (Campos et al., 2012; de Salles Painelli et al., 2013; Joyce, Minahan, Anderson, & Osborne, 2012; Kumstát, Hlinský, Struhár, & Thomas, 2018; Lindh, Peyrebrune, Ingham, Bailey, & Folland, 2008; Mero et al., 2013; Pierce, Eastman, Hammer, & Lynn, 1992; Pruscino, Ross, Gregory, Savage, & Flanagan, 2008; Yong, Yin, & Hoe, 2018). For example, in one study that involved nine elite-level swimmers, sodium bicarbonate ingestion improved 200-m freestyle swimming performance by 1.8 seconds (Lindh et al., 2018). However, a follow-up study that also involved elite swimmers and used the same swimming distance did not find a benefit of sodium bicarbonate ingestion (Joyce et al., 2012). One limitation of the studies on this topic is that they commonly include small sample sizes. For example, one study included only six participants (Pruscino et al., 2008). Due to the small sample sizes, it might be that some of the studies conducted on the topic were statistically underpowered to find small but practically meaningful ergogenic effects of sodium bicarbonate.

The limitation of small sample sizes in primary studies may be addressed by conducting a meta-analysis that allows combining data from different studies on a given topic to obtain a pooled estimate. Several meta-analyses explored sodium bicarbonate's effects on different exercise tasks and outcomes (Christensen, Shirai, Ritz, & Nordsborg, 2017; Grgic et al., 2020a; Grgic et al., 2020b; Lopes-Silva, Reale, & Franchini, 2019). However, none of these analyses focused specifically on swimming performance. Therefore, to address this gap in the literature, the aim of this review was to perform a meta-analysis on sodium bicarbonate's effects on swimming performance.

Methods

Search strategy

For this review, seven databases were searched, including: CINAHL, Networked Digital Library of Theses and Dissertations, Open Access Theses and Dissertations, PubMed/MEDLINE, SPORTDiscus, Scopus, and Web of Science. In all of these databases, the following search syntax was utilized: ("NaHCO3" OR "sodium bicarbonate" OR alkalosis) AND (swim OR swimming). The search was carried out on December 8th, 2020. In addition to the primary search, secondary searches were performed by examining: (i) studies that cited the included studies in Google Scholar and Scopus; and (ii) reference lists of included studies. The search for studies was performed independently by the two authors of the review.

Inclusion criteria

Studies that satisfied the following criteria were included: (i) explored the effects of isolated sodium bicarbonate ingestion on single-bout swimming performance, expressed as the time needed to complete a given event; (ii) utilized a randomized, double-blind, crossover and placebo-controlled study design; and (iii) included humans as study participants. Studies were excluded if they used repeated-bout swimming tests due to ecological validity, as competitions in this sport only include single-bout swimming. Still, studies that used a repeated-bout test were considered as long as they presented performance data for each bout separately. For example, one study used two 100-m freestyle swims and presented data for each 100-m bout separately (Mero et al., 2013). In this case, this study was included in the review, but only the first 100-m was considered for data analysis. Another study used eight 25-m front crawl maximal effort sprints, each separated by 5 seconds (Siegler & Gleadall-Siddall, 2010). However, this study was not included, as the authors only presented the total time needed to complete all eight sprints.

Data extraction

The two authors independently extracted the following data from the included studies: (i) lead author name and year of publication; (ii) participants characteristics; (iii) sodium bicarbonate supplementation protocol (e.g., dose, the timing of ingestion); (iv) changes blood bicarbonate from baseline levels to levels pre-exercise (if measured); (v) swimming test; and (vi) study findings. For studies that presented the data in the form of figures, Web Plot Digitizer software (https://apps.automeris.io/wpd/) was used to extract the necessary data. Standard errors (SEs) presented in one study (Pierce et al., 1992) were converted to standard deviation (SD).

Methodological quality

The methodological quality of the included studies was evaluated using the PEDro checklist (Maher, Sherrington, Herbert, Moseley, & Elkins, 2003). The PEDro checklist has 11 items that assess different methodological aspects, such as inclusion criteria, randomization, allocation concealment, blinding, attrition, and data reporting. Each item is scored with "1" provided the criterion is satisfied; if the criterion is not satisfied, the item is scored with "0". The first item on the PEDro checklist does not contribute to the total score, and therefore, the maximum possible number of points is 10. Studies were classified as excellent, good, fair, and poor methodological quality if they scored 9–10 points, 6–8 points, 4–5 points, and ≤3 points, respectively (Grgic et al., 2020b). The two authors of the review independently conducted the quality assessment. Upon completion, any discrepancies between the authors in the scores were resolved through discussion and agreement.

Statistical analysis

The swimming performance data were converted to standardized mean differences (SMD) and are presented with their respective 95% confidence intervals (CI). The performance mean ± SD data, total sample size, and inter-trial correlation are used to calculate SMDs. The included studies did not present inter-trial correlation, and therefore, correlation values were estimated as suggested in the Cochrane Handbook (Higgins & Altman, 2008). Two studies evaluated swimming performance under multiple sodium bicarbonate conditions (Joyce et al., 2012; Yong et al., 2018). To account for these correlated effects within the same study, we first calculated SMDs and variances for each comparison and then used the average values in the main analysis. In addition to the main analysis, two subgroup analyses were performed. One subgroup analysis examined the effects of sodium bicarbonate on performance in short-distance swimming tests (i.e., 91.4-m and 100-m). The second subgroup analysis explored the effects of sodium bicarbonate on performance in middle distance swimming tests (i.e., 200-m and 400-m). In this subgroup analysis, a sensitivity analysis was performed by excluding one study that used a 400-m swimming test. All meta-analyses were performed using the random-effects model. SMD values were interpreted as: trivial (<0.20), small (0.20–0.49), medium (0.50–0.79), and large (≥0.0.80), according to Cohen (1992). Negative SMD values indicate improvements in swimming performance (i.e., decreased time needed to complete a given test). Heterogeneity was explored using the I^2 statistic. I^2 was interpreted as low (<50%), moderate (50–75%), and high heterogeneity (>75%). The statistical significance threshold was set at $p < 0.05$. All analyses were performed using the Comprehensive Meta-analysis software, version 2 (Biostat Inc., Englewood, NJ, USA).

Results

Search results

In the primary search, there was a total of 221 results; 204 results were excluded after reading the title or abstract (Figure 1). After reading 17 full-text papers, nine studies were found that satisfied the inclusion criteria (Campos et al., 2012; de Salles Painelli et al., 2013; Joyce et al., 2012; Kumstát et al., 2018; Lindh et al., 2008; Mero et al., 2013; Pierce et al., 1992; Pruscino et al., 2008; Yong et al., 2018). There was an additional 818 search results in the secondary search, but there were no additional studies that met the inclusion criteria.

Summary of studies

Sample sizes in the included studies ranged from 6 to 13 participants (median: 8 participants). All studies included swimmers as study participants, even though they differed in their competitive levels (i.e., junior-standard swimmers, nationally ranked swimmers, varsity swimmers, or recreationally active swimmers). One study used a 91.4-m swimming distance, two studies used 100-m, five studies used 200-m, and one study used 400-m (Table 1). Doses of sodium bicarbonate ranged from 0.2 $g \cdot kg^{-1}$ to 0.3 $g \cdot kg^{-1}$. Timing of ingestion ranged from 60 to 120 minutes before exercise. One study also used a chronic sodium bicarbonate ingestion protocol, where a daily dose of 0.3 $g \cdot kg^{-1}$ was ingested for 3 days before the swimming test (Joyce et al., 2012). Performance data are reported in Table 2.

Methodological quality

All included studies scored either 9 or 10 points and were classified as being of excellent methodological quality (Table 1).

Meta-analysis results

In the main meta-analysis that considered data from all included studies, there was no significant difference between placebo and sodium bicarbonate (SMD: –0.10; 95% CI: –0.25, 0.06; p = 0.208; percent change: –0.8%; I^2 = 0%; Figure 2). In the subgroup analysis for 91.4-m and 100-m swimming tests, there was no significant difference between placebo and sodium bicarbonate (SMD: 0.11; 95% CI: –0.09, 0.31; p = 0.261; percent change: 0.6%; I^2 = 14%; Figure 2). In the subgroup analysis for 200-m and 400-m swimming tests, there was a significant ergogenic effect of sodium bicarbonate (SMD: –0.22; 95% CI: –0.35, –0.10; percent change: –1.3%; $p < 0.001$; I^2 = 0%; Figure 2). These results remained consistent in the sensitivity analysis where the study that used 400-m swimming test was excluded (SMD: –0.22; 95% CI: –0.35, –0.09; average percent change: –1.4%; p = 0.001; I^2 = 0%).

Discussion

In the primary meta-analysis that considered the data from all included studies, there was no significant difference between placebo and sodium bicarbonate. Additionally, there was no significant difference between sodium bicarbonate and placebo for short-distance swimming tests (i.e., 91.4-m and 100-m). However, when analyzing the data from studies using 200-m and 400-m swimming tests, sodium bicarbonate ingestion improved swimming performance by decreasing the time needed to complete the swimming event. Even though the effect size of sodium bicarbonate on swimming performance may be classified as small, it may also be of substantial practical importance given that placings in swimming competitions are commonly determined by narrow margins.

The exercise tasks' duration is an important methodological consideration when discussing the ergogenic effects of sodium bicarbonate. The International Olympic Committee concluded that sodium bicarbonate is ergogenic for exercise tests lasting between 1 and 10 minutes (Maughan et al., 2018). This duration-dependent effect might explain why this meta-analysis found an ergogenic effect of sodium bicarbonate on middle distance (i.e., 200-m and 400-m), but not short-distance (i.e., 91.4-m and 100-m) swimming tests. The time needed for the participants among the included studies to complete 91.4-m or 100-m swimming tests was between 53 and 64 seconds. In contrast, 200-m and 400-m swimming tests lasted much longer and were completed between 113 and 270 seconds. Therefore, based on the results presented in this meta-analysis, it seems that sodium bicarbonate ingestion is ergogenic only for middle distance swimming tests. These findings also provided further support for the results presented by McNaughton (1992). This study explored the effects of sodium bicarbonate on performance in cycling tasks lasting 10 s, 30 s, 120 s, and 240 s. An ergogenic effect of sodium bicarbonate on total work and peak power was shown only for the two cycling tests of longer duration. It was concluded that sodium bicarbonate may not be ergogenic for exercise tasks of shorter duration, given that performance in these tasks is not likely to be limited by the accumulation of H^+. These previous findings may explain why we observed an ergogenic effect of sodium bicarbonate only for middle distance swimming tests. Still, it should be considered that included studies used either short or middle distance swimming tasks. Therefore, this comparison is based on independent studies that also varied in other methodological aspects. Future studies that use different swimming tests are needed to directly establish the relationship between sodium bicarbonate's ergogenic effect and the distance (and duration) of the test.

Maximum effort swimming tests may cause a considerable amount of fatigue. After a single 200-m swimming event, several studies found very high blood lactate concentrations (~14 to 18 $mmol \cdot L^{-1}$), which is indicative of acidosis (Kachaunov, 2018; Vescovi, Falenchuk, & Wells, 2011). Indeed, one study reported that pH is reduced from 7.4 (recorded during rest) to 7.1 after maximum effort 200-m front crawl swimming (Kapus, Usaj, Strumbelj, & Kapus, 2008). Muscle acidosis may cause fatigue because the accumulating H^+ may impair muscle contractions (Lancha Junior et al., 2015). Additionally, acidosis is associated with an inhibition of phosphocreatine re-synthesis and inhibition of enzymes related to the glycolytic pathway (Lancha Junior et al., 2015). When sodium bicarbonate is ingested before an event, there is an increase in blood bicarbonate and pH levels (Bishop & Claudius, 2005; Lindh et al., 2008). Parallel with these physiological changes, there is an increase in extracellular buffering during high-intensity exercise, which ultimately contributes to pH maintenance and a delay in fatigue (Lancha Junior et al., 2015). These physiological mechanisms may explain the ergogenic effect of sodium bicarbonate found in this meta-analysis.

It has been recently suggested that the increase in blood bicarbonate from baseline levels to those recorded directly before exercise is one of the key factors determining the ergogenic effects of sodium bicarbonate (Heibel et al., 2018). Specifically, one recent review suggested that an increase by 5 $mmol \cdot L^{-1}$ and 6 $mmol \cdot L^{-1}$ will lead to a *likely* and *almost certain* ergogenic effect of sodium bicarbonate (Heibel et al., 2018). Four studies included in this review did not measure blood parameters, and therefore the increase in blood bicarbonate levels remains unclear (Campos et al., 2012; de Salles Painelli et al., 2013; Pierce et al., 1992; Yong et al., 2018). Out of the five studies that assessed blood bicarbonate changes, all reported an increase of around 5 to 7 $mmol \cdot L^{-1}$. In four of these studies, the SMD was towards the "favors sodium bicarbonate" side of the forest plot, and the 95% CIs of these studies overlapped (Joyce et al., 2012; Kumstát et al., 2018; Lindh et al., 2008; Pruscino et al., 2008). One study recorded an increase of 6 mmol·L^{-1}, but this study's effect was in the opposite direction and favored placebo (Mero et al., 2013). This might suggest that the changes in blood bicarbonate levels might not determine the ergogenic potential of sodium bicarbonate. However, it should also be considered that this study used a 100-m swimming distance while all other studies that measured blood bicarbonate used 200-m or 400-m swimming events, which might largely explain this variation in effects between studies.

It has been suggested that the effects of sodium bicarbonate may be greater in smaller vs. larger muscle groups (Sostaric et al., 2006). This hypothesis is based on the higher blood flow in small muscle groups during exercise, which may be associated with a greater ion exchange within the muscle (Sostaric et al., 2006). Therefore, the effects of sodium bicarbonate on swimming performance, which is a whole-body exercise, might be smaller than the effects of sodium bicarbonate on predominantly lower-limb exercise (e.g., running or cycling). However, the pooled effect size and its corresponding 95% CI (SMD: 0.22; 95% CI: 0.09, 0.35) observed in this meta-analysis largely overlaps with the ergogenic effects of sodium bicarbonate previously reported for Yo-Yo test (SMD: 0.36; 95% CI: 0.10, 0.63) and Wingate test performance (SMD: 0.09 to 0.62; 95% CI: 0.03 to 1.08) (Grgic, 2020; Grgic et al., 2020a). Based on this comparison, it would seem that the ergogenic effects of sodium bicarbonate are not likely to be influenced by the size of the muscles activated during exercise. This is further supported by one meta-analysis that reported similar ergogenic effects of sodium bicarbonate on muscular endurance of small (SMD: 0.31; 95% CI: 0.04, 0.59) and large muscle groups (SMD: 0.40; 95% CI: 0.13, 0.66) (Grgic et al., 2020b).

Methodological quality

All included studies utilized a randomized, double-blind design, which is considered the "gold standard" study design in sports nutrition (Maughan et al., 2018). Accordingly, all studies were classified as "excellent" methodological quality on the PEDro checklist. One limitation observed in the included studies is that they generally did not evaluate the effectiveness of the blinding to the placebo and sodium bicarbonate conditions. This should be highlighted given the recent findings that correct supplement identification may impact the outcome of an exercise task and lead to bias in the results (Saunders et al., 2017). Only one study explored the effectiveness of blinding and found that 60% of participants correctly identified the sodium bicarbonate condition (de Salles Painelli et al., 2013). Given that this procedure was employed only in one study, this limitation should be addressed in future research. On a final note, none of the included studies reported any funding from parties that might have had some financial interest, suggesting that the results presented in this review are not likely confounded by the inclusion of studies that might have been influenced by financial bias.

Conclusion

When considering the data from all available studies, there was no significant difference between placebo and sodium bicarbonate for swimming performance. Additionally, there was no significant difference in a subgroup analysis that considered short-distance swimming tests (i.e., 91.4-m and 100-m). Still, when considering data from studies that used 200-m and 400-m swimming tests, this meta-analysis found that sodium bicarbonate ingestion improves swimming performance by decreasing the time needed to complete a given swimming event (SMD: –0.22; percent change: –1.3%). Even though the effect size of sodium bicarbonate on swimming performance may be classified as small, it may also be of substantial practical importance given that placings in swimming competitions are commonly determined by narrow margins.

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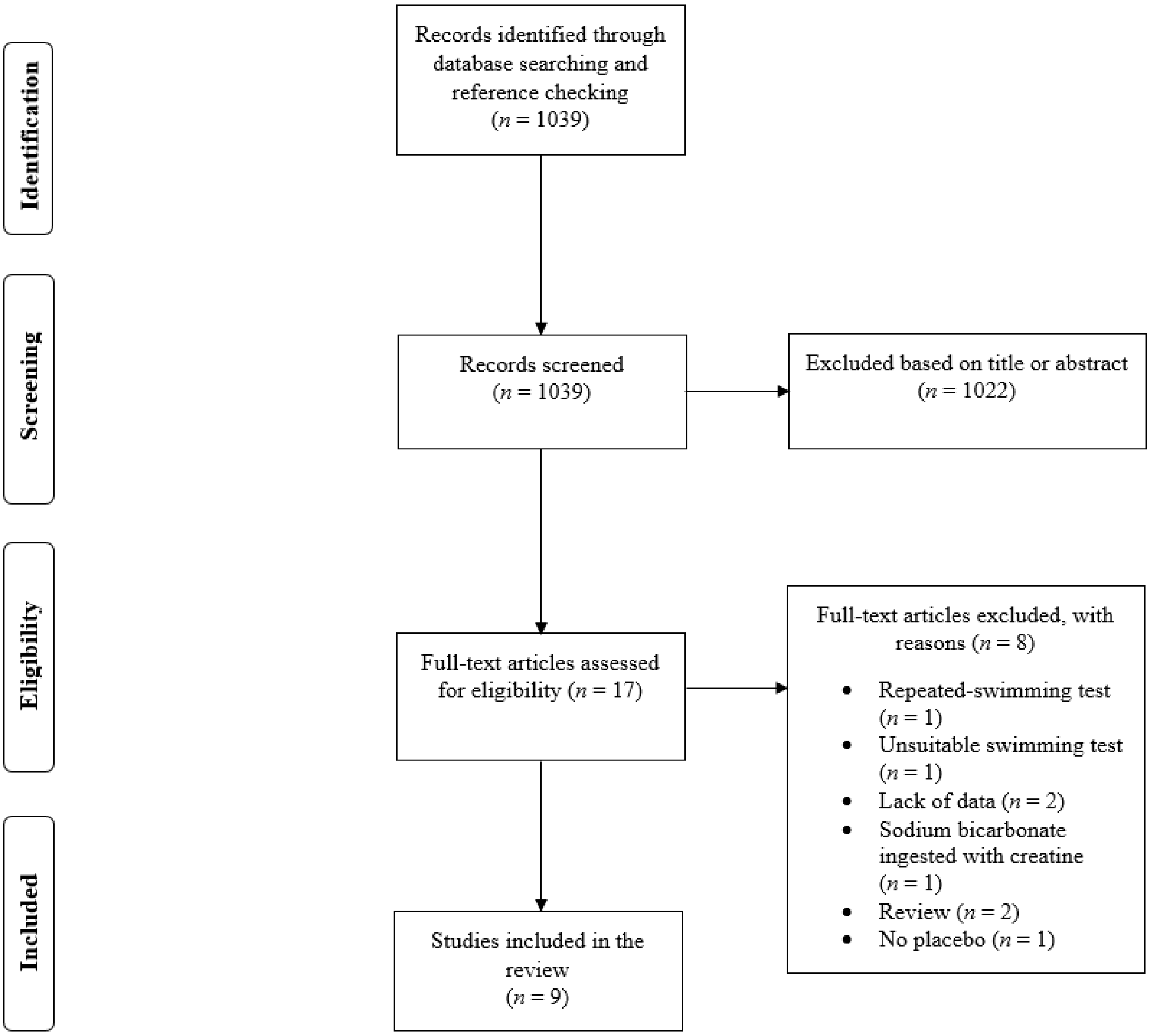
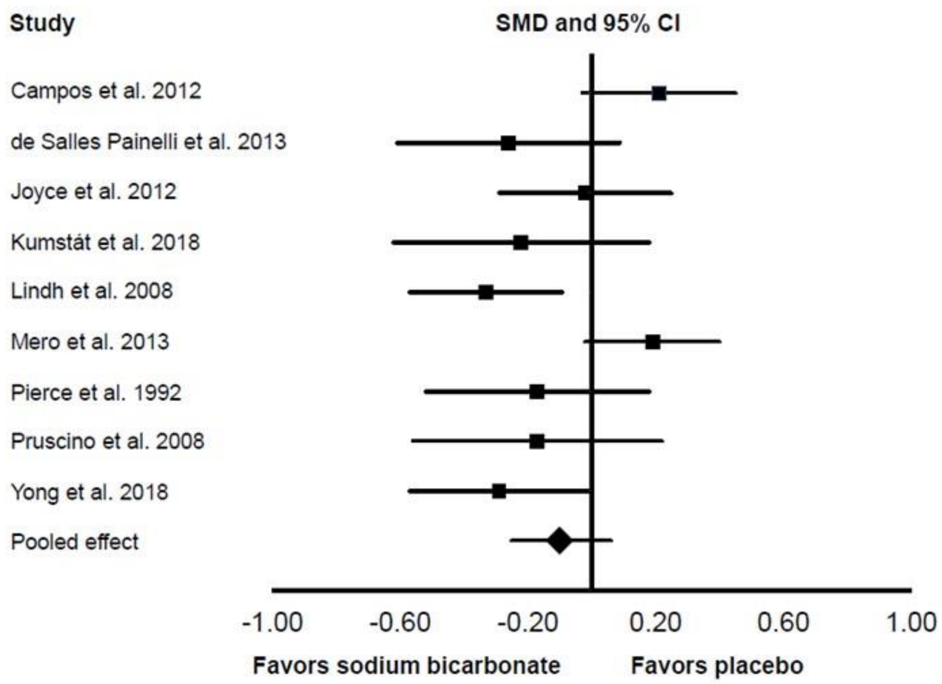
Figure 1. Flow diagram of the search process

Figure 2. Forest plot presenting the results of the random-effects meta-analysis comparing the effects of placebo vs. sodium bicarbonate swimming performance (upper-section); comparing the effects of placebo vs. sodium bicarbonate swimming performance when considering only data from studies that used 91.4-m or 100-m swimming tests (middle-section); comparing the effects of placebo vs. sodium bicarbonate swimming performance when considering only data from studies that used 200-m or 400-m swimming tests (lower-section). Data are reported as standardized mean differences (SMD) and 95% confidence intervals (CIs). The diamond at the bottom presents the overall effect. The plotted squares denote SMD and the whiskers denote their 95% CIs.




Study
SMD and 95% CI
Campos et al. 2012
de Salles Painelli et al. 2013
Joyce et al. 2012
Kumstát et al. 2018
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Mero et al. 2013
Pierce et al. 1992
Pruscino et al. 2008
Yong et al. 2018
Pooled effect
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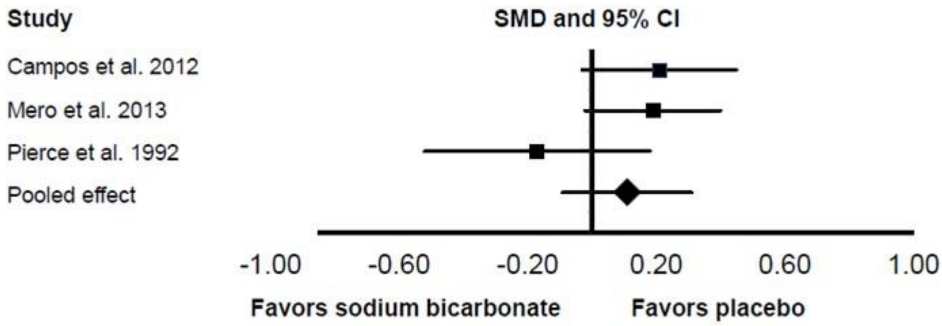
Favors sodium bicarbonate
Favors placebo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Favors sodium bicarbonate
Favors placebo

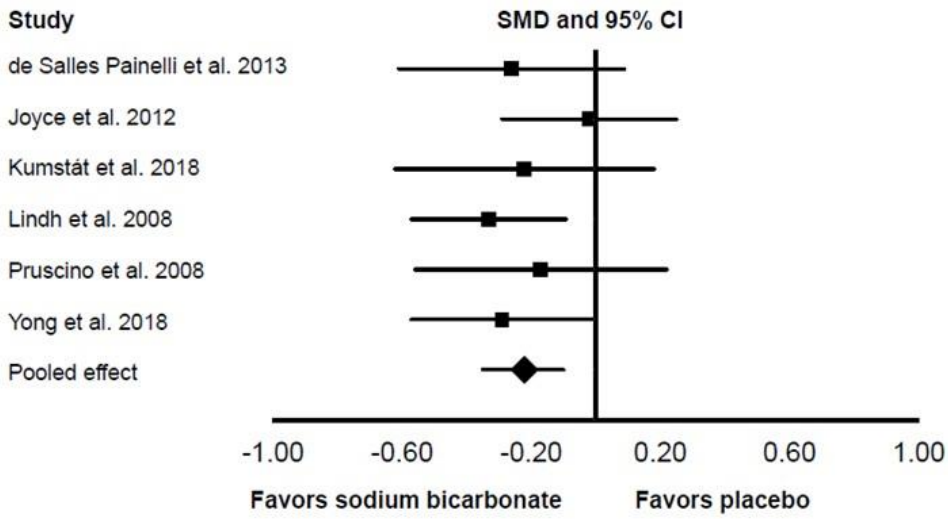
Study
SMD and 95% CI
de Salles Painelli et al. 2013
Joyce et al. 2012
Kumstát et al. 2018
Lindh et al. 2008
Pruscino et al. 2008
Yong et al. 2018
Pooled effect
-1.00
-0.60
-0.20
0.20
0.60
1.00
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Table 1. Summary of studies included in the review

Reference	Participants	Sodium bicarbonate protocol	Swimming test	Changes in blood bicarbonate[a]	Percentage change	PEDro score
Campos et al. (2012)	10 competitive swimmers (7 male, 3 female)	0.3 g·kg^{-1} ingested 60 minutes before exercise	100-m front crawl	Not assessed	↑ 0.9%	9
de Salles Painelli et al. (2013)	14 junior-standard swimmers (7 male, 7 female)[b]	0.3 g·kg^{-1} ingested 90 minutes before exercise	200-m freestyle	Not assessed	200-m: ↓ 2.4%	9
Joyce et al. (2012)	8 highly trained male swimmers	Acute: 0.3 g·kg^{-1} ingested 120-90 minutes before exercise Chronic: daily dose of 0.3 g·kg^{-1} ingested for 3 days before exercise; 0.1 g·kg^{-1} ingested 120-90 minutes before exercise	200-m using preferred stroke	Acute: ~6 mmol·L^{-1} Chronic: ~3 mmol·L^{-1}	Acute: ↑ 0.3% Chronic: ↓ 0.6%	10
Kumstát et al. (2018)	6 nationally ranked male swimmers	0.3 g·kg^{-1} ingested 90 minutes before exercise	400-m freestyle	~ 5 mmol·L^{-1}	↓ 0.3%	9
Lindh et al. (2008)	9 male elite-standard swimmers	0.3 g·kg^{-1} ingested 90 minutes before exercise	200-m freestyle	~ 6 mmol·L^{-1}	↓ 1.6%	9
Mero et al. (2013)	13 competitive male swimmers	0.3 g·kg^{-1} ingested 60 minutes before exercise	100-m freestyle	~ 6 mmol·L^{-1}	↑ 0.9%	9
Pierce et al. (1992)	7 male varsity swimmers	0.2 g·kg^{-1} ingested 60 minutes before exercise	91.4-m freestyle	Not assessed	↓ 0.8%	9
Pruscino et al. (2008)	6 elite male freestyle swimmers	0.3 g·kg^{-1} ingested 90 minutes before exercise in seven smaller doses	200-m freestyle	~ 7 mmol·L^{-1}	↓ 0.6%	9
Yong et al. (2018)	8 recreationally active male swimmers	0.2 g·kg^{-1} or 0.3 g·kg^{-1} ingested 90 minutes before exercise	200-m freestyle	Not assessed	0.2 g·kg^{-1}: ↓ 4.1% 0.3 g·kg^{-1}: ↓ 1.3%	9

[a]changes in blood bicarbonate from baseline values to values pre-exercise; [b]data from only 7 participants were included in the analysis: ↑ increase in the time needed to complete the swimming event (favoring of placebo); ↓ decrease in the time needed to complete the swimming event (favoring of sodium bicarbonate)

Table 2. Data reported in the included studies

Study	Swimming test	Sodium bicarbonate dose	Swimming time (sodium bicarbonte)*	Swimming time (placebo)*
Campos et al. (2012)	100-m front crawl	0.3 g/kg pre-exercise	63.0 ± 2.37 s	62.4 ± 2.65 s
de Salles Painelli et al. (2013)	200-m freestyle	0.3 g/kg pre-exercise	135.4 ± 10.0 s	138.7 ± 11.4 s
Joyce et al. (2012)	200-m using preferred stroke	0.3 g/kg pre-exercise	119.57 ± 6.21 s	119.2 ± 5.82 s
	200-m using preferred stroke	0.3 g/kg consumed for 3 days pre-exercise	118.53 ± 5.64 s	119.2 ± 5.82 s
Kumstát et al. (2018)	400-m freestyle	0.3 g/kg pre-exercise	269.48 ± 2.8 s	270.21 ± 2.7 s
Lindh et al. (2008)	200-m freestyle	0.3 g/kg pre-exercise	112.2 ± 4.7 s	114.0 ± 3.6 s
Mero et al. (2013)	100-m freestyle	0.3 g/kg pre-exercise	57.6 ± 2.47 s	57.1 ± 2.47 s
Pierce et al. (1992)	91.4-m freestyle	0.2 g/kg pre-exercise	53.63 ± 2.22	54.08 ± 2.33 s
Pruscino et al. (2008)	200-m freestyle	0.3 g/kg pre-exercise	123.01 ± 3.68 s	123.77 ± 3.21 s
Yong et al. (2018)	200-m freestyle	0.2 g/kg pre-exercise	162 ± 12 s	169 ± 17 s
	200-m freestyle	0.3 g/kg pre-exercise	164 ± 17 s	169 ± 17 s
* Data are reported as mean ± standard deviation				