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Title	Isolated effects of caffeine and sodium bicarbonate ingestion on performance in the Yo-Yo test: A systematic review and meta-analysis
Type	Article
URL	https://clock.uclan.ac.uk/29792/
DOI	https://doi.org/10.1016/j.jsams.2019.08.016
Date	2019
Citation	Grgic, Jozo, Garofolini, Alessandro, Pickering, Craig, Duncan, Michael J, Tinsley, Grant M and Del Coso, Juan (2019) Isolated effects of caffeine and sodium bicarbonate ingestion on performance in the Yo-Yo test: A systematic review and meta-analysis. Journal of Science and Medicine in Sport. ISSN 1440-2440
Creators	Grgic, Jozo, Garofolini, Alessandro, Pickering, Craig, Duncan, Michael J, Tinsley, Grant M and Del Coso, Juan

It is advisable to refer to the publisher's version if you intend to cite from the work.
<https://doi.org/10.1016/j.jsams.2019.08.016>

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1 **Abstract**

2 **OBJECTIVES:** To conduct a systematic review and a meta-analysis of studies exploring the
3 effects of caffeine and/or sodium bicarbonate on performance in the Yo-Yo test.

4 **DESIGN:** Systematic review/meta-analysis.

5 **METHODS:** A total of six databases were searched, and random-effects meta-analyses were
6 performed examining the isolated effects of caffeine and sodium bicarbonate on performance
7 in the Yo-Yo test.

8 **RESULTS:** After reviewing 988 search records, 15 studies were included. For the effects of
9 caffeine on performance in the Yo-Yo test, the meta-analysis indicated a significant favoring
10 of caffeine as compared with the placebo conditions ($p = 0.022$; standardized mean difference
11 [SMD] = 0.17; 95% CI: 0.08, 0.32; +7.5%). Subgroup analyses indicated that the effects of
12 caffeine were significant for the level 2 version of the Yo-Yo test, but not level 1. Four out of
13 the five studies that explored the effects of sodium bicarbonate used the level 2 version of the
14 Yo-Yo test. **The pooled SMD favored the sodium bicarbonate condition as compared with the
15 placebo/control conditions ($p = 0.007$; SMD: 0.36; 95% CI: 0.10, 0.63; +16.0%).**

16 **CONCLUSIONS:** This review demonstrates that isolated ingestion of caffeine and sodium
17 bicarbonate enhances performance in the Yo-Yo test. Given these ergogenic effects, the
18 intake of caffeine and sodium bicarbonate before the Yo-Yo test needs to be standardized
19 **(i.e., either restricted or used in the same way before each testing session).** Furthermore, the
20 results suggest that individuals competing in sports involving intermittent exercise may
21 consider supplementing with caffeine or sodium bicarbonate for acute improvements in
22 performance.

23 **Introduction**

24 The Yo-Yo intermittent recovery test was introduced in the 1990s and has gained substantial
25 popularity as a method of estimating aerobic and anaerobic capacity in team-sports players.¹
26 In undertaking the Yo-Yo intermittent recovery test, participants are required to run distances
27 of 2×20 m at progressively increasing speeds. Each 2×20 m work block is interspersed with
28 a 10-s period of jogging around a marker placed 5 m behind the finish line. The test ends
29 when the individual cannot complete the run within the prescribed time, on two consecutive
30 occasions. The outcome of this test is the total covered distance. This test is comprised of two
31 sub-levels, level 1 and level 2, with level 2 starting at a higher initial speed and necessitating a
32 large contribution from the anaerobic energy system.¹ These tests are widely used in field
33 settings as a practical method to: (a) determine current fitness status; and (b) prescribe
34 training programs and explore their effectiveness.²

35
36 Caffeine and sodium bicarbonate are two supplements that have been shown to acutely
37 enhance exercise performance.³ The effects of caffeine and sodium bicarbonate have also
38 been explored in the context of Yo-Yo test performance, with equivocal findings.⁴⁻⁸ Some
39 reported an increase in performance following the ingestion of either caffeine or sodium
40 bicarbonate, while others report that performance in this test is unaffected by the use of these
41 supplements.⁴⁻⁸ Differences between the studies such as the dose, ingestion timing, and
42 training status may explain some of these discrepancies.⁹ Perhaps even more importantly, the
43 studies conducted on the effects of sports supplements tend to be performed with small
44 sample sizes.³ For example, one study that explored the effects of sodium bicarbonate on
45 performance in the Yo-Yo test included only six participants.⁸ Therefore, there remains a
46 possibility that some studies were statistically underpowered to observe significant effects,
47 which may have resulted in increased probabilities of type II errors. Meta-analysis is a

48 statistical method that can be used to overcome the limitation of underpowered studies
49 because it allows combining of data from different cohorts to obtain a pooled estimated value.

50

51 To address the apparent discrepancies between individual studies two previous meta-analyses
52 explored the effects of caffeine on performance in the Yo-Yo test. In the first analysis,
53 Gonçalves Ribeiro et al.¹⁰ reported no significant effects of caffeine on performance in this
54 test. However, the analysis included only two studies with a combined number of participants
55 amounting to 31. Such a small number of studies was included given that the authors limited
56 their inclusion criteria to studies published between 2010 and 2015, even though no rationale
57 was provided for this approach. Another limitation is that these authors included both cross-
58 over and between-group study designs. This may be relevant given that the inter-individual
59 variation in responses to caffeine ingestion is not as well controlled in between-group designs
60 as in cross-over trials.¹¹

61

62 In another review, Salinero et al.¹² reported that caffeine ingestion enhances performance in
63 the Yo-Yo test by an effect size of 0.22 with a 95% confidence interval (CI) ranging from
64 0.00 to 0.44. This meta-analysis included only four studies (pooled $n = 57$) given that studies
65 providing caffeine in doses lower than $2 \text{ mg}\cdot\text{kg}^{-1}$ were not considered. Additionally, this
66 review did not search through unpublished literature, which may have led to publication bias
67 due to the “file drawer” syndrome. The “file drawer” syndrome suggests that studies with
68 larger effect sizes are more likely to be published than those with small or non-significant
69 effect sizes; therefore, including only published studies may present a source of bias in a
70 given meta-analysis.^{13, 14} Additionally, two studies^{4, 15} were not included in the review by
71 Salinero et al.¹² and new studies on this topic have been published since this review.^{7, 16} All
72 these studies generated data for over 100 additional participants. Therefore, an updated meta-

73 analysis that would include these studies could contain almost a threefold increase in the
74 pooled sample size from the most recent meta-analysis¹² thus increasing the veracity of the
75 findings.

76

77 While the effects of caffeine have been explored using a meta-analytic approach, no previous
78 meta-analyses explored the effects of sodium bicarbonate on performance in the Yo-Yo test.
79 A meta-analysis exploring the effects of sodium bicarbonate on performance in this test is
80 needed because: (a) the equivocal evidence on this topic presented in the literature;^{5,6,8} and,
81 (b) the common anecdotal use of sodium bicarbonate by athletes.¹⁷ Therefore, the aim of this
82 review was to explore the effects of caffeine and sodium bicarbonate on performance in the
83 Yo-Yo testing using a meta-analysis and highlight the practical application of these findings.

84

85 **Methods**

86 For this review, peer-reviewed literature in the form of journal articles and unpublished
87 literature in the form of a thesis, dissertations, or conference abstracts that investigated the
88 effects of caffeine and/or sodium bicarbonate ingestion on performance in the Yo-Yo test was
89 examined. The search for studies was conducted on April 14th, 2019. The following databases
90 were searched: ERIC, PubMed/MEDLINE, SPORTDiscus, Open Access Thesis and
91 Dissertations, Web of Science, and Scopus. Additionally, searches were performed within
92 ResearchGate. In all of these databases, the following search syntax was used: ("caffeine" OR
93 "supplement" OR "coffee" OR "ergogenic" OR "NaHCO₃" OR "sodium bicarbonate") AND
94 ("yo-yo" OR "yoyo" OR "yo yo"). Secondary searches were performed by screening the
95 reference lists of the included studies, and by exploring the papers that cited the included
96 studies. The search was performed independently by two authors (JG and AG).

97

98 To be included in the review, studies were required to satisfy the following criteria: (1)
99 published in English; (2) included apparently healthy humans as participants; and (3)
100 employed a cross-over study design and explored the acute effects of caffeine and/or sodium
101 bicarbonate on performance in any variant of the Yo-Yo test.

102

103 Two authors of the review (JG and AG) extracted the following data from the included
104 studies: (1) author names and publication year; (2) sample size and the sample characteristics;
105 (3) the variant of the Yo-Yo test used for the testing; and (4) main findings regarding the
106 effects of caffeine and/or sodium bicarbonate on performance. In cases where the required
107 data was presented in figures, the Web Plot Digitizer software was used for the extraction of
108 raw values.

109

110 The PEDro checklist was used for assessing the quality of the included studies.¹⁸ This
111 checklist has 11 items; these items refer to eligibility criteria, randomization and blinding of
112 participants, blinding of assessors, the number of participants completing all testing sessions,
113 and reporting of data for the key outcomes. While this checklist has 11 points, the first item is
114 not included in the summary score, and therefore, the maximum number of points is 10.

115 Based on the summary scores, the studies were classified as being of excellent quality (9-10
116 points), good quality (6-8 points), fair quality (4-5 points) and poor methodological quality
117 (<3 points).¹⁹⁻²¹ The quality assessment was conducted independently by two authors of the
118 review (JG and AG).

119

120 The mean \pm standard deviation performance data extracted from the included studies were
121 converted to standardized mean differences (SMDs) and their respective 95% CIs. The
122 following data are required to calculate SMDs: (1) Yo-Yo test performance mean \pm standard

123 deviation of the caffeine/sodium bicarbonate and placebo/control trials, (2) total sample size,
124 and (3) inter-trial correlation. Inter-trial correlation was not presented in any of the included
125 studies. As suggested in the Cochrane Handbook the following formula was used to estimate
126 the correlation:

127

$$128 \quad r = \frac{S_{\text{placebo/control}}^2 + S_{\text{treatment}}^2 - S_D^2}{2 \cdot S_{\text{placebo/control}} \cdot S_{\text{treatment}}}$$

129

130

131 S represents the standard deviation while S_D is the standard deviation of the difference score,
132 which was calculated as:

133

$$134 \quad S_D = \left(\frac{S_{\text{placebo/control}}^2}{n} + \frac{S_{\text{treatment}}^2}{n} \right)^{1/2}$$

135

136 One of the studies that explored the effects of caffeine used multiple caffeine doses; for this
137 study, SMDs and variances were calculated for each dose separately and the average values
138 were used for the analysis. Two meta-analyses were performed: (1) for the effects of caffeine
139 on performance in the Yo-Yo test; and (2) for the effects of sodium bicarbonate on
140 performance in the Yo-Yo test. In the meta-analysis that focused on the effects of caffeine, a
141 sensitivity analysis was performed by excluding one study in which caffeine was not ingested
142 as it was provided in a mouth rinsing form.²² A subgroup analysis was performed for studies
143 exploring the effects of caffeine on Yo-Yo intermittent recovery level 1 and for those
144 exploring the level 2 variant of the test. In the meta-analysis for the effects of sodium
145 bicarbonate, a sensitivity analysis was performed by excluding the only study that used the

146 level 1 version of the test. SMD values of <0.20, 0.20-0.39, 0.40-0.59, 0.60-0.80, and >0.80
147 were considered to represent trivial, small, medium, large, and very large effects, respectively.
148 In each analysis, the I^2 statistic was used to explore heterogeneity with I^2 values of <50%, 50
149 to 75%, and >75% considered as low levels, moderate levels, and high levels of
150 heterogeneity.

151

152 In addition to 95% CIs, 95% prediction intervals (95% PI) were calculated for both analyses
153 by using the number of included studies in the meta-analysis, the pooled SMD, the upper limit
154 of the 95% CI and the tau-squared values. The 95% PI denotes the range in which the effect
155 size of a future study conducted on the topic will most likely be. Funnel plots asymmetry was
156 explored only for the effects of caffeine given that there were less than 10 studies included in
157 the analyses for sodium bicarbonate. Percent differences between supplement ingestion
158 conditions and the placebo/control conditions were also calculated. The random-effects model
159 was used for both analyses. The statistical significance threshold was set at $p < 0.05$. All
160 analyses were performed using the Comprehensive Meta-analysis software, version 2 (Biostat
161 Inc., Englewood, NJ, USA).

162

163 **Results**

164 The total number of search results across all databases was 164. Of this number of search
165 results, 21 full-text papers were read and 12 studies were included. The remaining documents
166 were excluded based on the title or abstract. The secondary searches resulted in another 824
167 search results and in the inclusion of three additional studies. Therefore, in total, 15 studies
168 were included; 13 studies were published as full-text manuscripts in peer-reviewed journals,
169 one study was published as a conference abstract, and one study is a part of a master's thesis.⁴⁻
170 ^{8,13,15,16,22-28} Eleven studies explored the effects of caffeine, whereas five studies examined the

171 effects of sodium bicarbonate on Yo-Yo test performance (Table 1). One study included
172 examined the isolated effects of both caffeine and sodium bicarbonate.

173

174 For studies that explored the effects of caffeine, the pooled number of participants across all
175 studies was 156 (21 females). The average sample size per study was 14 participants. In all of
176 the included studies, the sample was comprised of athletes. The doses of caffeine in the
177 studies ranged from 1 mg·kg⁻¹ to 6 mg·kg⁻¹. Five studies provided absolute doses of caffeine
178 ranging from 200 to 500 mg. One study used a caffeine mouth rinsing form where 1.2% of the
179 25 ml solution was caffeine. Timing of caffeine administration before exercise ranged from
180 immediately before (one study), 5 minutes (two studies), 45 minutes (two studies), 50 minutes
181 (one study), 60 minutes (four studies) and 70 minutes (one study) before exercise. Five
182 studies used the intermittent Yo-Yo recovery test level 1 and six used the level 2 version.

183

184 The pooled number of participants for the studies that explored the effects of sodium
185 bicarbonate was 46 (all males). The average sample size per study was 9 participants. Three
186 studies included athletes as their study participants while two included recreationally active
187 individuals. The doses of sodium bicarbonate in the studies ranged from 0.2 g·kg⁻¹ to 0.4 g·kg⁻¹
188 ¹. Sodium bicarbonate was ingested 40 minutes pre-exercise (one study), 60 minutes (one
189 study), and 90 minutes pre-exercise (two studies). One study used a protocol that included
190 splitting up a dose of 0.4 g·kg⁻¹ into five smaller doses taken at 90, 80, 70, 60, and 50 minutes
191 pre-exercise. Four studies used the intermitted Yo-Yo recovery test level 2, with only one
192 using the level 1 version.

193

194 Out of the eleven studies that explored the effects of caffeine on Yo-Yo test performance,
195 eight were classified as being of excellent quality with two studies being classified as good

196 methodological quality and one as fair methodological quality. Out of the five studies that
197 explored the effects of sodium bicarbonate on Yo-Yo test performance, three were classified
198 as being of excellent quality, one as good methodological quality and one study as being of
199 fair methodological quality. No studies were classified as being poor methodological quality.
200 Individual scores for the quality assessment can be found in Supplementary file 1.

201

202 The meta-analysis for the effects of caffeine included a total of ten studies given that in one
203 study, the data required for the analysis was not presented and the authors did not provide the
204 data upon written request.²² The main meta-analysis indicated a significant difference ($p =$
205 0.022) between the caffeine and placebo conditions with the SMD favoring the caffeine
206 condition (SMD: 0.17; 95% CI: 0.08, 0.32; percent change: +7.5%; I^2 : 28%; 95% PI: -0.32,
207 0.66; Figure 1). No funnel plot asymmetry was observed. In the sensitivity analysis in which
208 the study that provided caffeine in a mouth rinsing form was excluded, the SMD values
209 increased to 0.20 (95% CI: 0.05, 0.36; $p = 0.009$; percent change: +8.5%; I^2 : 26%). In the
210 subgroup analysis for the level 1 Yo-Yo test the SMD was 0.02 (95% CI: -0.21, 0.25; $p =$
211 0.880; percent change: +2.5%; I^2 : 0%). In the subgroup analysis for the level 2 Yo-Yo test the
212 SMD was 0.31 (95% CI: 0.12, 0.51; $p = 0.002$; percent change: +14.4%; I^2 : 11%).

213

214 The meta-analysis for the effects of sodium bicarbonate indicated a significant difference ($p =$
215 0.007) between the sodium bicarbonate and placebo/control conditions. The pooled SMD
216 favored the sodium bicarbonate condition (SMD: 0.36; 95% CI: 0.10, 0.63; percent change:
217 +16.0%; I^2 : 14%; 95% PI: -0.61, 1.33; Figure 2). In the sensitivity analysis in which the study
218 that used the level 1 Yo-Yo test version was excluded, the SMD values increased to 0.39
219 (95% CI: 0.08, 0.70; $p = 0.013$; percent change: +17.5%; I^2 : 25%).

220

221 **Discussion**

222 This review reports that isolated ingestion of caffeine and sodium bicarbonate enhances
223 performance in the Yo-Yo test. Both supplements seem to produce moderate performance-
224 enhancing effects. Due to these acute ergogenic effects, the intake of caffeine and sodium
225 bicarbonate before the Yo-Yo test needs to be standardized. The results also suggest that
226 individuals competing in sports involving intermittent exercise may consider supplementing
227 with caffeine or sodium bicarbonate for acute improvements in performance.

228

229 This meta-analysis adds further evidence that caffeine ingestion enhances performance in
230 field-based tests of fitness. These results are in line with prior work in the area, most of which
231 is based on tests performed in the laboratory.¹⁴ Caffeine's ergogenic effect is likely related to
232 its binding to adenosine receptors.²⁹ Caffeine has a similar structure to adenosine and
233 therefore, when ingested, caffeine binds to A₁ and A_{2A} receptors, ultimately blunting the
234 fatiguing effects of adenosine. As a result, acute caffeine ingestion may reduce perceived
235 effort and increase physical performance. Caffeine ingestion may also enhance motor unit
236 recruitment, thus leading to more forceful muscle contractions.^{30,31} These mechanisms might
237 explain why the pooled SMD increased when the study that provided caffeine in the mouth
238 rinsing form was excluded.²² After excluding the study that utilized caffeine mouth rinsing,
239 the SMD increased from 0.17 to 0.20. Specifically, caffeine provided in this form does not
240 increase plasma caffeine concentration³² which is a likely prerequisite for an ergogenic effect
241 of caffeine.

242

243 Due to a small number of included studies, previous meta-analyses did not examine if the
244 effects of caffeine differ between level 1 and level 2 versions of the Yo-Yo test. These

245 subgroup analyses were performed in the present review and indicated that the effects of
246 caffeine were significant only for the level 2 version. Such findings may suggest that caffeine
247 is more effective in tests with a greater contribution from the anaerobic energy system.¹ These
248 results were obtained from studies that examined the effects of caffeine on either level 1 or
249 level 2 versions of the test. However, given the inter-individual variation in responses to
250 caffeine ingestion,^{11,33,34} future studies may consider comparing the effects of caffeine on
251 performance in the level 1 and level 2 version of the test in the same group of participants.

252

253 Based on the results of this review, sodium bicarbonate is effective for acute increases in Yo-
254 Yo test performance. Sodium bicarbonate may elicit its ergogenic effects by: (a) acutely
255 increasing blood bicarbonate and leading to a greater efflux of hydrogen ions (H^+) and lactate
256 out of the active muscles and into the circulation; and subsequently, (b) maintenance of
257 intramuscular pH.^{35,36} Following acute sodium bicarbonate ingestion and subsequent increase
258 in blood bicarbonate concentration, the resultant pH gradient between the intracellular and
259 extracellular environments favors the efflux of H^+ from the exercising muscle to blood, aiding
260 intracellular pH regulation and reducing fatigue.^{35,36}

261

262 While no previous meta-analysis examined the effects of sodium bicarbonate on Yo-Yo test
263 performance, other meta-analyses have focused on different aspects of exercise performance.
264 For example, Matson and Tran³⁷ combined studies that explored the effects of sodium
265 bicarbonate on various exercise tests, with some lasting over 30 minutes and others being of
266 very short duration, and maximal intensity (e.g., 10-second “all-out” sprints). The pooled
267 ergogenic effect size of sodium bicarbonate was 0.44. The magnitude of the effect is
268 comparable to the effect size observed herein, even though an argument can be made that the

269 pooling of vastly different exercise tests (with different physiological demands) in the
270 analysis by Matson and Tran³⁷ might have been a methodological limitation. A meta-analysis
271 by Carr et al.³⁸ reported an ergogenic effect of acute sodium bicarbonate ingestion that
272 amounted to 1.7%. The performance-enhancing effect in the analysis by Carr et al.³⁸ was
273 small likely because it included many of the older studies that used protocols in which all
274 participants ingest sodium bicarbonate around 60 to 90 minutes before exercise.^{9,39,40}
275 However, in recent years, studies have started using individualized time to peak blood
276 bicarbonate protocols, and they generally report greater effect sizes.^{9,39,40} The majority of
277 studies included in the meta-analysis utilized performance tests lasting up to 30 seconds (i.e.,
278 much shorter than the average duration of the Yo-Yo test), which limits further comparison of
279 the results. Nonetheless, this review reinforces the suggestion of the International Olympic
280 Committee that acute sodium bicarbonate ingestion enhances short-term high-intensity
281 exercise performance.³

282

283 The results presented in this review highlight the need for standardizing caffeine and sodium
284 bicarbonate intake before the Yo-Yo test. **In other words, supplementation with caffeine or**
285 **sodium bicarbonate should be either restricted or used in the same way before each testing**
286 **session. If their use is not standardized, some individuals may ingest caffeine or sodium**
287 **bicarbonate before the testing and possibly experience a supplement-induced improvement**
288 **performance in the Yo-Yo test.** This may be especially important to control when using the
289 Yo-Yo test for the evaluation of the effectiveness of a given training program. Additionally,
290 standardization of caffeine and sodium bicarbonate intake may be important for studies that
291 focus on the reliability of the Yo-Yo test.⁴¹ If not standardized, ingestion of these supplements
292 may lead to improvements in performance by small to moderate effects (i.e., pooled SMDs in

293 this review ranged from 0.17 to 0.39); if not standardized, this improvement may affect the
294 validity of the data and lead to incorrect interpretation of the results.

295

296 One additional value of these substances is that their ingestion may improve performance in
297 training sessions or competitions with similar energy demands as the Yo-Yo test. This may be
298 especially relevant in soccer given that Krustup et al.⁴² observed that the performance in the
299 Yo-Yo test is significantly correlated ($r=0.81$) with the number of high-intensity running
300 actions performed at the end of each half of a game. These results suggest that caffeine or
301 sodium bicarbonate ingestion may even improve performance directly during sports
302 competitions. These supplements may also have the potential to enhance training responses
303 and adaptations; albeit, future long-term studies are needed to establish such effects. Still,
304 while the Yo-Yo test is valid for determining an individual's capacity to perform repeated
305 exercise,¹ future studies may consider exploring the effects of caffeine and sodium
306 bicarbonate using more specific team sport stimulations. **For example, one study explored the
307 effects of caffeine while using a performance test simulating physical and skill demands of a
308 rugby union game which included seven circuits in each of two 40-min halves with a 10-min
309 half-time rest.**⁴³

310

311 Using the PEDro checklist, the included studies are generally sound from a methodological
312 quality perspective. Nonetheless, several included studies used a single-blind protocol which
313 offers evidence of lower that the use of the "gold standard" double-blind study design. Of the
314 studies that blinded the participants, only two^{16,28} explored the effectiveness of this blinding
315 by asking the participants to indicate which condition was the placebo and which the
316 caffeine/sodium bicarbonate one. This limitation needs to be addressed in future studies given

317 that correct supplement identification may impact exercise outcomes and therefore lead to
318 bias in the results.⁴⁴

319

320 The main limitation is that some of the studies included in the meta-analysis on the effects of
321 sodium bicarbonate used a placebo condition as the comparison and other employed a non-
322 supplement, control trial. This methodological aspect may have affected the results given that
323 the act of ingesting a capsule (even though it does not contain an ergogenic compound) can
324 produce improvements in performance due to the placebo effect. However, the largest
325 improvement in performance following sodium bicarbonate ingestion was in a study²⁶ that
326 used a placebo vs. sodium bicarbonate comparison (SMD: 0.93; +30%) which may suggest
327 that this limitation may not be particularly impactful in this specific context (even though it
328 needs to be stated). Additionally, it needs to be mentioned that only one²⁵ of the five studies
329 that explored the effects of sodium bicarbonate used a sodium-matched placebo comparison.
330 Given that there are cases in which sodium can also be ergogenic,⁴⁵ future studies on this
331 topic should consider adding a condition with an equimolar amount of salt to the sodium
332 bicarbonate condition to isolate the effects of bicarbonate.⁴⁶

333

334 In the included studies, caffeine and sodium bicarbonate were provided in isolation. Given
335 that both supplements appear to be ergogenic, future work is needed to explore whether their
336 combined ingestion provides any additive benefits. It is possible that the combination of these
337 supplements would provide even greater effects because acute ingestion of caffeine and
338 sodium bicarbonate enhances performance through different physiological mechanisms. As
339 stated previously, caffeine's ergogenic effects are explained by its tendency to bind to
340 adenosine receptors while sodium bicarbonate elicits its ergogenic effect through pH

341 regulation. While there are several studies conducted on this topic, future work is needed to
342 provide greater clarity on the issue of supplement interactions.³⁵ This area may be particularly
343 relevant for athletes given that athletes often ingest more than one supplement,⁴⁷ and that
344 caffeine is often ingested as part of a multi-ingredient pre-workout supplement, or energy
345 drink. Future studies are needed to explore optimal doses of caffeine and sodium bicarbonate
346 that have the largest effect on performance while producing the least side-effects.⁴⁸ In
347 addition to doses, future work is need on the optimal timing of ingestion. Timing of ingestion
348 may be especially important to investigate when it comes to sodium bicarbonate given that
349 there is very large inter-individual variability in responses to sodium bicarbonate
350 ingestion,^{9,39,40} and the timing of ingestion is also affected by the mode of delivery.⁴⁹

351

352 **Conclusion**

353 The results of the present review indicate that isolated caffeine and sodium bicarbonate
354 ingestion enhances performance in the Yo-Yo test. Given these acute performance-enhancing
355 effects, the intake of caffeine and sodium bicarbonate before the Yo-Yo test needs to be
356 standardized (*i.e., either restricted or used in the same way before each testing session*). Also,
357 the results suggest that these substances may improve performance during exercise tasks with
358 similar energy demands to the Yo-Yo test and athletes competing in intermittent sports may
359 consider supplementing with caffeine or sodium bicarbonate for acute increases in
360 performance.

361 **Conflicts of interest**

362 None.

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