Effects of Caffeine, Sodium Bicarbonate, and Their Combined Ingestion on High-Intensity Cycling Performance

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Purpose: To determine the effects of ingesting caffeine (CAFF) and sodium bicarbonate (SB), taken individually and simultaneously, on 3-km cycling time-trial (TT) performance. Method: Ten well-trained cyclists, age 24.2 ± 5.4 yr, participated in this acute-treatment, double-blind, crossover study that involved four 3-km cycling TTs performed on separate days. Before each TT, participants ingested either 3 mg/kg body mass (BM) of CAFF, 0.3 g · kg⁻¹ · BM⁻¹ of SB, a combination of the two (CAFF+SB), or a placebo (PLAC). They completed each 3-km TT on a laboratory-based cycle ergometer, during which physiological, perceptual, and performance measurements were determined. For statistical analysis, the minimal worthwhile difference was considered ~1% based on previous research. Results: Pretrial pH and HCO₃ were higher in SB and CAFF+SB than in the CAFF and PLAC trials. Differences across treatments for perceived exertion and gastric discomfort were mostly unclear. Compared with PLAC, mean power output during the 3-km TT was higher in CAFF, SB, and CAFF+SB trials (2.4%, 2.6%, 2.7% respectively), resulting in faster performance times (–0.9, –1.2, –1.2% respectively). Effect sizes for all trials were small (0.21–0.24). Conclusions: When ingested individually, both CAFF and SB enhance high-intensity cycling TT performance in trained cyclists. However, the ergogenic effect of these 2 popular supplements was not additive, bringing into question the efficacy of coingesting the 2 supplements before short-duration high-intensity exercise. In this study there were no negative effects of combining CAFF and SB, 2 relatively inexpensive and safe supplements.

Keywords: supplements, ergogenic, dual, nutrition, time trial

The practice of elite athletes consuming potentially performance-enhancing nutritional supplements is common (Airstone, Fagbemi, & Morris, 2005; Huang, Johnson, & Pipe, 2006; Slater, Tan, & Teh, 2003). Among those available, caffeine (CAFF) and sodium bicarbonate (SB) are two supplements often consumed by athletes from a range of sports before competition. There is a variety of evidence supporting the effectiveness of CAFF and SB to enhance performance, although effects may be intensity-specific. Consumption of CAFF, for example, has been clearly shown to enhance performance in long-duration (>60 min), predominantly aerobic trials (Cox et al., 2002; Ivy, Costill, Fink, & Lower, 1979; Jenkins, Trilk, Singhal, O’Connor, & Cureton, 2008), but its effect on shorter duration performance (<5 min) is less clear, especially for sports demanding both aerobic- and anaerobic-fitness qualities, for which there is currently limited evidence (Davis & Green, 2009). Likewise, evidence supporting the effectiveness of SB to enhance performance in very high-intensity, short-duration events (<2 min) appears equivocal, with some (Goldfinch, McNaughton, & Davies, 1988; McNaughton & Thompson, 2001; McNaughton, Ford, & Newbould, 1997; Wilkes, Gledhill, & Smyth, 1983) but not all (Horswill et al., 1988; Marx et al., 2002; Pierce, Eastman, Hammer, & Lynn, 1992; Tiryaki & Attebom, 1995) studies reporting positive effects. The effects of SB are less clear for slightly longer (2–5 min) high-intensity trials, although in support of its efficacy, Cho, Chung, Park, and Choi (1990) reported improved performance in 3-km time-trial (TT) performance in trained cyclists, highlighting its usefulness to enhance performance in this intensity domain.

With respect to the mechanisms underlying performance enhancement after supplementation, CAFF has been shown to exert its ergogenicity both centrally and peripherally (for review, see Davis & Green, 2009). While the most likely effect of CAFF supplementation appears to be central, via antagonism of adenosine A1 and/or A2a receptors (Fredholm, 1995; Lynge & Hellsten, 2000) and reductions in perceived pain (Motl, O’Connor, & Dishman, 2003) and physical exertion (Davis et al., 2003; Doherty & Smith, 2005) during exercise, the placebo effect associated with CAFF consumption before endurance performance trials in athletes (Beedie, Stuart, Coleman, & Foad, 2006) should not be ignored. Conversely, the effects of SB are predominantly peripheral, given its alkalotic ability to elevate extracellular blood HCO₃⁻, increase the pH gradient across the cell membrane, and thus promote the efflux of H⁺ and lactate out of the muscle cell. This results in preservation of intracellular pH (Sutton, Jones, & Toews, 1981) and delays the onset of fatigue (Bishop, Edge, Davis, & Goodman, 2004;

Given that there are different mechanisms to explain the observed performance enhancement after supplementation with these two substances (Burke, 2008; Davis & Green, 2009; Requena, Zabala, Padial, & Feriche, 2005), a dual-supplementation approach could be a worthwhile strategy for athletes to adopt. Indeed, dual supplementation of CAFF and SB by athletes has been reported (Burke 2008), but to date there is surprisingly limited research supporting or refuting its efficacy to enhance exercise performance. Opposing this logical possibility, however, Vandenberghe et al. (1996) showed that CAFF eliminated the ergogenic effect of creatine supplementation, suggesting that dual supplementation of some substances may actually counteract the positive effects observed with single-supplementation approaches. To our knowledge, only two studies have reported the effects of athletes’ consuming CAFF and SB together before performance trials (Carr, Gore, & Dawson, 2011; Pruscino, Ross, Gregory, Savage, & Flanagan, 2008). Pruscino et al. examined the individual and combined effects of CAFF and SB ingestion on repeat 200-m swimming performance in 6 swimmers and reported that although there was a tendency for dual supplementation to both enhance (Trial 1) and maintain (Trial 2) performance more than CAFF and SB alone (in 50% of subjects), there was no significant advantage ($p = .06$). More recently, however, Carr, Gore, and Dawson (2011) reported that 2,000-m rowing performance was best after 6 mg/kg CAFF supplementation. In that group of elite rowers, CAFF plus SB was less effective, possibly due to gastrointestinal discomfort. Given the limited number of dual-supplementation studies to date, as well as the lack of high-intensity cycling-specific research for single- and dual-supplementation approaches, the aim of the current study was to determine the effects of consuming CAFF and SB individually and in combination on 3-km TT performance in well-trained cyclists.

**Methods**

**Participants**

After we obtained institutional ethics approval, 10 well-trained male cyclists ($M \pm SD$ age 24.2 ± 5.4 years, height 179.0 ± 5.1 cm, body mass 79.1 ± 7.2 kg) volunteered to participate in the study. Participants were free of injury and had been training consistently in the 6 weeks before the study (9.1 ± 2.3 hr/week). All were informed of the requirements, risks, and benefits of the study, and all provided written informed consent. None of the subjects reported using any nutritional supplements at the time of the study.

**Design**

This study employed a double-blind, crossover design. In a balanced, random order, participants came to the laboratory on five separate occasions over a 14-day period to perform 3-km TTs after consuming CAFF, SB, CAFF+SB, or a placebo (PLAC). On Day 1, participants performed a familiarization 3-km TT, during which mean power output (MPO) was determined for future standardization of prettrial warm-ups. Body mass was also determined so that individual supplement doses could be calculated. On Days 4, 7, 10, and 13, participants performed further TTs, under similar conditions, after consuming one of the supplements of interest.

**Procedures**

All tests were conducted in the morning (8–11 a.m.), 3 hr postprandial, in a temperature-controlled laboratory (20°C, relative humidity 60%) on an electromagnetically braked cycle ergometer (Velotron, RaceMate, USA). In the 24 hr before the first test, participants were asked to complete a detailed food and beverage consumption diary. Each participant was asked to replicate the same diet in the 24 hr before each subsequent test. Subjects were advised of CAFF sources in foods and beverages and were asked to avoid CAFF intake for the duration of the study. Participants were required to arrive 2 hr before the start of each TT. On arrival, a 0.5-ml fingertip blood sample was collected (baseline) and immediately analyzed for blood lactate, pH, and HCO₃ using a valid and reliable (Connelly, Magee, & Kiessling, 1996; Sediame, Zerah-Lancner, d’Ortho, Adnot, & Harf, 1999; Verwaerde, Malet, Lagente, de la Farge, & Braun, 2002) analyzer (i-STAT, Abbot, IL). These measures were repeated again after the warm-up (prettrial) and 1 min after completion of the 3-km TT (posttrial).

**Supplementation.** On each test day participants received one of the following four supplement combinations in random order: (a) 3 mg · kg⁻¹ · BM⁻¹ of CAFF (No-Doz, Key Pharmaceuticals, NSW, Australia) ingested in a single dose with 200 ml of water, 60 min before the TT, plus an SB PLAC (see below) ingested serially with 300 ml of water between 120 and 90 min before the TT; (b) 0.3 g · kg⁻¹ · BM⁻¹ of SB (ABM Pharma Ltd., Auckland, NZ) ingested serially with 300 ml of water between 120 and 90 min before the TT, plus a CAFF PLAC ingested in a single dose with 200 ml of water, 60 min before the TT; (c) 3 mg · kg⁻¹ · BM⁻¹ CAFF ingested in a single dose with 200 ml of water, 60 min before the TT and 0.3 g · kg⁻¹ · BM⁻¹ · of SB (CAFF+SB) ingested serially with 300 ml of water between 120 and 90 min before the TT; and (d) a corn-flour (Edmonds, Auckland, NZ) double PLAC ingested both as a single dose with 200 ml of water, 60 min before the TT to mimic real CAFF consumption and as a serial dose with 300 ml of water between 120 and 90 min before the TT to mimic real SB consumption. All supplement combinations and doses were prepared by a technician not involved in the data collection to ensure researcher and participant blinding. We ensured that participants consumed the same number of capsules and volumes of fluid at the same times regardless of the supplement condition. All supplements were provided to participants in gelatin capsules (Skybright NZ Ltd., Christchurch, NZ), making their content unrecognizable.
**Performance Trials.** Thirty minutes before the commencement of each TT, participants performed a standardized warm-up on the cycle ergometer. They cycled at 60–65% MPO for 20 min, after which they performed five high-intensity efforts (100% MPO) lasting 20 s, interspersed with 40-s recoveries. Subjects then rested, seated on the ergometer, for a further 5 min before commencing the 3-km TT, after a 5-s countdown from a stationary start. They were asked to complete the 3-km TT as fast as possible and were permitted to adjust the gearing on the ergometer to maximize their performance. All trials were conducted with only the subject and primary researcher present. Performance measures recorded during the trial included time to completion (s) and MPO (W). Heart rate was recorded at 5-s intervals throughout the TT using short-range telemetry (Polar 810, Polar Electro, Oy, Finland).

**Perceptual Responses.** Perceptual ratings including gastric discomfort and perceived exertion were obtained. For both measures, participants were asked to verbally rate on a scale of 1 to 5 how they felt, using language terms they were familiar with, with 1 representing no exertion and no gut discomfort and 5 representing maximal exertion and extreme gut discomfort. On completion of all trials, participants were also asked if they could guess the order of treatments they had been given during the study.

**Statistical Analysis**

All values are reported as $M \pm SD$. Data were log-transformed before any statistical analysis. To make assumptions about true (population) values of the effect of CAFF and SB (and their combination) on performance, the uncertainty of the effect was expressed as 90% confidence limits and as likelihoods that the true value of the effect represents substantial change (Batterham & Hopkins, 2006). An effect was deemed unclear if its confidence interval overlapped the thresholds for substantiveness, meaning that the effect could be substantially positive and negative. An estimate of the smallest substantial change in MPO was required to make these conclusions. Paton and Hopkins (2006) estimated smallest effects of 0.5–1.5% in MPO, based on variability in competitive performance cyclists in various TTs where drafting and group tactics did not contribute. A smallest worthwhile effect of 1% was therefore assumed. For all other measures, 0.2 of the baseline between-subjects SD was used (Hopkins, 2006).

**Results**

**Blood Measures**

Baseline blood HCO$_3$, pH, and lactate were similar across treatments (Figure 1). Pretrial blood HCO$_3$ was substantially lower in the PLAC (20.5 ± 2.5 mmol/L) and CAFF (20.1 ± 2.4 mmol/L) trials than baseline values (25.5 ± 1.4 and 25.0 ± 1.1 mmol/L, respectively). In the SB and CAFF+SB trials, a small increase in pretrial HCO$_3$ was observed compared with baseline values (SB: 25.5 ± 1.9 vs. 29.2 ± 4.1 mmol/L; CAFF+SB: 25.1 ± 1.4 vs. 28.5 ± 3.8 mmol/L). HCO$_3$ substantially decreased across all conditions from pretrial to posttrial measures, resulting in similar posttrial levels (Figure 1). Blood pH decreased substantially between baseline testing and pretrial measures, resulting in similar posttrial levels (Figure 1). Blood pH decreased substantially between baseline testing and pretrial measures, resulting in similar posttrial levels (Figure 1). Blood lactate increased between baseline and pre- and posttrial in all conditions, but there were no clear differences between conditions.
Perceptual Measures

There were no substantial differences between the conditions with regard to gastric discomfort (1.40 ± 0.48, 1.40 ± 0.52, 1.55 ± 0.60, 1.35 ± 0.60 AUs for CAFF, SB, CAFF+SB, and PLAC, respectively). There was a tendency for perceived exertion to be lower after CAFF (3.9 ± 0.8 AU) and CAFF+SB trials (4.0 ± 0.6 AU) than PLAC (4.3 ± 0.7 AU) and SB trials (4.2 ± 0.8 AU). Subjects perceived correctly that they had consumed CAFF when it was prescribed either individually (4 out of 10 subjects) or in combination with SB (3 out of 10 subjects). Likewise, 4 out of 10 subjects indicated correctly that they had consumed either SB alone or PLAC.

Performance Measures

The performance data from each trial are displayed in Table 1. In all supplement conditions, time and MPO during the 3-km TT were substantially improved compared with PLAC (Table 2). However, there were no substantial differences between CAFF, SB, and CAFF+SB. Effect sizes for all supplement trials were similar (0.21–0.24, Table 2). There was a small tendency for peak and average heart-rate responses to be elevated in all supplement trials compared with PLAC (Table 1).

Discussion

To our knowledge, this is the first study to investigate the impact of CAFF and SB ingested alone and in combination on 3-km TT cycling performance in trained athletes. We observed improved cycling performance after CAFF, SB, and CAFF+SB trials compared with PLAC, but combined ingestion of CAFF+SB neither further enhanced nor inhibited 3-km TT performance. We observed some subtle changes in perceived exertion between supplement conditions.

Cycling Performance

The performance improvement, expressed as MPO (W) and compared with PLAC, after consuming 3 mg · kg⁻¹ · BM⁻¹ CAFF was 2.4%, with a small effect size (ES 0.21; Table 2). Precise comparisons of our findings and previous studies is difficult since there were subtle differences in design, including supplement dose and timing, athlete training status, and the duration and intensity of the primary performance measure. However, our enhancement appears similar in magnitude to those in previous studies administering a similar CAFF dose before short-duration (2–6 min) cycling performance trials (Doherty, Smith, Hughes, & Davison, 2004; Wiles, Bird, Hopkins, & Riley, 1992) and other high-intensity endurance sports of similar duration (Anderson et al., 2000; Bruce et al., 2000; Carr, Gore, & Dawson, 2011; Wiles et al., 1992). Likewise, for SB, our findings of a small effect (2.8%, ES 0.24; Table 2) compared with PLAC cohere well with similar previous cycling (Cho et al., 1990) and running (Bird, Wiles, & Robbins, 1995) studies.

In the current study, our primary interest was determining the effect of combined CAFF and SB ingestion on short-term high-intensity cycling performance. Despite the different mechanisms of action of CAFF (Davis & Green, 2009) and SB (Requena et al., 2005), the magnitude of the performance enhancement after dual supple-

Table 1 Performance Measures Obtained During the 3-km Time Trial for Each Supplement Condition, $M \pm SD$

<table>
<thead>
<tr>
<th>Measure</th>
<th>Placebo</th>
<th>CAFF</th>
<th>SB</th>
<th>CAFF+SB</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-km time trial (s)</td>
<td>228.7 ± 10.8</td>
<td>226.5 ± 9.4</td>
<td>225.9 ± 11.3</td>
<td>226.0 ± 10.5</td>
</tr>
<tr>
<td>Mean power output (W)</td>
<td>373 ± 41</td>
<td>381 ± 37</td>
<td>383 ± 44</td>
<td>382 ± 39</td>
</tr>
<tr>
<td>Peak heart rate (beats/min)</td>
<td>186 ± 9</td>
<td>188 ± 8</td>
<td>188 ± 8</td>
<td>189 ± 6</td>
</tr>
<tr>
<td>Average heart rate (beats/min)</td>
<td>175 ± 10</td>
<td>177 ± 11</td>
<td>177 ± 9</td>
<td>177 ± 12</td>
</tr>
</tbody>
</table>

Note. CAFF = caffeine; SB = sodium bicarbonate.

Table 2 Pairwise Comparisons Quantifying Magnitudes of Effect of Each Supplement on 3-km Time-Trial Mean Power Output (W)

<table>
<thead>
<tr>
<th>Comparison</th>
<th>% Effect (90% CL)</th>
<th>ES (90% CL)</th>
<th>$p$</th>
<th>Practical outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAFF vs. PLAC</td>
<td>2.44 ± 1.38</td>
<td>0.21 ± 0.12</td>
<td>.010</td>
<td>Very likely positive effect of CAFF</td>
</tr>
<tr>
<td>SB vs. PLAC</td>
<td>2.79 ± 1.64</td>
<td>0.24 ± 0.38</td>
<td>.013</td>
<td>Very likely positive effect of SB</td>
</tr>
<tr>
<td>CAFF+SB vs. PLAC</td>
<td>2.70 ± 1.79</td>
<td>0.23 ± 0.15</td>
<td>.023</td>
<td>Very likely positive effect of CAFF+SB</td>
</tr>
<tr>
<td>CAFF vs. SB</td>
<td>0.34 ± 1.90</td>
<td>0.03 ± 0.17</td>
<td>.751</td>
<td>Differences possibly trivial</td>
</tr>
<tr>
<td>CAFF+SB vs. SB</td>
<td>-0.09 ± 2.11</td>
<td>-0.01 ± 0.19</td>
<td>.940</td>
<td>Differences possibly trivial</td>
</tr>
<tr>
<td>CAFF+SB vs. C</td>
<td>0.25 ± 0.81</td>
<td>0.02 ± 0.07</td>
<td>.586</td>
<td>Differences most likely trivial</td>
</tr>
</tbody>
</table>

Note. CL = confidence limits; ES = effect size; CAFF = caffeine; SB = sodium bicarbonate.
mentation was similar (~2.7%, ES 0.23; Table 2) to that observed for individual ingestion of CAFF or SB (Table 2). This key finding demonstrates that a dual-supplementation approach was ineffective at further augmenting short-duration, high-intensity exercise performance, which is in contrast to the recent findings of Carr, Gore, and Dawson (2011), who reported unclear performance effects after ingestion of SB, as well as CAFF+SB. Performance enhancements after CAFF alone in their study were similar in magnitude to our observations (~2%). In further comparison with our findings, Pruscino et al. (2008) reported that 50% of swimmers recorded their fastest times in a single 200-m TT after ingesting CAFF+SB (p = .06) compared with CAFF, SB, or PLAC alone. This greater effect of CAFF+SB could simply be due to the shorter duration performance measure than in both the current and another similar study (Carr, Gore, & Dawson, 2011) or due to the larger CAFF dose than ours (6.2 vs. 3 mg · kg⁻¹ · BM⁻¹). We adopted a lower dose of CAFF since recent evidence appears to suggest that small to moderate doses (1–3 mg · kg⁻¹ · BM⁻¹) are associated with worthwhile performance gains, at least in endurance sports, and that greater doses typically convey no further benefit (Burke, 2008). Based on the previous work of Graham and Spriet (1995), a dose of 3 mg/kg would be expected to raise plasma CAFF levels to ~15–20 μM in endurance-trained athletes, which would likely represent about a 10-fold increase above resting levels.

While we observed no further augmentation of 3-km TT performance after dual-supplementation trials compared with single-supplementation trials, it is still unclear which supplement contributed to the performance enhancement, compared with PLAC, when CAFF and SB were consumed together. It has been previously reported that CAFF inhibits the ergogenic effect of creatine despite notable changes in muscle [PCr] when creatine is ingested with and without CAFF (Vandenberghe et al., 1996). Consequently, several scenarios are possible in relation to combined effects of CAFF and SB on TT performance in the current study in light of similar physiological responses. For example, it is possible that in our study CAFF inhibited the effect of SB and that the only ergogenic effect came from CAFF. Conversely, it is possible that the SB provided the ergogenic benefit but inhibited the effects of CAFF or that each supplement was only half as effective in improving performance when the two were taken together. It would be difficult to identify or partition the relative effects of CAFF and SB to any performance enhancement, but more detailed physiological measures in future studies may provide some insight.

**Physiological Measures**

In the current study, as previously reported (Carr, Gore, & Dawson, 2011; Pruscino et al., 2008), CAFF ingestion did not alter blood pH or inhibit blood pH or HCO₃⁻ (Figure 1). Conversely, given that SB is an alkalizing agent, we expected that blood pH would substantially increase after SB ingestion. Indeed, there was clear pretrial alkalosis in both SB and CAFF+SB trials (Figure 1), which agrees well with previous studies (Price, Moss, & Rance, 2003). This notable pretrial alkalosis could serve to delay a decrease in pH (Marx et al., 2002), decrease muscle fatigue, and permit a greater contractile capacity of the muscle tissue involved (McNaughton, Backx, Palmer, & Strange, 1999; McNaughton et al., 1997) by enhancing muscle glycolytic ATP production (Bouissou, Defer, Guezennec, Estrade, & Serrurier, 1988; Kemp & Foe, 1983; Sutton et al., 1981), which, during short-duration cycling events, would be meaningful, given the significant anaerobic component (Craig et al., 1993).

Requena et al. (2005) previously suggested that ingestion of SB may increase the buffering capacity of the extracellular fluid and aid efflux of hydrogen ions away from working muscle and into the blood. It would therefore be expected that blood lactate levels would be higher in the SB trial than in the PLAC trial. Indeed, posttrial blood lactate in the current study was higher (~6–7%; Figure 1) after ingestion of SB and CAFF+SB than with either PLAC or CAFF, which supports several previous studies (Cameron, McLay-Cooke, Brown, Gray, & Fairbairn, 2010; Requena et al., 2005; Wilkes et al., 1983). Furthermore, Carr, Gore, and Dawson (2011) reported the highest blood lactate after CAFF+SB in their dual-supplementation study involving rowers. According to Davis and Green (2009), however, the literature exploring CAFF’s effect on lactate appears somewhat equivocal. Greater lactate levels after CAFF ingestion could be due to increased glycolytic turnover during exercise, as a result of adrenaline, or increased central nervous system activity (Davis & Green, 2009) causing a dampening of pain perception and an extension of exercise tolerance, both culminating in increased end-exercise lactate levels at the point of exhaustion. Unlike others (Bell, Jacobs, & Ellerington, 2001; Schneiker, Bishop, Dawson, & Hackett, 2006), however, we did not observe increased lactate levels after CAFF ingestion compared with PLAC in our study. This could be due to the smaller dose of CAFF or the shorter TT duration in our study. Regardless, it is clear from several studies that performance enhancement can still occur during high-intensity exercise without increased lactate after CAFF supplementation (Doherty, 1998; Doherty, Smith, Davison, & Hughes, 2002; Kang, Kim, & Kim, 1998).

**Perceptual Measures**

One of the most accepted theories on how CAFF improves performance is via its effect on the central nervous system (Davis & Green, 2009; Hudson, Green, Bishop, & Richardson, 2008). Specifically, CAFF is thought to blunt pain receptors, via the antagonistic role it has on adenosine receptors (Davis et al., 2003). This causes a reduction in perceived exertion, which might allow an athlete to work at a higher intensity for longer. Indeed, CAFF is typically associated with reduced perceived exertion after exhaustive endurance exercise (Doherty et al., 2004; Doherty & Smith, 2004, 2005). In a comprehensive meta-analysis,
Doherty and Smith (2005) reported that the magnitude of performance enhancement after CAFF ingestion was related to observed reductions in perceived exertion. In support, we observed a tendency for perceived exertion to be lower after consumption of CAFF, when ingested either alone (−0.30 points, 7%) or in combination with SB (−0.25 points, 5%). This reduction coheres well with relatively small performance gains (Table 2) during our short-duration trials (−3.8 min). In support, Carr, Gore, and Dawson (2011) reported a similar reduction (−6%) in rating of perceived exertion after dual CAFF+SB ingestion compared with placebo. As previously suggested by Doherty and Smith (2005), though not measured in the current study, an explanation for how CAFF improved performance is that the lowered perceived exertion during exercise allowed participants to centrally recruit and engage more motor units, which in turn would allow for an increased power output during the TT.

Reports of gastrointestinal side effects by athletes after SB supplementation are common (Carr, Gore, & Dawson, 2011; Stephens, McKenna, Canny, Snow, & McConell, 2002; Van Montfoort, Van Dieren, Hopkins, & Shearman, 2004). Indeed, a recent dual-supplementation study attributed a performance enhancement after SB trials to gastrointestinal symptoms reported by subjects (Carr, Gore, & Dawson, 2011). It is advised that SB be administered 60–90 min before exercise to minimize any associated gastric discomfort (Bishop & Claudius, 2005; Robergs, Hutchinson, Hendee, Madden, & Siegler, 2005). Furthermore, Carr, Slater, Gore, Dawson, and Burke (2011) recently demonstrated that the incidence of gastrointestinal symptoms experienced with SB supplementation can be substantially reduced when the ingestion protocol incorporates a preevent meal. To avoid such symptoms, we purposely asked athletes to consume a preevent breakfast, which was subsequently repeated for all trials. As a result, they reported limited gastrointestinal side effects using this approach. Despite the potential for inhibition of CAFF absorption after such a meal (Skinner, Jenkins, Coombes, Taaffe, & Leveritt, 2010), we consider the validity of this experimental approach high since consumption of a preevent meal is often standard practice for competitive athletes, and, perhaps more important, ensuring athlete comfort before performance trials is a priority.

From a controlled 3-km laboratory-based TT performance perspective, our results do not support dual supplementation of CAFF and SB as being further beneficial than ingesting them alone. However, the concept of taking two supplements in real competition situations may still be of interest to practitioners, both from a potential placebo-effect perspective and increasing the odds of giving athletes (responders and nonresponders) what they need, or could benefit from, on a given day. With regard to any potential PLAC effect, it has been shown that ingestion of two PLAC pills provides a better effect than taking one (Blackwell, Bloomfield, & Buncher, 1972). Indeed, athletes will know before a given performance whether they are either ingesting CAFF or SB alone or if they are taking both supplements together. In some circumstances, the belief that “two is better than one” could result in an increased PLAC effect and lead to a greater enhancement of performance. A PLAC effect for CAFF supplementation has been reported in athletes (Beedie et al., 2006), and it would therefore be useful if any biases athletes have could be quantified in future dual-supplementation studies in the laboratory or field. Finally, by taking two different supplements simultaneously, a given athlete may simply be increasing the odds of getting what he or she needs to optimize performance. Further research to quantify this possibility is required.

**Conclusion**

When ingested individually, both CAFF and SB exert physiological and perceptual effects that result in small, worthwhile enhancements in high-intensity exercise performance in trained cyclists. However, ingestion of CAFF and SB in combination before high-intensity exercise laboratory-based trials does not appear to further enhance or attenuate the ergogenic effect compared with ingesting them individually. Therefore, athletes may neither directly benefit nor be compromised with a combination supplement strategy, suggesting that for these two supplements individual strategies that take into consideration personal preferences may be more important than administering a standard dose. Further investigations into the efficacy of combined-supplement ingestion strategies before simulated and real competition scenarios for a range of exercise intensities and durations appear warranted.

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