Effects of caffeine and carbohydrate mouth rinses on repeated sprint performance

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Abstract: Our purpose was to examine the effectiveness of carbohydrate and caffeine mouth rinses in enhancing repeated sprint ability. Previously, studies have shown that a carbohydrate mouth rinse (without ingestion) has beneficial effects on endurance performance that are related to changes in brain activity. Caffeine ingestion has also demonstrated positive effects on sprint performance. However, the effects of carbohydrate or caffeine mouth rinses on intermittent sprints have not been examined previously. Twelve males performed 5 × 6-s sprints interspersed with 24 s of active recovery on a cycle ergometer. Twenty-five milliliters of either a noncaloric placebo, a 6% glucose, or a 1.2% caffeine solution was rinsed in the mouth for 5 s prior to each sprint in a double-blinded and balanced cross-over design. Postexercise maximal heart rate and perceived exertion were recorded, along with power measures. A second experiment compared a combined caffeine-carbohydrate rinse with carbohydrate only. Compared with the placebo mouth rinse, carbohydrate substantially increased peak power in sprint 1 (22.1 ± 19.5 W; Cohen’s effect size (ES), 0.81), and both caffeine (26.9 ± 26.9 W; ES, 0.71) and carbohydrate (39.1 ± 25.8 W; ES, 1.08) improved mean power in sprint 1. Experiment 2 demonstrated that a combination of caffeine and carbohydrate improved sprint 1 power production compared with carbohydrate alone (36.0 ± 37.3 W; ES, 0.81). We conclude that caffeine and (or) caffeine mouth rinses may rapidly enhance power production, which could have benefits for specific short sprint exercise performance. The ability of a mouth-rinse intervention to rapidly improve maximal exercise performance in the absence of fatigue suggests a central mechanism.

Key words: mouth wash, fatigue, power, cycle sprints.

Introduction

Recent research demonstrated that a carbohydrate mouth rinse enhanced endurance performance, and that this beneficial effect was related to changes in brain activity in the reward centre via a putative mechanism involving oral receptors (Chambers et al. 2009). This phenomenon was first reported in 2004 and has been demonstrated to improve time-trial performance in both running and cycling exercise (Carter et al. 2004; Pottier et al. 2010; Rollo et al. 2008). The study by Pottier et al. (2010) went on to show that a carbohydrate mouth rinse was superior to carbohydrate ingestion, suggesting that the duration of time the solution spent in the oral cavity is important. Further research showed that a carbohydrate mouth-rinse protocol that effectively increased treadmill running performance was not associated with changes in blood glucose concentration during exercise or at rest (Rollo et al. 2010). It should be noted that beneficial effects of a carbohydrate mouth
Caffeine ingestion can enhance endurance and sprint performance via a mechanism that is believed to involve the central modulation of motor unit activity and adenosine receptor antagonism (Kalmar 2005), and has been reported to enhance repeated sprint performance in running (Carr et al. 2008; Mohr et al. 2011) and cycling exercise (Lee et al. 2011). Paton et al. (2010) have also demonstrated that, in a group of trained cyclists, chewing caffeinated gum can improve repeated sprint performance. Although, interestingly, the caffeine was only administered immediately prior to the observed beneficial effects. The method of caffeine delivery here may be of interest because adenosine receptors have been identified in the oral cavity in other mammals (Rubenstein et al. 2001). The effects of a caffeine-containing mouth-rinse solution on exercise performance have not been investigated. One of the benefits of such a treatment would be the low systemic dose required, thus reducing the possible side effects of the caffeine. Although independently caffeine and carbohydrate have demonstrated positive effects on exercise performance, it is currently unknown whether a synergistic positive effect could be attained via a possible interaction with oral receptors. Of particular interest is the observation that both caffeine and carbohydrate have been suggested as activating the reward circuitry of the brain with potential to modulate behaviour (Hagger and Chatzisarantis 2007). Experiment 1

Participants

Twelve recreationally trained males (age, 32 ± 7.5 years; height, 175 ± 7.3 cm; mass, 82.2 ± 7.16 kg) volunteered to participate in the exercise trial. The subjects reported being low caffeine users, consuming ≤2 doses of caffeinated beverages daily. All participants were fully informed of the nature and possible risks of the study before giving written consent. The Waikato Institute of Technology Ethics Committee approved the experimental protocol.

Statistical analyses

The dependent variables were log-transformed before analysis to reduce nonuniformity of errors, with effects derived by back transformation as percentage changes (Hopkins et al. 2009), and a repeated-measures analysis of variance (ANOVA) was used to compare dependent variables among the conditions. Pairwise comparisons across time points were made among the conditions, and differences were interpreted in relation to the likelihood of exceeding the smallest worthwhile change (Cohen’s effect size (ES)), with individual change thresholds for each variable. Differences in the means of each measure were assessed by dividing the changes by the appropriate between-athlete SD. Magnitudes of the standardized effects were interpreted using thresholds of 0.2, 0.6, and 1.2 for small, moderate, and large, respectively (Hopkins et al. 2009). Standardized effects of between ~0.19 and 0.19 were termed trivial. To make inferences about the large-sample value of an effect, the uncertainty in the effect was expressed as 90%
Results

Experiment 1

The participants were unable to correctly identify the 3 solutions more than expected by chance, based on the percentage of successful guesses (25%) when questioned following each exercise bout, which indicates successful blinding. The order of testing was randomized, and all the subjects were familiarized with the test before the trial began, so the changes in performance could not be attributed to the effect of day-to-day variation or learning. Within-subject performance variation was calculated as a coefficient of variation of 3.7% for peak power and 4.8% for mean power. No order effect was detected. No differences in maximal HR (placebo, 158 ± 10 beats·min⁻¹; carbohydrate, 162 ± 15 beats·min⁻¹; caffeine, 157 ± 8 beats·min⁻¹) or RPE (placebo, 16.8 ± 1.3; carbohydrate, 16.9 ± 1.3; caffeine, 16.8 ± 1.1) were observed among the conditions. Data for the combined carbohydrate and caffeine condition are presented as change scores from the placebo data, it was apparent that peak power in sprint 1 was enhanced in the carbohydrate condition (22.1 ± 19.5 W; ES, 0.81; *p* = 0.0667), and that the mean power in sprint 1 was substantially improved in both the carbohydrate (39.1 ± 26.9 W; ES, 1.08; *p* = 0.0205) and caffeine conditions (26.9 ± 26.9 W; ES, 0.71; *p* = 0.0995) (Fig. 1). However, sprint 5 was negatively influenced for both peak power (−37.3 ± 30.2 W; ES, −0.84; *p* = 0.0480) and mean power (−39.6 ± 27.4 W; ES, −0.76; *p* = 0.0693) in the carbohydrate condition when compared with the placebo condition. This decrement was not as apparent in the caffeine condition, with no substantial differences observed between the caffeine and placebo conditions in sprint 5 and a substantial difference in mean power of 32.7 ± 43 W (ES, 0.52) between the caffeine and carbohydrate conditions. There was, however, a small decrease (ES, −0.56) in mean power production in the caffeine condition compared with the placebo in sprint 3. Six individuals produced their greatest maximal power during both of their first 2 sprints when they used the caffeine mouth rinse. In these “caffeine responders”, the peak power generated was substantially greater than that observed in the placebo condition for sprint 1 (103.8 ± 116.5 W; ES, 0.87; *p* = 0.1361), whereas in “nonresponders”, no clear difference was seen between the caffeine and placebo condition at any time point.

Discussion

Our data demonstrate that a carbohydrate and caffeine mouth rinse can rapidly enhance initial cycle sprint power production when compared with an indistinguishable sweet but noncaloric placebo. Numerous studies have reported power production and endurance benefits of a carbohydrate mouth rinse compared with a blinded placebo (Carter et al. 2004; Chambers et al. 2009; Fares and Kayser 2011; Jeukendrup and Chambers 2010; Pottier et al. 2010; Rollo et al. 2010) or a nonrinse control (Chong et al. 2011; Gam et al. 2012). A brief mouth rinse has been proposed as an alternative to carbohydrate ingestion and has even been proposed to be superior in terms of endurance performance measures (Pottier et al. 2010) and gastric distress (Place 2009). It has been demonstrated that a carbohydrate mouth-rinse protocol, admittedly at approximately 3 times the concentration of the current trial, has a marked effect on the anterior cingulate cortex and...
right caudate, which are believed to mediate the physiological response to reward (Chambers et al. 2009). It has been suggested that alterations in power are mediated by a “central governor” and that a carbohydrate stimulus may elicit positiveafferent signals capable of enhancing motor output (Jeukendrup and Chambers 2010).

Research employing transcranial stimulation has shown that the presence of carbohydrate in the oral cavity increases the excitability of the corticomotor pathway and can immediately increase maximal force production (Gant et al. 2010). Our data may provide some indirect evidence of improved motor output, because the enhanced maximal exercise performance in the mouth-rinse conditions occurred in the absence of fatigue. This observation suggests a central or supraspinal mechanism that is capable of enhancing the neural drive to the motor units and accessing the muscle recruitment reserve proposed by other researchers (Gandevia 2001; St Clair Gibson and Noakes 2004).

However, in experiment 1, the degree of performance decrement, as evidenced by the inability to maintain power across the 5 sprint efforts, was also greater in the carbohydrate intervention group. Although not measured in this study, this observation could possibly be due to the rapid depletion of ATP, which is the predominant fuel source during high-intensity repeated-sprint protocols. It could reasonably be argued that the increased power outputs in the early sprints came at a cost to the subsequent ones and, indeed, the greater degree of performance decrement observed in the nonplacebo mouth rinses appears to be a result of the relatively greater power produced during the initial sprint efforts.

The ingestion of caffeine as an ergogenic aid has been reported widely, with the antagonism of adenosine receptors being 1 of the mechanisms behind the beneficial effects on exercise performance (Carr et al. 2008; Davis and Green 2009; Kalmar 2005). The obvious difference between the current study and previous research into the effects of caffeine on exercise performance is the method, concentration, and timing of the delivery. The novel evidence presented here is that a 1.2% w/v caffeine solution rinsed in the mouth immediately prior to exercise, without ingestion, elicited a rapid performance-enhancing effect on maximal voluntary power production. These data suggest that a mechanism does exist by which caffeine can rapidly modulate physical capacity via the oral cavity.

Previous research using caffeine has often identified specific individuals who are apparently more susceptible to the performance-enhancing effects of caffeine (Astorino et al. 2011; Bruce et al. 2000; Cook et al. 2012; Jenkins et al. 2008). In the current study, individuals who were identified as a subgroup of caffeine responders generated significantly greater peak power during their initial sprints. This increase in peak power was approximately double the 5.5% CV reported for a similar cycle sprint protocol (McGawley and Bishop 2006). Notwithstanding the debate between statistical and practical significance, the findings of the current study demonstrate performance improvements in response to mouth-rinse protocols that are of a magnitude similar to those reported previously (Rollo and Williams 2011). It should be noted that few studies have reported performance enhancement greater than the day-to-day variation in testing method (Pottier et al. 2010; Rollo et al. 2010), whereas the results of other studies, although significant, did not meet this criterion (Carter et al. 2004; Chambers et al. 2009).

It is possible that some of the previous observations made with ingested caffeine may be related to localized central rather than systemic effects, depending on the method of delivery. A caffeine-containing gum has been reported to rapidly improve time-trial performance (Ryan et al. 2011) and increase power output in cycle sprints in a manner that was associated with modified salivary hormone responses compared with a placebo condition (Paton et al. 2010). Interestingly, the pattern of the salivary hormone stress response reported by Paton and colleagues (2010) was different from that reported by others who used caffeine ingestion as the method of delivery (Beaven et al. 2008).

The data from experiment 2 showing a substantial increase in sprint 1 peak power and an enhancement of mean power in sprint 5 resulting from the combined carbohydrate and caffeine mouth rinse when compared with the carbohydrate-only mouth rinse again demonstrate a rapid effect. Further, the additive positive effects of both caffeine and carbohydrate on power production suggest that distinct mechanisms are involved in the performance enhancement. Specifically, the data suggest a rapid contribution of central mechanisms to aspects of muscular function and sprint performance that can be directly manipulated using a mouth-rinse intervention.

A lack of difference in RPE is commonly reported in mouth rinse (Carter et al. 2004; Chambers et al. 2009; Gam et al. 2012; Lee et al. 2012; Pottier et al. 2010) and caffeine trials (Doherty et al. 2004). It has been suggested that lowering the perception of effort during exercise at a given intensity may be a viable mechanism for improved performance, because exercise intensity would increase to compensate for this decrease in perceived effort (Rollo and Williams 2011). Similar to the data presented here, previous research has reported no effect of a carbohydrate mouth rinse (Carter et al. 2004) or caffeinated gum (Ryan et al. 2012) on exercise-induced elevations in HR. An alternative explanation for the lack of difference in HR and RPE between the conditions is that the maximal sprint efforts elicited near-maximal RPE and HR values and, as a result, no appreciable differences in these data were observed (a ceiling effect).

It is worth considering a number of limitations to the current study. First, the participants were recreationally trained only, and thus, the ability to generalize the current results to highly trained individuals is limited. Second, caffeine habituation was not assessed and, although all subjects reported being low caffeine consumers, this may have affected the acute responses to the caffeine dose. Similarly, the effect of hunger and the length of the postprandial period may have influenced the results. There is some evidence to suggest that a carbohydrate mouth rinse is equally efficacious in both the fed and unfed state (Fares and Kayser 2011), although conflicting results have been reported (Beleen et al. 2009). We did, however, enforce a 2-h fasting duration prior to the exercise performance, which is of similar duration to that of previous work that has demonstrated a beneficial effect of a carbohydrate mouth rinse on cycling performance (Pottier et al. 2010). The current study did not utilize a nonrinse control, nor did it address the possibility of a dose–response, and neither blood levels of caffeine nor glucose were assessed. It remains to be established whether higher dosages administered solely within the oral cavity would result in a divergent physiological or functional response.

Overall, the current study adds to the series of mouth-rinse literature and suggests that a mouth rinse with carbohydrate can induce potentially worthwhile physiological outcomes, with increases in power output in a nonfatigued state. The rapidity of these responses suggests a supraspinal mechanism involving the CNS, possibly via oral receptors. These increases were tempered, however, by the observation of a decreased ability to maintain power over a series of repeated sprints when compared with a noncaloric placebo (experiment 1). Thus, in repeated intermittent sprints, there may be a metabolic cost associated with this initial improvement. Therefore, we contend that a carbohydrate mouth-rinse intervention is more likely to have a beneficial effect when longer recovery periods are available between the sprints or when only single efforts are required. A novel finding was that the addition of caffeine attenuated the performance decrement seen in the carbohydrate-only condition, both independently and in conjunction with carbohydrate, improving power output again via a putatively central mechanism. Further research into these effects would help elucidate where and how competitive advantage may
be obtained through the use of both caffeine and carbohydrate using an oral, noningestion approach.

References


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