THE EFFECTS OF CARBOHYDRATE AND CAFFEINE MOUTH RINSING ON ARM CRANK TIME-TRIAL PERFORMANCE

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ABSTRACT
This study aimed to determine whether carbohydrate (CHO) and caffeine (CAFF) mouth rinsing would improve 30 minute arm cranking time-trial performance. Twelve male participants (age 21.54 ± 1.28 years, height 179.46 ± 7.38 cm and mass 73.69 ± 5.40 kg) took part in the current investigation. Participants came to the laboratory on 3 occasions during which they performed 30 minute self-paced arm crank time trials. On one occasion water was given as a mouth rinse for 5 s (PLA), on another occasion a 6.4% CHO solution was given for 5 s and finally a 0.032% CAFF solution was given for 5s. Key measurements of distance covered, heart rate (HR), ratings of perceived exertion (RPE), cadence and power output were recorded throughout all trials. Distance covered during the CAFF (15.43 ± 3.27 km) and CHO (15.30 ± 3.31) mouth rinse trials were significantly (p<0.05) greater in comparison to PLA (13.15 ± 3.36 km). Cadence and power output and velocity were also significantly greater during the CAFF and CHO trials compared to PLA and CHO (p<0.05). No significant (P>0.05) differences between trials were observed for HR and RPE. CAFF and CHO mouth rinse serve to improve 30 minute arm cranking performance by mediating increasing cadence and power output without a concurrent increase in RPE and HR.

Keywords: Mouth rinse, Carbohydrate, Caffeine, Arm cranking, Physiology.

Contribution/ Originality
This study contributes in the existing literature as the first investigation to comparatively examine the influence of both carbohydrate and caffeine mouth rinsing on upper body time trial performance.

1. INTRODUCTION
There is now a considerable body of evidence indicating that the ingestion of both carbohydrate (CHO) and caffeine (CAFF) serve to improve endurance exercise performance
Costill et al., 1978; Angus et al., 2000; Cox et al., 2002; Andrews et al., 2003; Jacobs et al., 2003; Desbrow et al., 2004; Doherty and Smith, 2005; Beck et al., 2006; Astorino et al., 2008; Beaven et al., 2008; Burke, 2008; Osterberg et al., 2008; Hulston and Jeukendrup, 2009; Ganio et al., 2010). Endurance exercise has been shown to reduce the body’s glycogen stores (Grewe et al., 1999), as such supplementing with CHO may be a mechanism by which the onset of fatigue can be delayed (Coyle et al., 1983). Glycogen depletion as a function of exercise is the key mechanism by which sports performance decrements are mediated (Williams et al., 2012). Therefore, increased CHO ingestion availability has been advocated as a method of maintaining euglycaemia and blood oxidation rates (Tsintzas and Williams, 1998), thus allowing higher exercise intensities to be maintained during exercise. The ergogenic benefits of CAFF are attributed to its affinity with adenosine receptors. CAFF is able to bind to both pre and post synaptic receptors, which serve to inhibit adenosine action (Davis and Green, 2009). This promotes the discharge of excitatory neurotransmitters which enhance corticomotor sensitivity (Cerqueira et al., 2006). The stimulation of central effects by CAFF may be responsible for modifying the motivational factors that affect discomfort during exercise, leading to a reduction in perceived exertion/ pain during exercise (Kalmar and Cafarelli, 2004). This mechanism may also facilitate the release of calcium ($Ca^{2+}$) ions from the sarcoplasmic reticulum, which allows more frequent and forceful muscular contractions to take place (Klein et al., 1990).

In addition to the aforementioned mechanisms, there is now evidence to suggest that the ingestion of ergogenic aids may not be necessary in order to mediate improvements in athletic performance. Rinsing CHO in the mouth has been shown to improve high intensity exercise performance (Chambers et al., 2009; Pottier et al., 2010; Rollo et al., 2010; Sinclair et al., 2014). The mechanism by which CHO rinsing is thought to improve exercise is through carbohydrate mouth receptors which regulate the central mechanisms linked to motivation (Chambers et al., 2009). Furthermore, recent research has established that CAFF can be absorbed in the buccal mucosa (Kamimori et al., 2012) leading to research being undertaken in to CAFF chewing gum on cycling performance (Paton et al., 2010; Ryan et al., 2013). This suggests that caffeine mouth rinse will also improve exercise performance. This was confirmed by Beaven et al. (2013) who showed that rinsing a 1.2% CAFF mouth rinse solution improved repeated sprint cycling performance. In addition Bottoms et al. (2014) demonstrated that rinsing a 0.032% CAFF solution served to significantly enhance 30 min cycling time trial performance.

However, despite the sizeable body of evidence that now exists regarding the ergogenic benefits of both CHO and CAFF rinsing; the majority of these investigations have considered only lower body exercise. Therefore, the effects of both CHO and CAFF mouth rinsing on upper body exercise are not yet known. Typically the upper body has a greater proportion of type II muscles fibres in comparison to the lower extremities (Bernasconi et al., 2006). Type I fibres which are predominant in the lower body are metabolically more efficient than Type II fibres (Smith et al., 2006). Upper body exercise therefore necessitates a larger $O_2$ cost than does lower body exercise to produce the power output (Smith et al., 2006). As there are known differences in
muscle fibre contributions between upper and lower body exercise CHO and CAFF rinsing may have differential effects on different exercise modalities (Bottoms et al., 2014). Thus the observations from previous investigations which have focused on the lower body cannot be generalized to upper body exercise.

The aim of the current study was therefore to determine whether CHO and CAFF have any effect on 30 min arm crank time trial performance. A study of this nature will provide further insight into the ergogenic benefits of both CHO and CAFF rinsing. The current investigation tests the hypothesis that both CHO and CAFF rinsing will serve to significantly enhance upper body exercise in comparison to placebo (PLA).

2. METHODS
2.1. Participants

Twelve male participants (age 21.54 ± 1.28 years, height 179.46 ± 7.38 cm and mass 73.69 ± 5.40 kg) took part in this investigation. Participants were free from musculoskeletal injury and provided written informed consent. The investigation was approved by the University of Central Lancashire, School of Sport Tourism and Outdoors, ethical committee in accordance with the principles detailed in the declaration of Helsinki.

2.2. Procedure

Data collection was accomplished using an arm crank ergometer (MONARK, Cardio Rehab 891E, Nottingham). The data collection procedure required a total of four visits to a bespoke exercise physiology laboratory. Visit 1 served as a familiarization session, whilst visits 2-4 were used for data collection in which participants performed 30 min time trials using the arm crank ergometer for maximum distance. For data collection i.e. sessions 2-4 all participants were administered either 4 x 25ml of a tasteless 6.4 % maltodextrin (Maltodextrin, My Protein) solution (CHO), 0.032 % caffeine (MyProtein; this was representative of the caffeine concentrations observed in commercially available caffeinated drinks and in accordance with Bottoms et al. (2014) solution (CAFF) or a water bolus (PLA).

Visit 1

The first visit to the laboratory represented a familiarization session during which a 30 min time trial was performed using the same protocol as in the experimental trials.

Visit 2-4

Participants were instructed to report to the laboratory having refrained from alcohol, caffeine and exercise in the 24 hours prior and also having fasted for 4 hours \(^3\). Experimental data was obtained at the same time of day to avoid physiological fluctuations caused by circadian rhythmicity. Participants were firstly fitted with a heart rate monitor (Polar RS100, Polar Electro Oy Finland). They were asked to arm crank as far as possible in 30 min at a resistance of 1kg
added to the arm crank ergometer. The ergometer was interfaced with a computer which calculated the outcome measures of heart rate (HR), cadence (strokes.min\(^{-1}\)), power output (W) and distance covered (m) which were quantified at 6-min intervals throughout the 30-min time trials. In addition, participants were also asked to rate their perceived exertion (RPE) using the 6-to 20-point Borg scale (Borg, 1982) at 6-min intervals.

2.3. Mouth Rinse Administration
Each participant was given a 25 ml bolus of a tasteless CHO, CAFF or PLA every 6 minutes. The solutions were rinsed for a total of 5s and then spat into a bowl. The mouth rinses were controlled using a single-blind mechanism and the order in which they were administered was counterbalanced.

2.4. Blinding Efficacy
For the CHO trials 5 of the 12 participants correctly identified that they were receiving an ergogenic solution and for the CAFF trials 6 of the 12 participants were able to identify that they were receiving an ergogenic solution.

2.5. Statistical Analysis
To examine any effects of CHO, CAFF and PLA mouth rinsing 5 x 3 (time x condition) repeated measures ANOVA’s were conducted. Main effects were further explored using post-hoc pairwise comparisons and significant interactions were examined using simple main effects. Statistical significance throughout was accepted at the p<0.05 level. Effect sizes were calculated using partial Eta\(^2\) (p\(\eta^2\)). All statistical procedures were conducted using SPSS v22.0 (SPSS Inc., Chicago, IL, USA).

3. RESULTS
3.1. Distance Covered
Of the twelve participants 10 and 9 were able to complete a greater distance in the CHO and CAFF conditions respectively in comparison to PLA. Significant main effects were observed for both condition (p<0.05, p\(\eta^2 = 0.30\)) and time (p<0.05, p\(\eta^2 = 0.96\)). In addition a significant interaction (p<0.05, p\(\eta^2 = 0.27\)) was also observed between condition and time. Further analysis using simple main effects showed significant differences between conditions at 6 min (p<0.05, p\(\eta^2 = 0.26\)) 12 min (p<0.05, p\(\eta^2 = 0.28\)), 18 min (p<0.05, p\(\eta^2 = 0.26\), 24 min (p<0.05, p\(\eta^2 = 0.25\) and 30 min (p<0.05, p\(\eta^2 = 0.30\)) time points. Specifically the results indicated that distances covered during the CHO and CAFF trials were significantly greater than PLA at each of the time points. Overall distance covered was shown to be 15.30 ± 3.31 km in the CHO, 15.43 ± 3.27 km in the CAFF and 13.15 ± 3.36 km in the PLA trials (Figure 1).
3.2. Cadence and Power Output

For power output there was a significant main effect for time (p<0.05, $\eta^2 = 0.52$). Post-hoc analysis revealed that power output at 30 min was significantly (p<0.05) greater than any of the other time points. There was also a main effect for condition (p<0.05, $\eta^2 = 0.34$) for which post hoc analysis showed that power output was significantly greater (p<0.05) in the CAFF and CHO trials compared to PLA (Figure 2a). For cadence there was also a significant main effect for time (p<0.05, $\eta^2 = 0.55$). Post-hoc analysis revealed that power output at 30 min was significantly (p<0.05) greater than any of the other time points. There was also a main effect for condition (p<0.05, $\eta^2 = 0.33$) for which post hoc analysis showed that cadence was significantly larger (p<0.05) in the CAFF and CHO trials compared to PLA (Figure 2b).
3.3. Heart Rate and RPE

For HR there was a significant main effect for time (p<0.05, \( \eta^2 = 0.60 \)). Post-hoc analysis revealed that HR at 24 and 30 min were significantly (p<0.05) greater than any of the other time points (Figure 3a). For RPE there was also a significant main effect for time (p<0.05, \( \eta^2 = 0.76 \)). Post-hoc analysis revealed that RPE increased linearly as a function of time and that each time point different significantly (p<0.05) from the others (Figure 3b).

Figure-2b. Mean (±SD) cadence during the 30 minute exercise for each condition.

Figure-3a. Mean (±SD) heart rate during the 30 minute exercise for each condition.
4. DISCUSSION

The aim of the current investigation was to explore the effects of CHO and CAFF mouth rinsing on upper body exercise. This represents the first investigation to comparatively examine the influence of both CHO and CAFF mouth rinsing on upper body time trial performance.

In support of our hypothesis the results demonstrate that both CAFF and CHO mouth rinsing increased distance covered during the 30 minutes of self-paced arm cranking. This observation supports those that have been observed previously in lower body exercise regarding the positive performance influence of CHO mouth rinsing on high intensity exercise performance (Chambers et al., 2009; Pottier et al., 2010; Rollo et al., 2010; Sinclair et al., 2014). The results from this study also support those of Beaven et al. (2013) and Bottoms et al. (2014) who found that CAFF mouth rinsing improved performance in high intensity cycling. The key implication from the current investigation is that CHO and CAFF rinsing appear to also be beneficial to those undertaking upper body exercise.

There was a 17% improvement in performance during the CHO trial, which is by far greater than for lower body exercise trials which have previously found increases of around 2-3% (Chambers et al., 2009; Pottier et al., 2010; Rollo et al., 2010; Sinclair et al., 2014). This greater increase in performance could be due to the differences in musculature (the upper body has a greater percentage of Type II fibres compared to the lower body) as well as the fact submaximal arm exercise is metabolically less efficient and produces greater respiratory variables and perceived exertion (Ahlborg et al., 1986). These differences in physiological responses between the upper and lower body musculature suggest that carbohydrate utilisation is greater during work...
with the arms than the legs. Therefore, when carbohydrate activates the anterior cingulated cortex and ventral striatum as well as other brain regions during mouth rinsing which has previously been observed by Chambers et al. (2009) it could potentially stimulate a stronger increase in performance due to the increased demand for carbohydrate as fuel. In comparison, there was a 16% improvement in performance during the CAFF trial, which is similar to those found in lower body performance by meta-analyses by Doherty and Smith (2005) and Ganio et al. (2010) who found increases in endurance capacity of 12.3%. Caffeine has been observed to be absorbed rapidly in the buccal mucosa (Kamimori et al., 2012) which has led to researchers using caffeine chewing gum to observe improvements in cycling performance (Paton et al., 2010; Ryan et al., 2013). Caffeine could potentially be improving performance by decreasing perceived exertion and reducing pain perception due to the action of adenosine and dopamine acting on the brain (Meeusen et al., 2013).

The current study confirmed that no differences in RPE were observed between rinsing conditions despite the significant increase in distance covered in the CAFF and CHO trials. This finding is important as it shows that participants were able to exercise at a higher intensity but at a similar RPE in the CAFF and CHO conditions. This supports the findings of Pottier et al. (2010), who showed that participants were able to produce a larger external power output for the same level of perceived discomfort. This indicates that there may have been an increase in motivation during the CHO and CAFF trials (Kalmar and Cafarelli, 2004). The physiological mechanisms responsible for the positive effects of both CHO and CAFF on exercise performance are not yet fully understood. Chambers et al. (2009) utilized functional magnetic resonance techniques to study brain activation during carbohydrate mouth rinsing and determined that a CHO mouth rinse enhanced activation of the areas in the brain linked to motivation. The findings from the current investigation regarding performance benefits of CAFF rinsing indicate that further investigation is warranted using magnetic resonance imaging to determine whether similar brain functions are mediated when using a CAFF compared to CHO rinse or whether improvements are a result of absorption in the buccal mucosa.

The results from the current study may have important practical benefits for those who habitually partake in high intensity upper body exercise. It appears based on these observations that when undertaking upper body exercise athletes may benefit from rinsing instead of ingesting both CHO and CAFF solutions. Ingestion of both CHO and CAFF has been linked to gastrointestinal issues during exercise (Peters et al., 1993; Boekema et al., 1999). Therefore rinsing CAFF and CHO may allow athletes to have benefit from these ergogenic solutions but also avoid the gastrointestinal distress associated with their ingestion. Finally mouth rinsing CHO and CAFF could also be a mechanism by which athletes who have diabetes or are sensitive to caffeine could benefit from the ergogenic effects of CHO and CAFF without the detrimental health consequences (Sinclair et al., 2014).

In conclusion, although previous analyses have investigated the effects of both CAFF and CHO rinsing these studies had all been confined to lower body exercise modalities. The current
investigation addresses this gap in the literature by providing a comprehensive investigation of the effects of both CAFF and CHO mouth rinse on upper body exercise performance. This study provides evidence to suggest that both CHO and CAFF rinse can improve 30 min arm cranking performance. The underlying mechanisms behind these improvements in performance in the absence of ingestion are still not fully understood at the current time and future work should seek determine the physiological mechanisms by which mouth rinsing exerts its effects. Nonetheless, this work confirms that those performing in short duration upper body exercise based events may be able to improve their resultant performance through utilization of a CHO of CAFF mouth rinse.

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