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THE EFFECTS OF CARBOHYDRATE, CAFFEINE, AND COMBINED RINSES ON CYCLING PERFORMANCE

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ABSTRACT

Introduction: The purpose of this study was to investigate the effects of carbohydrate, caffeine and carbohydrate-caffeine mouth rinses on a cycling time trial performance with recreationally active college-aged females. **Methods**: Seven volunteers (age: 21.86±0.10 yrs, height: 165.48±1.24 cm, mass 65.40±1.42 kg, BMI 23.80±0.34 kg/m^2, Vo_{2max} 37.99±0.92 ml/kg/min) gave their written informed consent to participate in the study. The participants completed four trials on the cycle ergometer. The first was a VO_{2max} and Workloadmax test until volitional fatigue. The following visits included a 5 minute warm-up at 40% Wmax followed by completing a set amount of work of 0.6 * Wmax * 3600. Every 12.5% of work completed the subject rinsed their mouth for 5 seconds with 25 mL of either 1.2% caffeine, 6% carbohydrate or carbohydrate-caffeine solutions. **Results**: No significant differences in time trial performance were observed between the CHO (61.56±3.1 min), CAF (61.63±2.7 min), and CAF-CHO (63.89±3.7 min) trials (p=0.70). Split times between the CHO, CAF, and CAF-CHO trials approached significance (p=0.08). There were no significant differences observed in mean power (CHO: 125.35±11.0W, CAF: 124.87±10.5W, CAF-CHO: 121.65±11.9, p=0.98) or peak power (CHO: 184.14±17.4W, CAF: 204.71±32.2W, 167.00±12.7W, p=0.29) during any trial. Power outputs at each 12.5% of the distance completed approached significance (p=0.10) between the CHO, CAF, and CAF-CHO trials. **Conclusion**: The current study found that a caffeine rinse does not appear to improve endurance cycling performance in females when compared to a carbohydrate and carbohydrate/caffeine rinse.

Keywords: power output; ergogenic aid

INTRODUCTION

Endurance athletes have often supplemented with carbohydrate during events to improve performance by preventing hypoglycemia and allowing for provision of blood glucose for oxidation late in exercise and create a hepatic glycogen sparing scenario (1, 2, 3). However, in exercise lasting less than 1 hour, hypoglycemia does not develop and glycogen depletion is not a performance-limiting factor. This indicates that other mechanisms, such as the central nervous system, may play a role in the ergogenic effects of carbohydrate. Carter et al (4) found that rinsing with a 6.4%

maltodextrin solution improved performance over a water rinse supporting the aforementioned theory. It is suggested that besides serving as an energy substrate the sight, smell, and taste of food functions as a positive reinforcement resulting in the body responding as it is about to receive food; there are specific oropharyngeal receptors in the mouth that are linked to brain centers related to motivation and reward (5).

Caffeine is well supported as an ergogenic aid during endurance events (6, 7, 8, 9). Caffeine exerts its effect on many tissues and has been shown to improve endurance performance by increasing free fatty acid availability via epinephrine secretion which results in a glycogen sparing effect (8). The most impactful mechanism of action may be caffeine's role in adenosine receptor binding. Caffeine can bind to adenosine receptors therefore blocking their action. These receptors can be found in most tissues, resulting in a wide range of responses. It appears that the most powerful ergogenic effects of caffeine are neural in nature (6, 7, 10). Additionally, recent evidence suggests that caffeine does not need to be ingested in order to be absorbed into the bloodstream. Rather, caffeine that is not ingested but comes into contact with the buccal cavity increases plasma caffeine (5, 11).

The combined effect of caffeine and carbohydrate supplementation has also been discussed recently (12). Both of these ergogenic aids are commonly used by athletes to improve endurance performance. The theory that the central nervous system (CNS) is involved in both situations has led to the question of how they would work together. In a meta-analysis of such studies, Conger et al. (12) concluded that carbohydrate and caffeine co-ingestion results in larger improvements in endurance performance when compared to carbohydrate supplementation alone.

While both caffeine and carbohydrate supplementation has shown performance benefits both separately and combined, some athletes avoid acute supplementations for several reasons. In some athletes, particularly in sports that involve running, gastrointestinal discomfort may be an issue with supplementation (13). Other athletes, whose sports are highly dependent on body weight, such as cyclists, may not want to consume the excess calories that go along with supplementation. This is why the idea of mouth rinses including carbohydrate and caffeine, if shown to be as effective, may become a more applicable, practical way to supplement during prolonged aerobic activities. The purpose of this study was to investigate the effects of carbohydrate, caffeine and carbohydrate-caffeine mouth rinses on a cycling time trial with recreationally active college-aged females.

METHODS

Seven college-aged recreationally active female volunteers gave their written informed consent to participate, and have personal information collected, in the study that was approved by the Institutional Review Board at East Stroudsburg University (Protocol #ESU-IRB-030-1314). All personal information and data collected remained confidential throughout the study. All participants were considered recreationally active as defined by American College of Sports Medicine (14).

Familiarization

All subjects participated in a familiarization trial prior to testing. During the familiarization session, all subjects were familiarized with the cycle ergometer, metabolic equipment, and Borg rate of perceived exertion (RPE) chart (15).

Pre-Experimental Trial Conditions

All subjects were asked to log their food intake 24 hours prior to the first trial. Subjects were given a copy of the first food log and asked to replicate all meals prior to trials two and three. Though subjects were asked to replicate their food log, subjects were instructed to log all food and drink intake for 24 hours prior to each trial to ensure compliance. The return rate for the food logs was low and is a limitation for this study as we cannot quantify dietary compliance. All participants were asked to arrive at the laboratory 2-hours post absorptive.

All subjects were asked to refrain for exhaustive exercise 24 hours prior to their experimental trials. Subjects were also asked to refrain from caffeine ingestion (beverages, foods, medications, etc.) for three days leading up to their experimental trials.

Experimental Design

The double blind, randomized protocol consisted of four visits in the laboratory. All exercise tests were carried out on an electrically braked cycle ergometer (Lode Excalibur, Groningen, The Netherlands). Visit 1 was an incremental exercise test to exhaustion to determine maximum oxygen uptake (VO_{2max}) and maximum power output (Wmax). Visits 2, 3 and 4 were the simulated time trials involving the completion of a set amount of work in the shortest amount of time possible. Each visit was separated by 7 days. The amount of work completed was equal the work if the participant maintained their self-selected, preferred cadence for 60 minutes at 60% Wmax.

For the experimental trials, the participant randomly received one of three mouth rinses (6% carbohydrate solution, 1.2% caffeine solution or carbohydrate (6%)-caffeine (1.2%) solution). The carbohydrate solution was a commercially available fruit-punch flavored glucose sports-drink (Gatorade, PepsiCo, USA). The caffeine solution was mixed with caffeine powder (Nutrabio, Middlesex, NJ) flavored with a non-caloric lemon flavored powder (Crystal Light, Kraft Foods, USA). The carbohydrate-caffeine solution was the sports-drink mixed with caffeine powder. All rinses were mixed for the same amount of time to ensure equal consistency. The participants rinsed their solution around their mouth for 5s at regular intervals.

Visit 1:

Participants received information regarding the expectations and the nature of the study and were given time to ask any questions. Once familiar with the experimental procedures, they gave their written informed consent to participate in the study. The participants then performed an incremental exercise test to volitional fatigue at a self-selected cadence on a cycle ergometer. The appropriate seat position, handlebar height, and orientation used during testing were replicated in the following visits. The initial workload was 50 W and increased by 25 W every minute until volitional fatigue or when the participant dropped below 50 rpms. Ventilation and oxygen uptake were recorded continuously using the metabolic cart. Heart rate was also continuously tracked using Polar T-31 Heart Rate Monitors (Polar Electro Inc., Lake Success, NY). Blood lactate was measured using a Lactate Pro Analyzer (LT-1710, Arkray Inc, Kyoto, Japan). Lactate and RPE were collected every minute.

Visit 2-4:

Participants visited the lab after having abstained from caffeine for the past 3 days as well as alcohol, tobacco and exercise in the previous 24 hr. On arrival to the

laboratory, participants gave a urine sample, were weighed, and fitted with a heart rate monitor. Urine analysis was completed using an Atago URC-NE Hand Refractometer (Atago USA, Inc., Bellevue, Washington). After a 5-min warm-up at 40% Wmax, the participants were asked to perform a certain amount of work as fast as possible. The total amount of work was calculated according to the formula modified from Carter et al (4):
Total work = 0.6 * Wmax * 3600

The ergometer was set in the linear mode so that 60% Wmax was achieved when the participant pedaled at the preferred cadence, determined during the VO_{2max} test. The cycle ergometer was connected to the computer which calculated and displayed the amount of work performed. The only information that the participant received was the amount of work completed. Every 12.5% of the time the participant was administered the mouth rinse, asked for local and overall RPE and heart rate and lactate were recorded. During the time trial the participants were allowed to drink water ad libitum. The amount consumed during the first trial was measured, recorded and repeated for all trials to maintain consistency.

Mouth Rinse Protocol

Each participant was given 25-mL of the solution for every 12.5% of their work completed, starting immediately after the warm-up. They were instructed to rinse the solution around their mouth for a 5s countdown and then spit the fluid into a cup held by the investigator. The participants were kept blind to the composition of their solutions until the end of the study.

Data Analysis:

All of the analyses were performed using the Statistical Package for the Social Sciences (SPSS for Windows, version 20.0, SPSS Inc., Chicago, IL). Participant demographic data was evaluated using descriptive statistics including means, standard deviations and standard errors. A one-way repeated measures ANOVA was used to test for significant differences in time to completion, RPE, peak RPMS and power output, mean cadence, and power output, and heart rate. A two-way repeated measures ANOVA was run to test for significant differences in power output and split times throughout each 12.5% of the time trial completed. The significance level was set at $P \leq 0.05$. All data for each group were expressed as mean ± SEM.

RESULTS

Subjects

The subjects who participated in this study were 21.86±0.1 years old, 165.48±0.5 cm tall, weighed 65.40±1.4 kg and had a body mass index (BMI) of 23.80±0.3 kg/m^2.

VO_{2max}

Subjects had a VO_{2max} of 37.99±0.9 ml/kg/min. The subjects' maximal workload (Wmax) was 210.71±5.0 watts and mean pedaling cadence was 67.94±1.3 rpm.

Urine Specific Gravity (USG)

Subjects had a USG of 1.017±0.003, 1.018±0.002, and 1.019±0.003 prior to the carbohydrate (CHO), caffeine (CAF) and caffeine/carbohydrate (CAF-CHO) trials, respectively. Subjects had a post-trial USG of 1.013±0.003, 1.019±0.004, and 1.018±0.003 in the CHO, CAF, and CAF-CHO trials, respectively. These results indicate no differences in hydration status existed in any condition prior to and after each trial. (p=.855 pre, p=.456 post)

Performance

Total times to complete the cycling time trial during each condition are displayed in Figure 1. No significant difference in time trial completion were observed between the CHO (61.56±3.1 min), CAF (61.63±2.7 min), and CAF-CHO (63.89±3.8 min) trials (p=0.70).

Split times during the time trial are displayed in Figure 2. Spit times between the CHO, CAF, and CAF-CHO trials approached significance (p=0.08).

Mean power output and pedaling cadence are displayed in Table 1. There were no significant differences observed in mean power (p=0.98), peak power (p=0.29), mean pedaling cadence (p=0.86), or maximum pedaling cadence (p=0.67) during any trial.

Power outputs at each 12.5% of the distance completed are displayed in Figure 3. Power outputs between the CHO, CAF, and CAF-CHO trials approached significance (p=0.10).

Mean heart rate was not different (p=0.78) during any of the trials (CHO: 165.44±7.6 bpm, CAF: 164.10±6.3bpm, CAF-CHO: 163.88±6.5bpm).

Mean lactate was not different (p=0.55) during any of the trials (CHO: 4.61±0.6 mmol/L, CAF: 5.29±0.6 mmol/L, CAF-CHO: 4.51±0.6 mmol/L).

Mean general rate of perceived exertion (RPE) were not different (p=0.80) during any of the trials (CHO: 14.7±0.7, CAF: 13.55±0.8, and CAF-CHO: 13.82±0.8). Local RPE were not different (p=0.94) during any of the trials (CHO: 15.25±0.7, CAF: 14.28±0.6, and CAF-CHO: 14.48±0.8).

Table 1: Power output and pedaling cadence during cycling time trial with a carbohydrate rinse (CHO), caffeine rinse (CAF), or combined caffeine and carbohydrate rinse (CAF-CHO). No significant differences were observed in mean or peak power and mean or peak pedaling cadence. Data are expressed as mean±SE.

	Mean Power (W)	**Peak Power (W)**	**Mean RPMs**	**Peak RPMs**
CHO	125.35 ± 11.04	184.14 ± 17.38	66.62 ± 2.29	82.00 ± 4.74
CAF	124.87 ± 10.53	204.71 ± 32.18	66.51 ± 2.41	84.29 ± 3.83
CAF-CHO	121.65 ± 11.85	167.00 ± 12.67	65.47 ± 2.17	78.14 ± 3.59

Figure 1: Time to time trial completion with a carbohydrate rinse (CHO), caffeine rinse (CAF), or combined caffeine and carbohydrate rinse (CAF-CHO). No significant differences (p=0.69) were observed in time trial completion under any condition. Data are expressed as mean±SE.

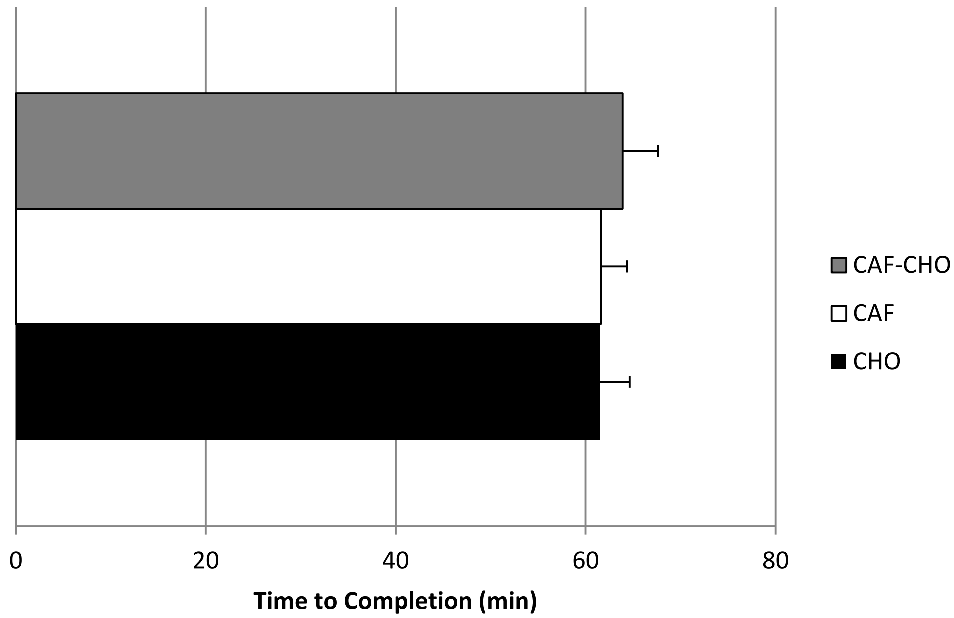

Figure 2: Split times during the cycling time trial with a carbohydrate rinse (CHO), caffeine rinse (CAF), or combined caffeine and carbohydrate rinse (CAF-CHO). Split times approached statistical significance (p=0.08). Data are expressed as mean±SE.

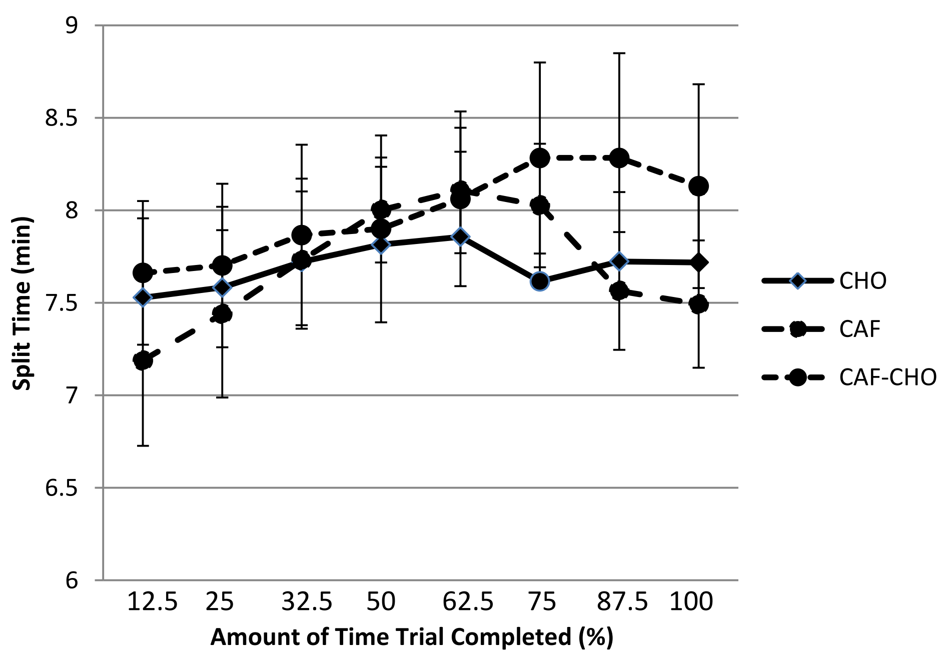

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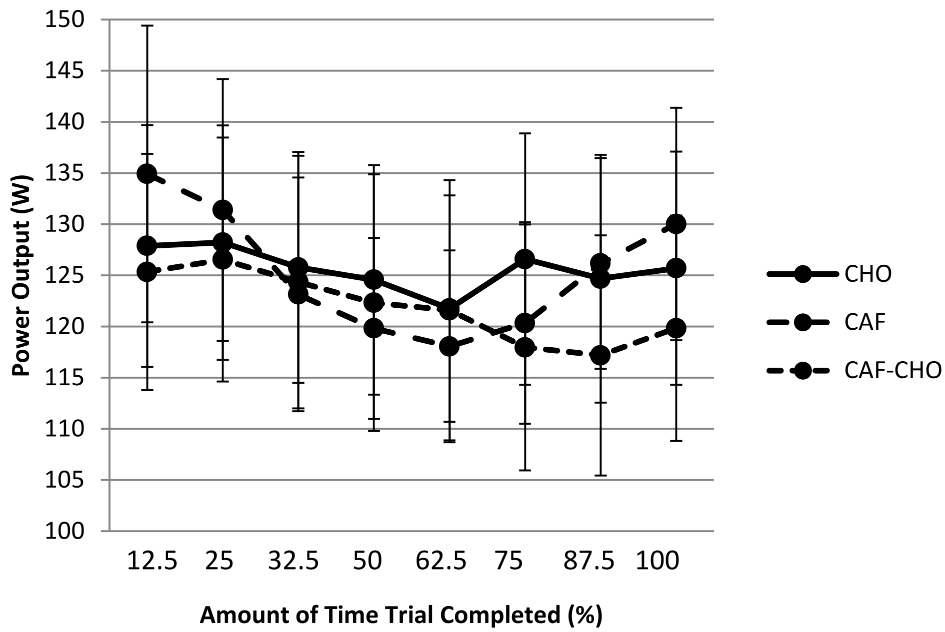
Figure 3: Power output during the cycling time trial with a carbohydrate rinse (CHO), caffeine rinse (CAF), or combined caffeine and carbohydrate rinse (CAF-CHO). Power outputs approached statistical significance (p=0.10). Data are expressed as mean±SE.



DISCUSSION

The purpose of this study was to investigate the effects of carbohydrate, caffeine and carbohydrate-caffeine mouth rinses on a cycling time trial with recreationally active college-aged females. The current study found no significant differences in time trial performance between carbohydrate rinse, caffeine rinse and combined carbohydrate-caffeine rinse. The current study agrees with Doering et al. (11), who found caffeine mouth rinses neither improved endurance cycling time-trial performance nor significantly impacted RPE or heart rate throughout the study. Doering et al. (11) used a solution of 35mg of anhydrous caffeine dissolved in non-caffeinated, de-carbonated diet cola during their protocol, and had the subjects rinse with the solution for 10s every 12.5% of the time trial completed. No elevation in plasma caffeine throughout the caffeine trials was noted, suggesting that the caffeine mouth rinse needs a longer duration in the buccal cavity to produce an ergogenic effect. We cannot confirm whether caffeine from the mouthrinse was or was not absorbed into the bloodstream as plasma caffeine was not measured in the current study.

Caffeinated gum has been found to produce an ergogenic effect in cycling performance. Ryan et al. (16) found that chewing caffeinated gum immediately prior to and during a cycling time trial enhanced performance but also led to increases in plasma caffeine levels suggesting that caffeine does not need to be ingested to be absorbed into the bloodstream via the buccal cavity; this theory has been previously supported (17). This also suggests that while caffeinated gum does have an ergogenic effect, it is more likely a systemic effect and not central, as increases in performance are seen with increases in plasma caffeine. This may help to explain the lack of time trial improvement with the caffeine rinse trial in the present study.

Several studies have shown improvements in endurance performance with carbohydrate mouth rinses (4, 5, 18). However in the present study, carbohydrate rinses showed no ergogenic benefits when compared to caffeine or combined carbohydrate-caffeine rinses. Jeukendrup et al. (13) suggest that carbohydrate mouth rinses are beneficial for high intensity activity (greater than 75% VO2max) lasting 30-60 minutes. The subjects for the current study performed their time trials at 60% Wmax, which may not have been intense enough to elicit performance benefits via the carbohydrate mouth rinse. During pilot testing, we determined that our subjects had difficulty completing a one hour time trial at a workload corresponding to 75% Wmax. WE therefore adjusted the intensity to ensure completion. Carter et al. (4) found significant increases in time trial performance and mean power output compared to a placebo when subjects rinsed with a 6.4% maltodextrin solution throughout a 1-hr time trial on the cycle ergometer. It is noteworthy that in the study by Carter et al. (4), the subjects performed their time trials at 75% Wmax and after a 4-hour fast. Beelen et al (19) completed a similar study using the same rinse protocol and workload, but gave their subjects a carbohydrate rich breakfast two hours before the time trial. They found no significant differences in time trial performance, heart rate, RPE or power output. Other studies have shown that carbohydrate rinsing is effective in both the fasted and the fed state (18) but that improvements are more pronounced in the fasted state (13). Similar results were found in the present study which suggests that, while the possibility of glucose receptors in the mouth exists, they may only be beneficial during times when skeletal muscle glycogen stores are low, not in the case of a fed state (19). This theory may explain why no significant differences were found between the three rinse trials in the current study where the participants were two hours post absorptive.

Furthermore, Chambers et al. (5) suggests that prolonged exercise results in afferent information arising from muscles, joints and lungs which may eventually be perceived as unpleasant, thus consciously, or unconsciously, leading to inhibition of motor output also known as “central fatigue.” The authors then showed that the presence of both sweet and non-sweet carbohydrate in the human mouth activates a variety of brain areas that may be involved in reward and the regulation of motor activity. Therefore, we speculate that the current study was not performed at a high enough intensity to activate the reward centers using carbohydrate mouth rinses. Future studies focusing on moderate and high intensity exercise would be advantageous to clarify exercise intensities most impacted by carbohydrate rinsing.

There are very few studies testing the effects of a combined carbohydrate-caffeine rinse on performance. Beaven et al. (17) compared a combined carbohydrate-caffeine rinse to carbohydrate rinse condition during repeated cycle ergometer sprints and found that the combined rinse elicited a higher peak power during the first sprint and higher mean power during the last (fifth) sprint in comparison to the carbohydrate mouth rinse trial. It should be noted that during the carbohydrate rinse trial there was a significant decrease in mean power during the fifth trial, however it is unknown if the combined carbohydrate-caffeine rinse showed improvement compared to placebo or any other trial due to the authors’ data comparisons.

Gam et al. (20) suggest that the act of mouth rinsing itself has a detrimental effect on performance. They found that a no rinse time-trial was significantly faster than the water rinse trial, although there was no difference between the carbohydrate rinse trial and the no rinse trial. This suggests that, while in some way the addition of carbohydrates to a rinse balances out the effect of rinsing, it may not be any more beneficial than not rinsing at all. The authors suggest that the tendency of power output to decrease during the act of rinsing may have added up to an overall decrease. It is also suggested that rinsing may have impaired performance by disrupting breathing rhythm (18). This theory may explain the results of the current study, as a no-rinse trial was not used. None of the participants in the current study were able to correctly identify any of the rinses.

The primary limitation for this study is the lack of a placebo trial. This limits the comparison of performance between carbohydrate, caffeine and the combined carbohydrate-caffeine rinses to an actual control group. While no significant differences were found between trials, it is interesting to note that the combined carbohydrate-caffeine rinse showed an increase, approaching significance, in split times while the time trial progressed, whereas the carbohydrate rinse tended to maintain split times. Split times approached significance ($p=0.08$) and is a concept that should be further examined.

CONCLUSION

The current study found that a caffeine rinse does not appear to improve endurance cycling performance in females when compared to a carbohydrate and carbohydrate/caffeine rinse.

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The authors declare that there are no competing interests in the conduction of this investigation.

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