Carbohydrate and caffeine mouth rinses do not affect maximum strength and muscular endurance performance

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Article Title: CARBOHYDRATE AND CAFFEINE MOUTH RINSES DO NOT AFFECT MAXIMUM STRENGTH AND MUSCULAR ENDURANCE PERFORMANCE.

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ABSTRACT

Oral carbohydrate rinsing has beneficial effects on endurance performance and caffeine mouth rinsing either independently or in conjunction with carbohydrate may enhance sprinting performance. However, the effects of carbohydrate and/ or caffeine mouth rinses on resistance exercise have not been examined previously. The purpose of this study was to investigate the effects of carbohydrate and/ or caffeine rinsing on maximum strength and muscular endurance performance. Fifteen recreationally resistance trained males completed an exercise protocol which involved a one repetition maximum (1-RM) bench press followed by 60% of their 1-RM to failure in a double-blind, randomised, counterbalanced crossover design. Prior to exercise either 25 ml of a 6% (15 g; 0.20±0.02 $g \cdot kg^{-1}$) carbohydrate (CHO), 1.2% (300 mg; 3.9±0.3 $mg \cdot kg^{-1}$) caffeine (CAF), carbohydrate with caffeine (C+C) solutions, or water (PLA) were rinsed for 10 s. During the remaining session, no solution was rinsed (CON). All solutions were flavoured with (200 mg) sucralose. Felt arousal was recorded pre- and post-rinse and rating of perceived exertion was recorded immediately after the repetitions to failure. There were no significant differences in 1-RM (P=0.808; η_p^2=0.02), the number of repetitions performed (P=0.682; η_p^2=0.03) or the total exercise volume (P=0.482; η_p^2=0.03) between conditions. RPE was similar for all trials (P=0.330; η_p^2=0.08), while Felt arousal increased as a consequence of rinsing (P=0.001; η_p^2=0.58), but was not different between trials (P=0.335; η_p^2=0.08). These results suggest that rinsing with a carbohydrate and caffeine solution either independently or combined has no significant effect on maximum strength or muscular endurance performance.

Key Words: Rinsing, Resistance exercise, Bench press, Arousal

INTRODUCTION

Orally rinsing a carbohydrate solution prior to exercise can improve performance without altering metabolic responses (7). Rollo et al. (24) observed similar performance benefits when rinsing or ingesting a carbohydrate solution before and during endurance-based exercise. It is theorised that these benefits arise from receptors in the mouth that detect the presence of carbohydrate (8), which elicit increased activation of the areas of the brain responsible for motivation and motor control (7,21). Kringelbach et al. (19) also suggested that taste sensitive areas of the brain, that when stimulated, can influence behaviour and emotion and therefore arousal, which may influence exercise performance.

Oral carbohydrate rinsing has been shown to improve endurance-based cycling and running performance (7,8,14,21,23). However, not all studies support these findings, Beelen et al. (4) observed that oral carbohydrate rinsing did not influence 1h time trial performance, power output, heart rate or perceived exertion. Carbohydrate rinsing has also been reported to have no effect on repeated sprint ability (6,10). These results may be inconclusive due to variability in practices, such as rinse duration, exercise type and feeding status. Furthermore, the majority of literature focuses on endurance-based exercise, so evidence of possible ergogenic benefits on resistance exercise is lacking. One such study conducted by Painelli et al. (20) investigated the influence of carbohydrate mouth rinsing on one repetition maximum (1-RM) and muscular endurance. Results indicated that the carbohydrate rinse did not improve 1-RM or muscular endurance. However, Painelli et al. (20) suggested that further research is warranted as it may be possible for a carbohydrate rinse to enhance strength performance in other populations including: a) the untrained, b) well-trained individuals when under excessive training load or c) when exercise is muscular endurance orientated.

Similarly to carbohydrate rinsing, the concept of caffeine rinsing is relatively recent. Caffeine is thought to facilitate its effects on the body through antagonising adenosine receptors, causing cell activity to increase (22). Furthermore, adenosine receptors have been shown to exist in the cheek pouch of mammals (25). Therefore, the oral rinsing of caffeine may have the potential to improve performance. At present, few studies examining caffeine rinsing have been conducted and results appear to be inconclusive. Doering et al. (9) observed that a caffeinated mouth rinse had no effect on perceived exertion, heart rate or overall cycling time trial performance. In contrast, Beaven et al. (3) demonstrated that caffeine rinsing may rapidly increase power production in cycle sprints. Interestingly, when carbohydrate and caffeine were synergistically rinsed (3), greater increases in power production were observed when compared with carbohydrate alone.

Walker et al (29) have suggested that the predominant cause of fatigue during maximal strength loading is reduced neural drive. Furthermore, it has been suggested that during a high number of submaximal repetitions, muscle electrical activity increases to maintain the required power output (27). Therefore, any strategy that increases central drive has the potential to enhance strength training protocols. However, despite reports of carbohydrate (16) and caffeine (12) ingestion improving resistance exercise performance, the effects of carbohydrate and/ or caffeine mouth rinses on resistance exercise have not yet been examined. In addition, one limitation of the majority of carbohydrate rinse studies is that they have not compared the effect of a carbohydrate mouth rinse with a no-mouth rinse control condition (14). Therefore, the purpose of this study was to investigate the effects of carbohydrate and/ or caffeine rinsing on maximum strength and muscular endurance performance.

METHODS

Experimental Approach to the Problem

The aim of the present study was to investigate the effect of individual and combined carbohydrate and caffeine rinsing on maximum strength and muscular endurance performance. The experimental design used to address this question incorporated completing an exercise protocol which involved a one repetition maximum (1-RM) using the bench press followed by 60% of their 1-RM to failure on five separate occasions in a Latin-square, double-blind, randomised, counterbalanced crossover design. A bench press protocol was employed due to the relatively untrained nature of the subjects. The main considerations were the response to carbohydrate or caffeine rinsing (hypothesis 1) and a combined solution was also used to evaluate the potential synergistic effect (hypothesis 2). A control condition was added to increase the validity of the study and interventions were randomized to prevent any learning effect. The two performance assessments, 1-RM and 60% 1-RM to failure were selected for their specificity to training and research.

Subjects

Following institutional ethical approval and familiarisation, fifteen recreationally resistance trained males (mean±SD age: 21±2 years (range 19-26 years), height: 176±5 cm, weight: 77±6 kg) participated. All subjects were required to have been injury free and have been taking part in upper body resistance training at least once a week (mean±SD: 3±1 times per week) and for a minimum of six months i.e. recreationally trained. Subjects were instructed to avoid caffeine ingestion for a minimum of 12 hours prior to the trials and refrain from strenuous exercise 24 hours prior to the trials. A 24 hour dietary recall was completed by each subject during the familiarisation session; it was then photocopied and handed back to the subjects in order for the same diet to be repeated for subsequent trials (1). All procedures were undertaken in accordance with the Declaration of Helsinki.

Procedures

Subjects completed a five minute warm-up on an upright bike. Following the warm-up 1-RM was assessed using the protocol outlined by Earle and Baechle (13). Each subject warmed up on the bench press with a light weight (20-kg Eleiko bar, Eleiko AB, Halmstad, Sweden) for ten repetitions. They then rested for one minute, after which 10% more weight (Eleiko Olympic disks, Eleiko AB, Halmstad, Sweden) was added and the subject performed a further 3-5 repetitions. The subject was then allowed to rest for a further two minutes, before a load known to be near maximal was selected to be lifted for 2-3 repetitions. A further 3 minute rest period was then allowed, and the weight further increased by between 5 and 10%. The subject then attempted this weight as their 1-RM. If the lift was successful a further increase of 5 to 10% was attempted after another 3 minutes rest. If the subject failed, the load was lightened by 2.5-5% and after 3 minutes was attempted again. This process was repeated until each subject's 1-RM was established. Once the subject's 1-RM had been identified, they rested for one minute to allow the weight to be adjusted to 60% of their 1-RM. They then performed repetitions to failure at that weight, ensuring that every repetition was lowered to the chest in order to standardise the process. The total weight lifted was calculated by multiplying the 60% of 1-RM weight (kg) by total number of reps performed. Pilot testing revealed a coefficient of variation of 4.1% for 1-RM, 7.7% for the number of reps completed at 60% of 1-RM and 6.5% for total weight lifted.

Immediately after completing the 60% to failure protocol subjects provided their rating of perceived exertion (RPE) (5). The Felt arousal scale (28) was used to measure arousal. The value subjects gave from this scale was recorded along with their HR, both pre- and post-rinse (Figure 1). The subject's HR was also measured post 1-RM and pre- and post-failure while they lay supine on the bench. All experimental trials were conducted at the same time of day (09:00-12:00) in order to avoid circadian variation and trials were separated by a minimum two days in order to avoid fatigue.

FIGURE 1 ABOUT HERE

Rinsing protocol

Prior to exercise either 25 ml of a 6% (15 g; 0.20±0.02 $g \cdot kg^{-1}$) carbohydrate solution (maltodextrin: My Protein, Manchester, UK) (CHO), 1.2% (300 mg; 3.9±0.3 mg·kg^{-1}) caffeine solution (My Protein, Manchester, UK) (CAF), 6% (15 g; 0.20±0.02 g·kg^{-1}) carbohydrate with 1.2% (300 mg; 3.9±0.3 mg·kg^{-1}) caffeine solution (C+C), or water (PLA) were rinsed around the buccal cavity for ten seconds (3,26). Subjects then expectorated the solution back into the plastic cup before starting the exercise protocol. All solutions were flavoured with 0.8% (200 mg) sucralose (My Protein, Manchester, UK). During the remaining session, no solution was rinsed (CON).

Statistical analysis

Data are reported as the mean ± the standard deviation (SD). The Shapiro-Wilk test was applied to the data in order to assess for a normal distribution. A one-way analysis of variance (ANOVA) with repeated measures was used to compare all data except for felt arousal and heart rate, which were analysed with two-way ANOVA with repeated measures. Sphericity was analysed by Mauchly's test of sphericity followed by the Greenhouse-Geisser adjustment where required. Where any differences were identified, pairwise comparisons with Bonferroni correction were used in order to show where they lay. All statistical procedures were conducted using IBM SPSS Statistics for Windows, Version 20.0 (Armonk, NY: IBM Corp.) and an alpha level of $P<0.05$ was considered statistically significant. Furthermore, effect sizes using partial eta squared (η_p^2) were calculated, which were defined as trivial, small, moderate and large (17).

RESULTS

FIGURE 2 ABOUT HERE

FIGURE 3 ABOUT HERE

FIGURE 4 ABOUT HERE

No significant differences in 1-RM (kg) were observed between experimental conditions ($F_{2,28}$=0.223; P=0.808; η_p^2=0.02; Figure 2). Furthermore, the number of repetitions performed ($F_{2,33}$=0.440; P=0.682; η_p^2=0.03; Figure 3) and the total exercise volume ($F_{4,56}$=0.482; P=0.749; η_p^2=0.03; Figure 4) were not significantly different between trials. In addition, no significant order effects for 1-RM ($F_{1,17}$=0.595; P=0.485; η_p^2=0.04), repetitions to failure ($F_{2,23}$=0.146; P=0.823; η_p^2=0.01) and total exercise volume ($F_{2,29}$=0.002; P=0.999; η_p^2=0.00) were observed.

TABLE 1 ABOUT HERE

Felt arousal (Table 1) significantly increased to a large extent as a consequence of rinsing ($F_{1,14}$=18.951; P=0.001; η_p^2=0.58), but there were no significant differences between trials ($F_{4,56}$=1.167; P=0.335; η_p^2=0.08). Heart rate (Table 1) followed a similar pattern with a significant increase during exercise ($F_{1,14}$=241.723; P<0.001; η_p^2=0.95) with no significant differences between conditions ($F_{4,56}$=0.125; P=0.973; η_p^2=0.01). Rating of perceived exertion during the repetitions to failure was similar for all trials ($F_{4,56}$=1.178; P=0.330; η_p^2=0.08; Table 1).

DISCUSSION

The key findings of the present suggest that rinsing with a carbohydrate and caffeine solution either independently or combined has no meaningful effect on maximum strength or muscular endurance performance. Furthermore, the composition of the fluid has no effect on felt arousal, heart rate or RPE.

One repetition maximum, number of repetitions and total weight lifted exhibited no significant differences between conditions. In this novel area of study, few comparative studies exist that have examined the impact of carbohydrate and caffeine rinsing on resistance exercise. Recently, Painelli et al. (20) observed that a CHO mouth rinse did not improve muscular endurance during six sets to failure at 70% of 1-RM. Carbohydrate rinsing is believed to stimulate the areas of the brain responsible for motor control and motivation (7,21) and caffeine rinsing is believed to facilitate ergogenic effects on performance through antagonising adenosine receptors located in the buccal cavity (25) which influences central mechanisms (3). However, evidence from the present study and Painelli et al. (20) suggest that the increase in performance from central effects of carbohydrate rinsing observed in endurance-based exercise (8,14,21,23) are not apparent during resistance exercise.

One potential explanation for the present study demonstrating no improvement during the exercise protocol could be that when exercise intensity elicits near maximal RPE and HR values, as seen in the present study, it creates a "ceiling effect" which makes any appreciable differences between conditions extremely hard to distinguish (3). In addition, the mode of exercise may not be sensitive enough to detect any impact carbohydrate and / or caffeine rinsing has on performance (20). There has been shown to be an inter-day variation in strength of 5% (2), and as results from carbohydrate rinsing in endurance exercise have shown a 2-3% improvement in performance (18), any benefits from carbohydrate and caffeine rinsing on resistance exercise may be lost in large inter-day strength variations. Furthermore, despite using the same concentration of caffeine as previous rinsing studies (3), there may be benefit in increasing this dose as bench press performance has been shown to be improved with the ingestion of 5 $mg \cdot kg^{-1}$ (12). Similarly, a number of non-resistance exercise protocols (7,8,14,21,23) have employed serial rinsing, therefore it may have been beneficial to have included an additional rinse between the maximal strength and muscular endurance assessments.

There were no significant differences in RPE or heart rate between experimental conditions and despite large increases in felt arousal following the rinsing, there were no significant differences between the conditions. The results of the present study are similar to a number of studies previously conducted. Beaven et al. (3) also observed no difference in RPE or heart rate between placebo, carbohydrate or caffeine rinse trials. Furthermore, no elevation in heart rate or reduction of RPE was observed by Doering *et al.* (9) following caffeine rinsing. Carbohydrate rinsing has also been reported to not reduce RPE (7,21) or affect heart rate (4). A possible explanation for the lack of difference in heart rate and RPE between the conditions is that the maximal efforts elicit a "ceiling effect" where no appreciable differences can be observed (3).

In conclusion, these results suggest that rinsing with a carbohydrate and caffeine solution either independently or combined has no significant effect on maximum strength or muscular endurance performance, possibly due to the nature of the exercise causing a "ceiling effect".

PRACTICAL APPLICATIONS

On a practical level the findings of the present study suggest that unlike during endurance exercise, rinsing with carbohydrate and/ or caffeine has no benefit on maximum strength and muscular endurance performance. There may be beneficial effects when employing a lower percentage of 1-RM, thus evolving the exercise mode into more of an upper body muscular endurance test. At 30-40% 1-RM some of the central effects observed in previous endurance-based studies may be visible, although this is only speculation at this point.

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Figure 1: A schematic diagram of the experimental protocol.

Figure 2: Mean (±SD) one repetition maximum (1-RM) achieved in each condition.

Figure 3: Mean (±SD) number of repetitions performed in each condition.

Figure 4: Mean (±SD) total exercise volume performed in each condition.

Table 1: Mean (±SD) Felt arousal, heart rate and RPE during the exercise protocol. A main effect for time for arousal (*P*=0.001) and heart rate was found (*P*<0.001).

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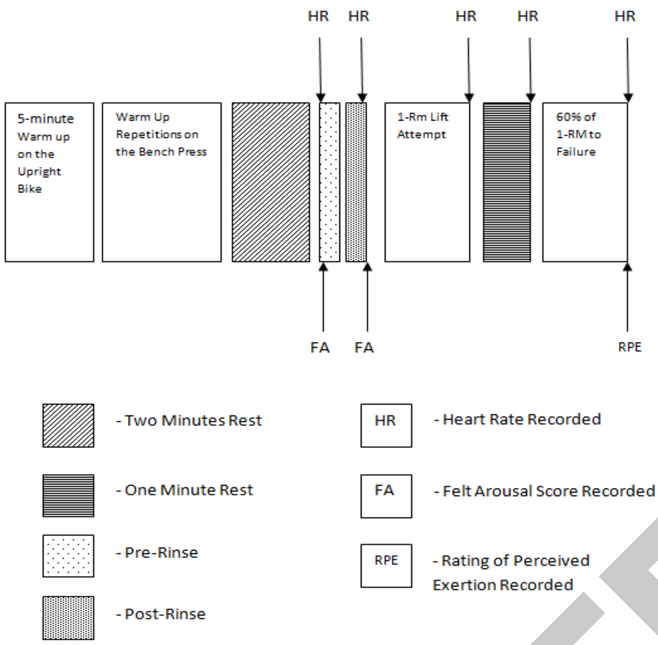
	CHO	**CAF**	**C+C**	**PLA**	**CON**
Arousal					
Pre-rinse	4±1	3±1	3±1	3±1	3±1
Post-rinse	4±1	4±1	4±1	4±1	4±1
Heart Rate (beats·min^{-1})					
Pre-rinse	94±18	91±24	95±17	94±16	95±18
Post-exercise	152±19	154±29	154±20	151±27	149±24
RPE	17±3	17±2	17±2	18±2	17±2



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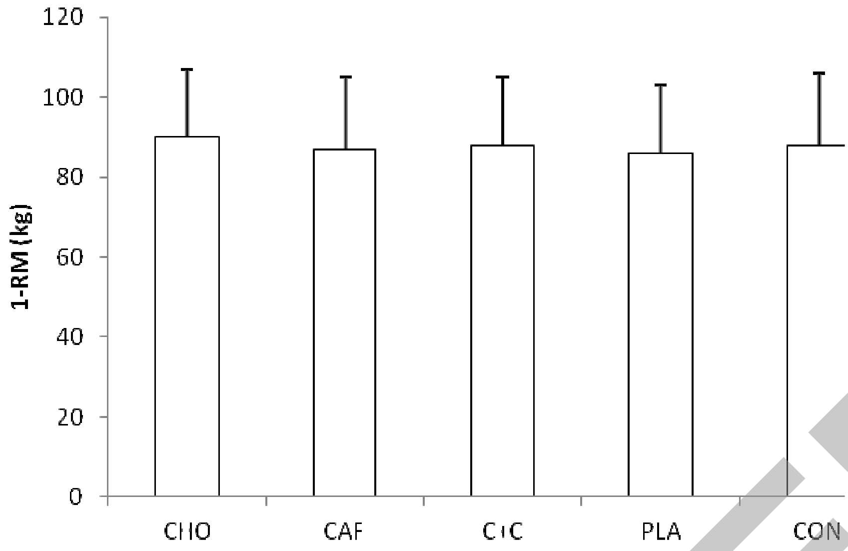

Figure 2: Mean (±SD) one repetition maximum (1-RM) achieved in each condition.

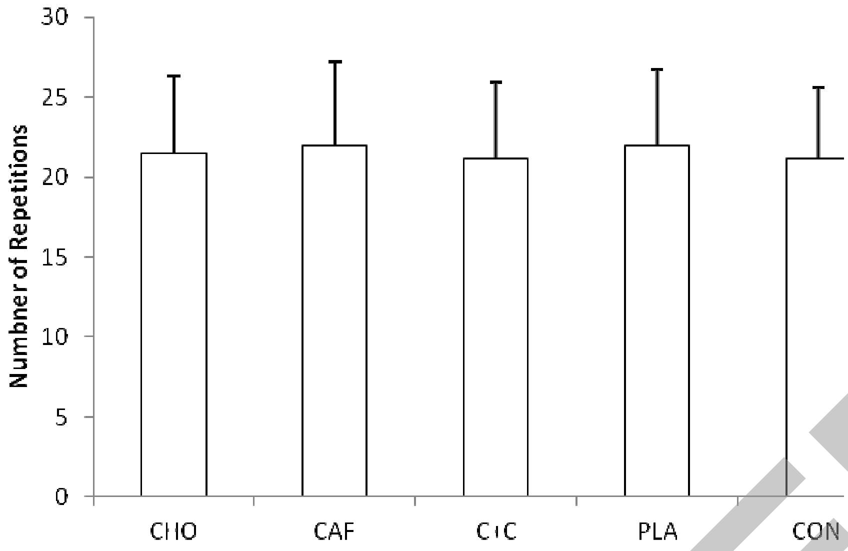

Figure 3: Mean (±SD) number of repetitions performed in each condition.

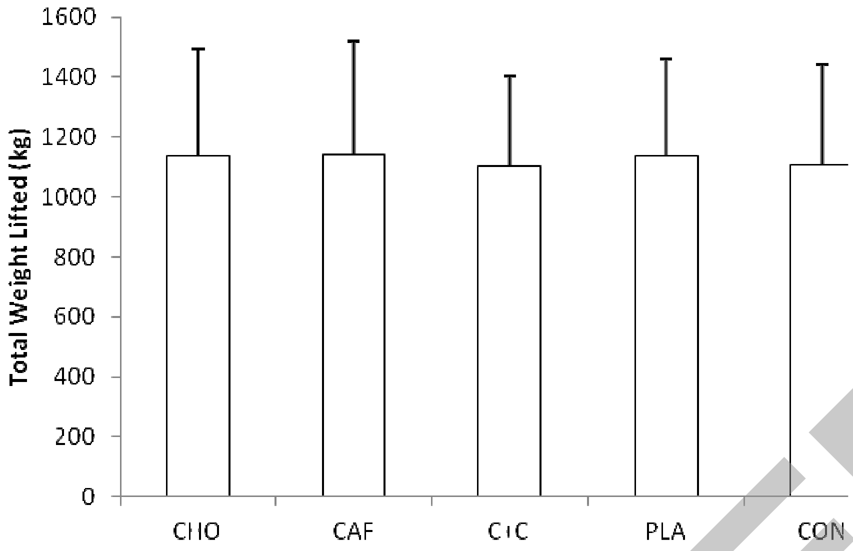

Figure 4: Mean (±SD) total exercise volume performed in each condition.