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The Effect of a Carbohydrate Mouth Rinse on Upper Body Muscular Strength and Endurance

Abstract

Carbohydrate (CHO) mouth rinsing rapidly increases corticomotor output and maximal muscle force production, which could enhance muscular strength and endurance during resistance exercise. However, previous research has found no effect of CHO rinsing on muscular strength or endurance. The current study altered the CHO rinse composition and frequency, and the muscular endurance test, to further investigate the effects of a CHO mouth rinse on upper body muscular strength and endurance. Twelve recreationally resistance trained males (mean ± SD age 22 ± 1 years, height 179.2 ± 1.8 cm, body mass 80.9 ± 6.1 kg) completed a bench press protocol (1 repetition maximum (RM) test followed by repetitions to failure at 40% of 1RM) on three occasions. Subjects rinsed 25ml of an 18% CHO solution or a placebo for 10 seconds before 1RM and repetitions to failure, and completed a no-rinse control condition. Felt arousal (FA) was measured before and after each rinse, heart rate (HR) was measured before and after both exercise protocols, and rating of perceived exertion (RPE) was recorded after repetitions to failure. Rinsing did not influence 1RM (p = 0.680, η_p^2 = 0.03), repetitions to failure (p = 0.677, η_p^2 = 0.04) or exercise volume (load x reps; p = 0.600, η_p^2 = 0.05). There were no significant treatment effects for HR (p = 0.677, η_p^2 = 0.04), FA (p = 0.674, η_p^2 = 0.04) or RPE (p = 0.604, η_p^2 = 0.05). A CHO mouth rinse does not improve upper body muscular strength or endurance.

Key words: resistance exercise; bench press; fatigue; arousal

INTRODUCTION

Rinsing a carbohydrate (CHO) solution around the oral cavity without ingestion can significantly enhance performance during running and cycling lasting ~30-90 min (6,25,29). The efficacy of CHO rinsing is thought to be related to detection of CHO by oral receptors and subsequent stimulation of brain regions associated with motor control, motivation, and arousal (7,20).

Most early work investigating CHO mouth rinses focused on endurance (≥ 30 minutes) exercise. However, Gant et al. (14) reported significant increases in corticomotor excitability and maximal voluntary force of the elbow flexors immediately following the introduction of a CHO mouth rinse to the oral cavity. The rapid influence of a CHO mouth rinse on muscle force production suggests a potential role for this practice during shorter duration work requiring higher force output, such as resistance training. However, the data on CHO mouth rinsing and muscular strength and endurance is conflicting. Jensen et al. (19) reported significantly better maintenance of peak and average knee extensor torque during a maximal voluntary contraction following a fatiguing submaximal contraction. However, the use of a single leg isometric protocol limits ecological validity. Using a more ecologically valid protocol, Painelli et al. (24) found no influence of a CHO mouth rinse on bench press maximum strength (1 repetition maximum (1RM)) or strength endurance (six sets to failure at 70% 1RM). Clarke et al. (9) also examined the influence of a CHO mouth rinse on bench press maximal strength, but also utilised a more muscular endurance oriented test (repetitions to failure at 60% 1RM). There was no benefit of the CHO mouth rinse on strength or endurance. Clarke et al (9) stated that their muscular endurance protocol elicited near maximal rating of perceived exertion (RPE) and heart rate (HR) values, and that this "ceiling effect" may have made any potential differences between conditions hard to distinguish. The authors suggested that making the test more endurance-focused by reducing the percentage of 1RM may have revealed some of the central ergogenic effects of a CHO mouth rinse that have been reported in previous endurance-based studies.

Methodological considerations regarding the mouth rinse protocol may also influence the efficacy of mouth rinsing on muscular strength and endurance. Firstly, a dose response relationship may exist between duration of oral exposure to a CHO mouth rinse and the efficacy of the rinse (26). Therefore, utilising an additional mouth rinse between the strength and endurance protocols, as suggested by Clarke et al. (9), may be more appropriate for facilitating any potential ergogenic effects of the rinse (6,7,25). Secondly, studies that have documented changes in brain imaging with CHO mouth rinses (7,28) employed a greater CHO concentration than that used in previous muscular strength and endurance research (9,24). Using a CHO concentration that has been shown to alter brain activity in ways analogous to the proposed mechanisms for enhancement of muscular strength and endurance may also potentiate the ergogenic effect of a mouth rinse during resistance exercise.

The current study was designed as an extension of previous research to further investigate the influence of CHO mouth rinsing on resistance exercise. The aim of the study was to investigate the effect of a CHO mouth rinse on upper body maximal muscular strength and endurance. It was hypothesised that the CHO mouth rinse would significantly increase muscular strength and endurance.

METHODS

Experimental Approach to the Problem

This study used a repeated measures, randomised, counterbalanced design with double blinded prescription of mouth rinses. All trials took place in the afternoon (14.00-1600) to minimise the diurnal influence on muscle strength (8). The experimental design was based on the work of Painelli et al. (24) and Clarke et al. (9), using a bench press protocol due to the relatively untrained nature of the subjects (9). A no-rinse control condition was incorporated in line with recommendations for mouth rinse research (13). To maintain ecological validity, subjects were not requested to fast for an extended period of time prior to testing (4), but were requested to consume only water for the 90 minutes prior to testing to reduce the possibility of gastrointestinal disturbances.

Subjects

Twelve recreationally resistance trained males (mean ± SD age: 22 ± 1 years, height: 179.2 ± 1.8 cm, body mass (BM): 80.9 ± 6.1 kg) participated. Subjects were required to have been injury free and taking part in recreational upper body resistance training at least once a week (mean 3 ± 1 times per week) for a minimum of 6 months (9). Subjects attended 4 trials each separated by 2-7 days to limit fatigue and training effects. Subjects were asked to refrain from exercise, alcohol and caffeine intake for 24 hours prior to each session, to complete a 24 hour dietary record prior to the first testing session, and to replicate this diet for 24 hours before each subsequent session to standardise endogenous energy content (12,22). Adherence to these procedures was verbally confirmed at the beginning of each trial. The potential risks and benefits of the protocol were explained to the subjects, after which they provided written informed consent. The study received institutional ethical approval and was conducted in line with the declaration of Helsinki.

Procedures

Subjects attended a familiarization session where anthropometric data were collected (height: Seca stadiometer; Seca, Birmingham, UK; BM: Seca scales; Seca, Birmingham, UK). The full protocol was then undertaken, using plain water as the mouth rinse.

The 1RM and repetitions to failure protocols were conducted on a bench press rack with safety bars in place (Power Lift, Iowa, USA), and in the presence of a qualified spotter. Strong verbal encouragement was provided for all maximal lifts and during the repetitions to exhaustion test. Subjects' 1RM was assessed using the protocol of Earle and Beachle (11) as described by Clarke et al. (9). The subject warmed up by performing 10 repetitions with a 20kg bar (Eleiko; Eleiko AB, Halmstad, Sweden) followed by 1 minute rest. The weight (Eleiko Olympic disks; Eleiko AB, Halmstad, Sweden) was then increased by 10% and the subject performed 3-5 repetitions. After a 2 minute rest, a weight near maximum was chosen by the subject, based on past training experience, and was lifted for 2-3 repetitions. The subject then rested for 3 minutes, the load was increased by 5-10% based on researcher and subject perceptions (9), and the subject performed their first 1RM attempt. If successful, the load was increased by 5-10% and attempted again after a 3 minute rest. If unsuccessful, the load was decreased by 2.5-5% for another attempt after a 3 minute rest. This process was repeated for a maximum of five attempts until a 1RM was identified. One repetition was defined as lowering the bar so it touched the chest then raising the bar until elbows were fully extended. Bar grip position was recorded at each subjects' familiarisation session, and replicated for subsequent sessions. Subjects were instructed to keep their buttocks on the bench and their heels touching the floor for every repetition to standardize lifting technique.

Following determination of 1RM, the subject rested for 1 minute to allow the weight to be adjusted to 40% 1RM (9). They then performed repetitions to failure at this load (9). Repetitions to failure was defined as the maximum number of unassisted repetitions using correct technique that participants could carry out before volitionally terminating the test. Total exercise volume (kg) was calculated by multiplying 40% of the subjects' 1RM by the number of repetitions completed.

Rating of perceived exertion (RPE) (5) was recorded immediately following the repetitions to exhaustion. Heart rate (Polar FS1 heart rate monitor; Polar Electro, Warwick, UK) was recorded immediately before each mouth rinse and immediately after each exercise protocol. Felt arousal (FA) (27) was recorded immediately before and after both mouth rinses (9). The FA scale measures arousal levels on a scale ranging from 1 (low arousal, including sensations such as relaxation, boredom, or calmness) to 6 (high arousal, including sensations such as excitement, anxiety, and anger) (27).

Rinsing Protocol

Subjects carried out three trials using the same procedures described above. Two mouth rinses were used: An 18% maltodextrin (Bulk Powders maltodextrin; Bulk Powders TM, Colchester, UK) solution

(CHO) (7) and a water placebo solution (PLA). A no-rinse control trial was also used (CON). A commercially available electrolyte tablet (HighFive, Bardon, Leicestershire) was dissolved into each solution, providing the following electrolyte profile per litre: sodium 250 mg, magnesium 60 mg, potassium 90 mg, calcium 20mg. The tablet contained a small amount of artificial sweetener (Saccharine) and was citrus flavoured. Previous research has demonstrated that the electrolyte tablets are effective blinding agents (23), and pilot testing confirmed this for the higher CHO concentration used in the current study. An individual unrelated to the study coded and distributed the mouth rinses, and the nature of the coding was only revealed after data collection was completed. Subjects swilled a 25 ml bolus (6,23) around their oral cavity for 10 seconds (26) before expectorating it into a plastic container prior to the first 1RM attempt (9) and repetitions to failure. There was a 10 second gap between expectorating the mouth rinse and beginning the exercise.

Statistical Analyses

Data are reported as mean ± SD, unless specified. Statistical analyses were conducted using IBM SPSS Statistics for Windows, version 21 (IBM Corp, Armonk, NY, USA). The Shapiro-Wilk test assessed the distribution of all data sets. A one way analysis of variance (ANOVA) with repeated measures compared order and treatment main effects for 1RM, repetitions to failure, total exercise volume, RPE, and FA, and treatment main effects for RPE. Unstandardized mean differences with 95% confidence intervals (95% CI) between the CHO and PLA trials and the CON trial were also calculated for 1RM, repetitions to failure, and total exercise volume. Heart rate and FA were analysed using two way (trial x time) ANOVA with repeated measures. Mauchly's test analysed the sphericity assumption and the Greenhouse-Geisser adjustment was used when required. Significant main effects were explored using pairwise comparisons with the Bonferroni correction applied. An alpha of $p \leq 0.05$ was the threshold for statistical significance. Effect sizes for ANOVA main effects were presented using partial eta-squared (η_p^2). For pairwise comparisons, Cohen's *d* effect sizes for within-subjects designs (21) were calculated and defined as trivial ($d < 0.2$), small ($d \geq 0.2, < 0.8$), and large ($d \geq 0.8$) (10).

RESULTS

No significant order effects were found for 1RM ($F_{2,22}$ = 2.424; p = 0.112, η_p^2 = 0.18), repetitions to failure ($F_{2,22}$ = 1.047; p = 0.368, η_p^2 = 0.09), or total exercise volume ($F_{1.3,13.8}$ = 2.871; p = 0.107, η_p^2 = 0.21). Similarly, there were no order effects for RPE ($F_{2,22}$ = 1.526; p = 0.240, η_p^2 = 0.12) or FA ($F_{2,22}$ = 1.000; p = 0.384, η_p^2 = 0.08).

No significant differences in 1RM were found between trials ($F_{2,22}$ = 0.393; p = 0.680, η_p^2 = 0.03; CHO vs. PLA: d = 0.21; CHO vs. CON: d = 0.13; PLA vs. CON: d = 0.16; Figure 1A). Figure 1B displays the mean (± 95% CI) difference in 1RM in the CHO and PLA trials vs. CON. While the mean change in the CHO trial was positive, the CI for the CHO and PLA trial was large and included the null value (zero change).

There were no significant differences between trials for repetitions to failure ($F_{2,22}$ = 0.397; p = 0.677, η_p^2 = 0.04; CHO vs. PLA: d = 0.21; CHO vs. CON: d = 0.22; PLA vs. CON: d = 0.07; Figure 1C). Figure 1D displays the mean (± 95% CI) difference in 1RM in the CHO and PLA trials vs. CON. The difference in repetitions to exhaustion was positive for both trials, however as with the 1RM data, the CIs were large and included the null value (zero change).

There were no significant differences between trials for total exercise volume ($F_{2,22}$ = 0.523; p = 0.600, η_p^2 = 0.05; CHO vs. PLA: d = 0.30; CHO vs. CON: d = 0.22; PLA vs. CON: d = 0.01, Figure 1E). Figure 1F displays the mean (± 95% CI) difference in total exercise volume in the CHO and PLA trials vs. CON. The difference in total exercise volume was positive for the CHO trial; however the CI for the CHO and PLA trials was large and included the null value (zero change).

* FIGURE 1 HERE *

Heart rate (Table 1) did not differ significantly between trials ($F_{2,22}$ = 0.396; p = 0.677, η_p^2 = 0.04). There was a significant main effect of time ($F_{1.7,19.0}$ = 213.669; p < 0.001, η_p^2 = 0.95), with HR significantly increasing from pre-to post-1RM testing (p < 0.001, d = 4.10) and from pre- to post-repetitions to failure (p < 0.001, d = 4.87). There was no significant trial x time interaction ($F_{2.6,28.6}$ = 2.071; p = 0.133, η_p^2 = 0.16). Felt arousal (Table 1) did not differ significantly between trials ($F_{2,22}$ = 0.401; p = 0.674, η_p^2 = 0.04). There was a significant main effect of time ($F_{3,33}$ = 237.239; p < 0.001, η_p^2 = 0.96), with FA /significantly increasing pre second rinse compared to post first rinse (p < 0.001, d = 5.23). There was no significant trial x time interaction ($F_{2.8,30.6}$ = 0.880; p = 0.455, η_p^2 = 0.07). Rating of perceived exertion did not differ significantly between trials (CHO 17 ± 1, PLA 17 ± 1, CON 17 ± 0, $F_{2,22}$ = 0.517, p =0.604, η_p^2 = 0.05).

* TABLE 1 HERE *

DISCUSSION

The main finding of the current study is that a CHO mouth rinse does not increase maximum muscular strength or endurance in recreationally resistance trained subjects. Both study hypotheses are therefore rejected.

There may be a dose response relationship between duration of oral exposure to a CHO mouth rinse and its efficacy (26). The current study incorporated an additional mouth rinse prior to the repetitions to exhaustion test, in contrast to Clarke et al. (9). However, this did not potentiate the effect of the mouth rinse. This finding is in line with Painelli et al. (24), who found no significant improvement in muscular strength or strength-endurance with multiple administrations of a CHO mouth rinse. Any effects of a CHO mouth rinse on muscle function may be short-lived (19); therefore the time between administrations should be considered. In the current study, the time between the two CHO mouth rinse administrations may have been too long for a cumulative effect to be seen.

Painelli et al. (24) fasted their subjects overnight prior to testing, whereas the current study and Clarke et al. (9) did not. Utilising a CHO mouth rinse in a fasted state may potentiate its ergogenic effect, at least on endurance performance (4,12). Based on the different methodological approaches of Painelli et al. (24) and Clarke et al. (9), it appears that the effect of a CHO mouth rinse on resistance exercise performance is not influenced by subjects' dietary status. However, the influence of dietary status as the sole independent variable on muscular strength and endurance remains to be fully elucidated.

Foods with a higher energy density activate more brain regions than foods with a lower energy density (7,15,17). Studies that have demonstrated significant increases in activity of brain regions associated with motor control, motivation, and arousal with CHO mouth rinses used CHO concentrations of 15-18% (7,28). These concentrations are notably higherthan the majority of performance research which has employed concentrations of ~6% (6,9,23,24). The current study utilised an 18% concentration mouth rinse. While brain imaging was not possible in this study, the lack of effect of an 18% CHO mouth rinse on muscular strength or endurance provides further evidence that CHO mouth rinsing is not beneficial for improving these parameters. While it is possible that a specific combination of mouth rinse composition and administration frequency could elicit muscular strength or endurance enhancements, the available literature suggests that CHO mouth rinsing is not a practical strategy for enhancing this form of exercise.

Clarke et al. (9) suggested that the lack of influence of a CHO mouth rinse on muscular endurance in their study may have been due to the attainment of near-maximal HR and RPE values creating a "ceiling-effect", making it difficult to observe appreciable differences between conditions. For this reason, Clarke et al. (9) recommended that future studies utilise a lower percentage of 1RM in the endurance test, as the current study did. The current study reported almost identical RPE values to Clarke et al. (9), and similar HR (with the exception of the CHO trial, which was ~15 $b.min^{-1}$ lower in the current study). Therefore, the use of a lower load does not enable performance enhancing effects of a CHO mouth rinse to be seen. It also questions the "ceiling-effect" suggestion of Clarke et al. (9). The highest mean HR value recorded by Clarke et al. (9) and the current study at the end of the endurance test was ~77% of age-predicted maximum HR, and the RPE values were ~17. These values, particularly for HR, are not "near maximal". Furthermore, values similar to or notably higher than these have been reported in previous studies that found significant improvements in performance with a CHO mouth rinse, albeit in different exercise modalities (3,6,18,23). It therefore appears that the centrally-mediated improvement in exercise performance sometimes observed with a CHO mouth rinse is not evident during resistance exercise of the type used in this study (9,24). This statement is further supported by the lack of influence of CHO mouth rinsing on FA, with the significant main effect of time on FA likely due to the performance of the 1RM test (9), as the test took place between the post 1st rinse and pre 2nd rinse measures of FA, and FA increased to the same extent across all three trials.

Strength trained people can produce greater neuromuscular activation than non-strength trained people (2). This has led to the suggestion that the stimulation of brain regions associated with motivation and motor control by CHO mouth rinses is insufficient to affect strength performance in strength trained individuals, but may elicit improvements in non-strength trained subjects (24). However, the rationale for non-strength trained individuals using a CHO mouth rinse to enhance strength is questionable when it is considered that much of the initial increase in muscular strength following the onset of a resistance exercise programme is attributable to neural adaptations (1). Furthermore, subjects in the studies of Clarke et al. (9), Painelli et al. (24), and the current study could not be classed as strength trained, as the approximate relative strength (1RM/BM) of the subjects places them around the 60th-70th percentile based on general population normative data (16). Therefore, any potential influence of a CHO mouth rinse in less well resistance trained subjects could have been expected to manifest across these three studies.

A limitation of the current study is the use of a bench press protocol, as this is not an activity that will be routinely used in the training of most athletes. However, the bench press protocol provided a balance between ecological validity, particularly compared to protocols using isometric single leg dynamometry (19), and retaining experimental control. Future work should enhance the ecological validity of the muscular strength and endurance protocols. The fixed load nature of the protocol was also a potential limitation, as it did not allow the subjects to self-select loads. Employing a self-managed resistance training protocol more analogous to a normal training scenario would elucidate whether CHO mouth rinsing allows the selection of higher loads for a given intensity/repetition target, similar to the self-selection of higher power output observed when CHO rinsing during endurance exercise (6,25,29). Finally, subjects were requested to replicate their dietary intake for 24 hours before each trial, but dietary intake was not analysed to confirm standardisation of macronutrient consumption prior to the three trials. It would have been useful to analyse dietary composition to control for the potentially confounding factor of endogenous energy availability on CHO rinse efficacy.

In conclusion, a CHO mouth rinse does not significantly affect maximal muscular strength or endurance. Carbohydrate mouth rinsing may not provide a sufficient central stimulus to improve resistance exercise performance under the conditions and with the subjects used in the study.

PRACTICAL APPLICATIONS

The data from the current study found no significant or practically meaningful improvement or detriment in muscular strength and endurance with the use of a CHO mouth rinse compared to a PLA or CON. This data suggests that athletes and coaches should not employ a CHO mouth rinse to enhance upper body maximal muscular strength or endurance. Research has not focussed on upper body exercises other than the bench press, ecologically valid lower body exercises, or differently structured resistance training sessions, therefore practical applications cannot currently extend to these scenarios.

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FIGURE CAPTIONS

Figure 1. Mean (± SD) one repetition maximum (A), repetitions to failure (C), and total exercise volume (E) in each trial. Mean (± 95% CI) difference in 1RM (B), repetitions to failure (D), and total exercise volume (F) in the carbohydrate and placebo trials compared to the control trial. Dashed line indicates no change compared to CON. RM = repetition maximum; CHO = carbohydrate; PLA = placebo; CON = control.

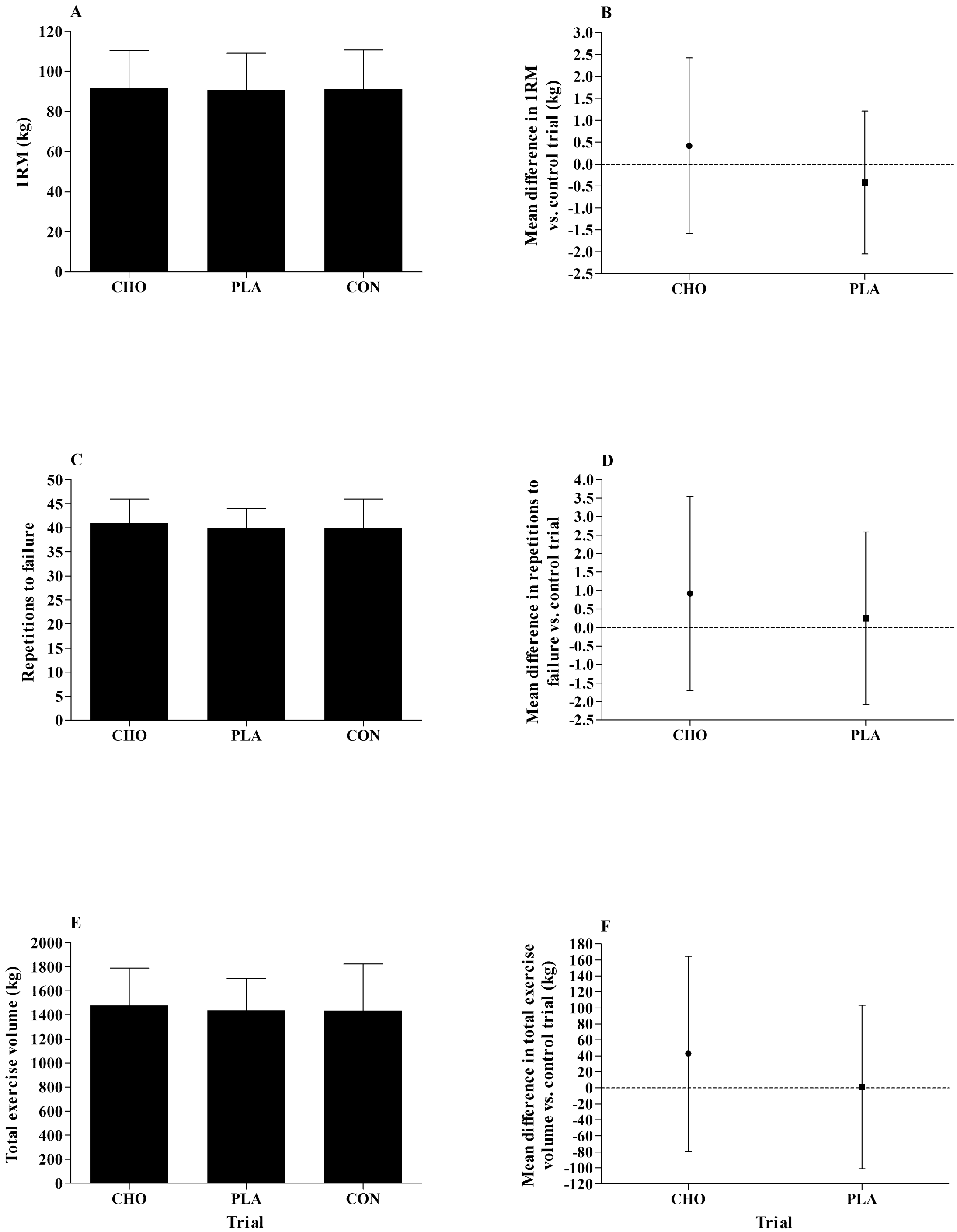
A
1RM (kg)
120
100
80
60
40
20
0
CHO
PLA
CON
B
Mean difference in 1RM vs. control trial (kg)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
CHO
PLA
C
Repetitions to failure
50
45
40
35
30
25
20
15
10
5
0
CHO
PLA
CON
D
Mean difference in repetitions to failure vs. control trial
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
CHO
PLA
E
Total exercise volume (kg)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
CHO
PLA
CON
Trial
F
Mean difference in total exercise volume vs. control trial (kg)
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
CHO
PLA
Trial

Table 1. Mean (± SD) heart rate and felt arousal in all trials.

	CHO	PLA	CON
Heart rate (b.min^{-1})			
Pre 1st rinse	95 ± 8	94 ± 13	92 ± 9
Post 1RM*	125 ± 9	124 ± 16	123 ± 10
Pre 2nd rinse	96 ± 9	95 ± 10	94 ± 7
Post repetitions to failure**	137 ± 14	148 ± 16	143 ± 12
Felt Arousal			
Pre 1st rinse	3 ± 1	3 ± 1	3 ± 1
Post 1st rinse	3 ± 1	3 ± 1	3 ± 1
Pre 2nd rinse†	4 ± 1	4 ± 1	4 ± 1
Post 2nd rinse	4 ± 1	4 ± 1	4 ± 1

CHO = carbohydrate; PLA = placebo; CON = control.

* Significantly greater than pre 1st rinse ($p < 0.001$); ** Significantly greater than pre 2nd rinse ($p < 0.001$); † Significantly greater than post 1st rinse ($p < 0.001$).