International Journal of Sport Nutrition and Exercise Metabolism, 2020, 30, 42-47
https://doi.org/10.1123/ijsnem.2019-0073

Human Kinetics
ORIGINAL RESEARCH

Effects of Carbohydrate Mouth Rinsing on Upper Body Resistance Exercise Performance

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Carbohydrate mouth rinsing has been shown to enhance aerobic exercise performance, but there is limited research with resistance exercise (RE). Therefore, the purpose of this investigation was to examine the effects of carbohydrate mouth rinsing during a high-volume upper body RE protocol on performance, heart rate responses, ratings of perceived exertion, and felt arousal. Recreationally experienced resistance-trained males ($N = 17$, age: 21 ± 1 years, height: 177.3 ± 5.2 cm, mass: 83.5 ± 9.3 kg) completed three experimental sessions, with the first serving as familiarization to the RE protocol. During the final two trials, the participants rinsed a 25-ml solution containing either a 6% carbohydrate solution or an artificially flavored placebo in a randomized, counterbalanced, and double-blinded fashion. The participants rinsed a total of nine times immediately before beginning the protocol and 20 s before repetitions to failure with the exercises bench press, bent-over row, incline bench press, close-grip row, hammer curls, skull crushers (all completed at 70% one-repetition maximum), push-ups, and pull-ups. Heart rate, ratings of perceived exertion, and felt arousal were measured at the baseline and immediately after each set of repetitions to failure. There were no differences for the total repetitions completed (carbohydrate = 203 ± 25 repetitions vs. placebo = 201 ± 23 repetitions, $p = .46$, Cohen's $d = 0.10$). No treatment differences were observed for heart rate, ratings of perceived exertion, or felt arousal ($p > .05$). Although carbohydrate mouth rinsing has been shown to be effective in increasing aerobic performance, the results from this investigation show no benefit in RE performance in resistance-trained males.

Keywords*:* ergogenic aids, sports nutrition, weight training

Carbohydrate mouth rinsing (CMR) has been proposed to enhance exercise performance by stimulating reward centers (Chambers et al., 2009) and areas of the brain involved in motor performance and sensory perception (Turner et al., 2014). The technique was first utilized in an investigation by Carter et al. (2004), who discovered performance enhancements in a 1-hr cycling time trial with CMR, but not carbohydrate ingestion (Carter et al., 2004). Following initial research efforts, researchers have investigated the effects of CMR during endurance exercise (Beelen et al., 2009; Pottier et al., 2010; Rollo et al., 2010; Whitham & McKinney, 2007), high-intensity exercise (Beaven et al., 2013; Dorling & Earnest, 2013; Krings et al., 2017), and resistance exercise (RE; Bastos-Silva et al., 2019; Decimoni et al., 2018). Although research supports the efficacy of CMR during endurance exercise, there is a limited amount of evidence to suggest the efficacy of CMR during RE (Bastos-Silva et al., 2019; Clarke et al., 2017; Decimoni et al., 2018).

Current sports nutrition guidelines recommend CMR for short-duration activities (Thomas et al., 2016), but translating these recommendations to RE is less understood. RE is characterized by short, repeated bouts of intense effort, and CMR may be a beneficial nutritional strategy to stimulate increases in performance. Recently, beneficial effects with CMR have been observed during bench press (BP) and back squat exercises (Clarke et al., 2017), RE session volume (Bastos-Silva et al., 2019; Decimoni et al., 2018), isokinetic exercise (Bailey et al., 2019; Bazzucchi et al., 2016), and isometric exercise (Jensen et al., 2015). However, CMR has also been found to not improve maximal muscular strength, endurance (Clarke et al.,

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2015; Dunkin & Phillips, 2017; Painelli et al., 2011), and isometric exercise (Black et al., 2018). The differences in results among current research may be a result of varying degrees of protocols, outcome variables, study time of day, and feeding status of participants. Clarke et al. (2017) utilized a protocol including back squats, BP, sprints, isometric strength, and jump height and observed performance benefits. The same group of authors found no benefit during a BP endurance test (Clarke et al., 2015). It is difficult to fully elucidate the differences in results, but both protocols utilized specific exercises that did not represent a traditional RE workout session.

Due to the differences in protocols and CMR applications in the current research, it is difficult to interpret meaningful findings to a resistance training population. However, Decimoni et al. (2018) recently utilized a repetition-to-failure protocol with the exercises of half squat, leg press, BP, military press, and seated row in females, observing a ~12% increase in training session volume. Similar results have been observed with BP and leg press training session volume in males (Bastos-Silva et al., 2019). With limited research examining the effects of CMR on a traditional RE session, the purpose of this investigation was to examine the effects of CMR on performance during a high-volume upper body RE session. A secondary purpose was to examine heart rate [HR] responses, ratings of perceived exertion [RPE], and felt arousal [FA]. It was hypothesized that CMR would increase RE training session volume in resistance-trained males.

Methods

Design

The current investigation employed a randomized, counter-balanced, and double-blinded design, with the participants completing a total of five sessions. During Session 1, the participants were informed of the purposes of the investigation, and they gave written informed consent in accordance with the institutional review board. The participants also completed a physical activity readiness questionnaire and health history form. Session 2 served as one-repetition maximum (1RM) testing for exercises such as BP, bent-over row (BR), incline press (IP), close-grip row (CR), hammer curls (HC), and skull crushers (SC). Session 3 served as familiarization to the RE protocol (Table 1), including a water rinsing, and familiarity with the RPE and FA scales. During Sessions 4 and 5, the participants completed the RE protocol, while rinsing either a 6% carbohydrate solution (CHO) or an artificially flavored placebo a total of nine times. An overview of the investigation can be seen in Figure 1.

Participants

A total of 17 healthy and recreationally experienced resistance-trained males (age: 21 ± 1 years, height: 177.3 ± 5.2 cm, mass: 83.5 ± 9.3 kg) participated in the current investigation. The inclusion criteria included (a) meeting the intermediate resistance training classification according to the National Strength and Conditioning Association (Haff & Triplett, 2015), (b) being classified as low risk according to a physical activity readiness questionnaire, (c) having had no current or previous musculoskeletal injuries within the last year, and (d) meeting the minimal physical activity guidelines according to the American College of Sports Medicine (2013). The participants were asked to refrain from taking any preworkout supplements at least 72 hr prior to Sessions 2–5 and to continue to take supplements that they were habitually using. In an attempt to ensure that the participants completed Sessions 2–5 with adequate rest, each session was separated by at least 7 days, and the participants were asked to

Table 1 Comparison of Individual Exercises

Exercise	Carbohydrate (repetitions)	Placebo (repetitions)	*p* value	Cohen's *d*	95% confidence interval
Bench press	29 ± 6	28 ± 5	.12	0.21	(–0.35, 2.70)
Bent-over row	40 ± 6	40 ± 7	.90	0.02	(–1.78, 2.01)
Incline press	22 ± 5	23 ± 5	.61	0.08	(–1.81, 1.10)
Close-grip row	39 ± 6	39 ± 6	.95	0.01	(–1.79, 1.91)
Hammer curl	27 ± 4	26 ± 4	.09	0.01	(–0.21, 2.56)
Skull crushers	27 ± 5	27 ± 4	.56	0.09	(–1.61, 0.91)
Push-ups	16 ± 7	15 ± 6	.29	0.11	(0.68, –0.41)
Pull-ups	4 ± 4	4 ± 4	.67	0.05	(–1.03, 0.68)

Note. Data are reported as mean ± *SD*.

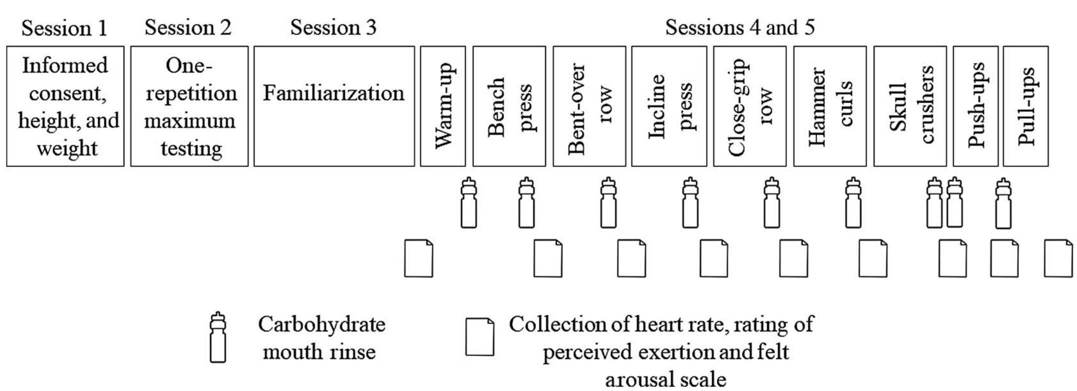

Figure 1 — A schematic diagram representing the study design.

refrain from upper body RE 48 hr and lower body RE 24 hr prior to Sessions 2–5.

1RM Testing

Bench press 1RM was assessed by true 1RM testing, whereas the exercises of BR, IP, CR, HC, and SC utilized predicted 1RM testing. During the BP 1RM testing, the participants completed an initial warm-up set with a light resistance for five to 10 repetitions, followed by a 1-min rest. Approximately 4.5–18 kg (10–40 lb) was added to the barbell, and three to five repetitions were completed, followed by 2 min of rest. After the final warm-up set, the participants were instructed to lift a 1RM within five sets, with 2 min of rest between sets. During the predicted 1RM testing for BR, IP, and CR, a three-set approach was used (ie, one warm-up with a light weight [five to 10 repetitions], one warm-up with 50–80% perceived 1RM [three to five repetitions], and one maximum estimation set) with 1 min of rest between the first two sets, and 2 min of rest between the final two sets. HC and SC 1RM utilized a two-set approach (one warm-up with 50–80% perceived 1RM [three to five repetitions] and one maximum estimation set) with 2 min of rest between the sets. During the predicted 1RM estimation sets, the participants were instructed to lift a weight maximally for no more than 5 repetitions. The repetitions and weight lifted were used to predict 1RM (Brzycki, 1993). Following the true and predicted 1RM testing, the participants completed maximal repetitions to failure with push-ups and pull-ups. The results from 1RM testing and the maximum number of push-ups and pull-ups were as follows: BP (107.6 ± 18.5 kg), BR (98.7 ± 18.2 kg), IP (83.2 ± 15.9 kg), CR (90.0 ± 22.6 kg), HC (46.8 ± 9.0 kg), SC (49.1 ± 10.1 kg), push-ups (30.5 ± 12.8 repetitions), and pull-ups (7.6 ± 4.6 repetitions).

RE Protocol

The RE protocol utilized was designed to mimic a high-volume upper body training session and is displayed in Table 1. Prior to beginning Sessions 3 to 5, a dynamic warm-up was completed. The warm-up included 5 min of full-body exercises and two sets of six repetitions, with a self-selected weight for the exercises of BP and BR. The warm-up weight was noted and repeated for the final two sessions. The participants then completed the exercises of BP, BR, IP, and CR for three sets of 10 repetitions, with a fourth set completed until failure, all at 70% 1RM. HC and SC were completed for two sets of 10 repetitions, and a third set until failure at 70% 1RM. The final two exercises of push-ups and pull-ups were completed for one set until failure. Between each set and exercise, the participants received 90 s of rest. Each experimental session was supervised by a strength and conditioning coach certified by the National Strength and Conditioning Association, who ensured proper form and safety. When the RE sets were completed until failure, failure was deemed as the point where the participants failed, or failure was deemed due to a break in form by the principal investigator. Due to the inability of all participants to complete each set of ten repetitions, the total repetitions across each set for each exercise was utilized to represent the session volume completed. The participants arrived at Sessions 3–5 in the morning hours, 05:00–11:00, with at least a 10 hr fast. Furthermore, following the 1RM session, the participants were given a 24-hr diet recall form. Food consumed, portion size, and time consumed was recorded on the day prior to Session 3. The diet recall form was photocopied and given back to the participants, and they were instructed to maintain the same dietary habits the day prior to Sessions 4–5.

Heart Rate, RPE, and FA

Prior to beginning each RE session, the participants were fitted with a HR monitor (H10; Polar Electro Inc., Lake Success, NY). HR was measured a total of nine times: at the baseline (before beginning the warm-up) and immediately after each set completed until failure. The RPE (6–20 scale; Borg, 1982) and FA (0–6 scale; Svebak & Murgatroyd, 1985) were measured at the same time points as the HR. The participants were familiarized with the RPE and FA scales during Session 3.

Supplementation Schedule

Immediately after the warm-up and 20 s prior to each RE set to failure, 25 ml of the experimental beverage was rinsed (nine total rinses). The beverages were delivered in a plastic cup, and the participants were instructed to swish the solution in the buccal cavity for 10 s. The experimental beverage was then expectorated back into the cup. The CHO beverage contained a 6% solution consisting of a 2:1 glucose to fructose ratio (Dymatize Enterprises, LLC, Dallas, TX). The placebo beverage contained artificial sweeteners and was matched for taste (lemon-lime), color, and scent with the CHO beverage (Dymatize Enterprises, LLC). During Session 3, the participants were familiarized with the supplementation protocol by rinsing with water. The beverages were mixed the day prior to the experimental trials by a researcher who was not present at any of the experimental sessions and stored in a refrigerator at 4° C.

Statistical Analysis

The data are reported for each dependent variable as mean ± *SD*, with an alpha level of $p < .05$. The training session volume for each exercise (total repetitions) and the individual exercises was compared using a paired samples *t* test. The 95% confidence intervals were calculated for comparison of individual exercises. HR, RPE, and FA were analyzed using a two-way (Treatment × Time) repeated-measures analysis of variance. If significant interaction or main effects was observed, pairwise comparisons with Bonferroni's correction were applied. Partial eta squared (η_p^2) was calculated for each repeated-measures analysis of variance, and Cohen's *d* was calculated to interpret meaningful differences between treatments for exercise training volumes, with interpretations as follows: $\eta_p^2 = .2$ (small effect), $\eta_p^2 = .5$ (moderate effect), and $\eta_p^2 = .8$ (large effect) (Cohen, 1988). All of the statistical analyses were carried out using SPSS (version 24; IBM Corporation, Armonk, NY)

Results

RE Performance

There were no differences between the total number of repetitions completed or the total session volume between treatments (CHO = 203 ± 25 repetitions vs. placebo = 201 ± 23 repetitions, $p = .46$, Cohen's $d = 0.10$). A comparison of individual exercises and effect sizes is presented in Table 1.

Heart Rate

There was no Treatment × Time interaction effect, $F = 0.78$, $p = .62$, $\eta_p^2 = .05$, or treatment effect for HR, $F = 0.23$, $p = .64$, $\eta_p^2 = .01$. However, there was a significant main effect for time, $F = 249.40$,

$p < .001$, $\eta_p^2 = .94$. The pre-exercise HR was significantly lower than HR measured after each of the eight exercises ($p < .001$). The BP HR was significantly lower than IP, push-up, and pull-up HR ($p < .05$). The IP HR was significantly lower than the post pull-up HR ($p = .02$). The CR HR was significantly higher than the SK HR ($p = .02$). The HC HR was higher than the SK HR ($p = .03$) and significantly lower than the pull-up HR ($p = .03$). The SK HR was significantly lower than the push-up and pull-up HR ($p < .05$). The HR responses are presented in Figure 2a.

Ratings of Perceived Exertion

No significant Treatment × Time interaction effect, $F = 2.06$, $p = .09$, $\eta_p^2 = .11$, or treatment effect was observed for RPE, $F = 0.01$, $p = .82$, $\eta_p^2 = .00$. There was a significant main effect of time, $F = 95.27$, $p < .001$, $\eta_p^2 = .86$. The pre-exercise RPE was significantly lower than the RPE after each exercise ($p < .001$). The BP RPE was significantly lower than each exercise ($p < .05$), except the BR ($p = .09$). The BR RPE was significantly lower than the IP, CR, HC, SK, push-up, and pull-up RPE ($p < .05$). The RPE results are presented in Figure 2b.

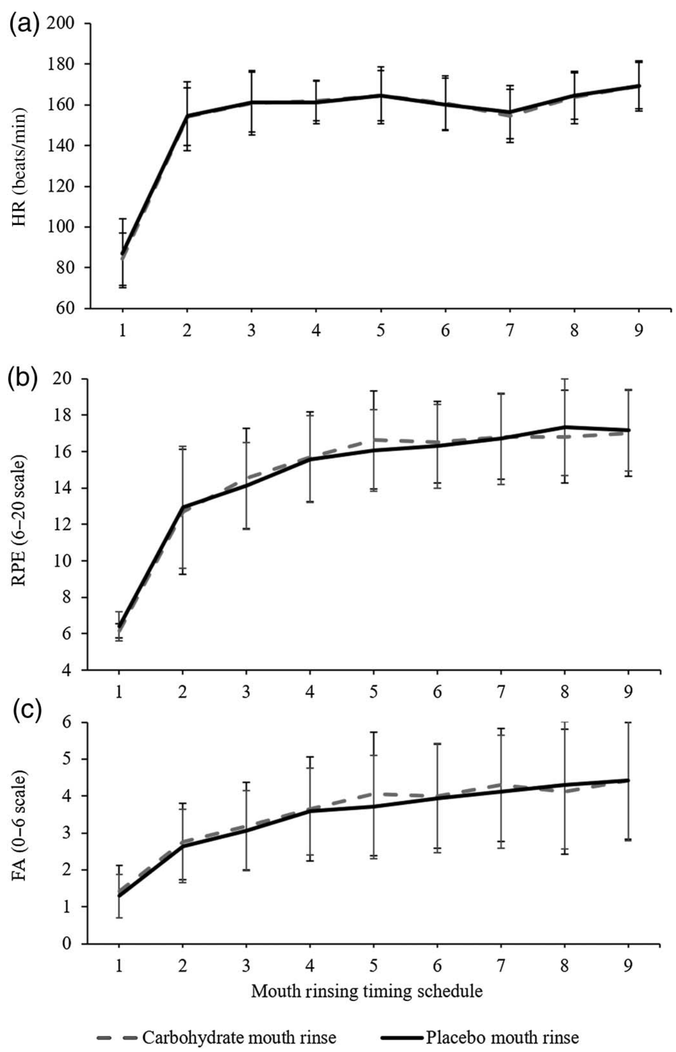

Figure 2 — Changes in HR, RPE, and FA scale across time, comparing placebo and carbohydrate mouth rinsing. HR = heart rate; RPE = ratings of perceived exertion; FA = felt arousal. Data are reported as $M \pm SD$.

Felt Arousal Scale

There was no Treatment × Time interaction effect, $F = 0.82$, $p = .58$, $\eta_p^2 = .05$, or treatment effect for FA scale, $F = 0.76$, $p = .40$, $\eta_p^2 = .05$. However, there was a main effect for time, $F = 33.16$, $p < .0001$, $\eta_p^2 = .68$. The pre-exercise FA was significantly lower than the FA after each exercise ($p < .0001$). The BP FA was significantly lower than the FA measured after each subsequent exercise ($p < .05$). The BR FA was significantly lower than the CR, SK, and pull-up FA ($p < .05$). The IP FA was significantly lower than the SK and pull-up FA ($p < .05$). The FA results are presented in Figure 2c.

Discussion

The purpose of the present investigation was to examine the effects of CHO mouth rinsing on RE performance. Based on the results, there were no differences in performance across an upper body RE protocol, and there were no treatment effects for HR, FA, or RPE. Although previous research has shown potential benefits in RE performance, the lack of a traditional training session had yet to be explored in recreationally active males.

It was hypothesized that fatiguing upper body musculature with completion of sets to failure would lead to an enhancement of RE performance. The authors utilized a serial mouth rinsing protocol with the goal of exposing subjects to CHO in the oral cavity immediately before each set to failure. A similar serial mouth rinsing protocol was used and was successful in increasing the power output, except for one 30-s all-out cycling sprint and the use of maltodextrin (Phillips et al., 2014). In a recent study, Decimoni et al. (2018) had females complete a repetition-to-failure protocol with a full-body RE protocol and observed a ~12% increase in training session volume, while seeing reductions in RPE. The current investigation differed in several ways, as follows: the use of recreationally trained males, completing a familiarization session with the subjects mouth rinsing water, the use of only upper body exercise, and an estimated training load through predictive 1RM testing. Another recent investigation showed that BP performance increased with a set until failure, but the load varied from the current investigation by using 80% 1RM and maltodextrin was used as the carbohydrate form (Bastos-Silva et al., 2019). Overall differences in training protocols, supplementation, participant demographics, and training experiences might explain the differences in performance responses across the current and previous investigations.

The use of CHOs as an ergogenic aid in short-duration activities such as RE have received minimal research compared with aerobic exercise. Based on current sports nutrition recommendations (Thomas et al., 2016) with short-duration activities, as well as results from the current investigation and previous muscular fatiguing investigations (Black et al., 2018; Clarke et al., 2015; Dunkin & Phillips, 2017; Painelli et al., 2011), the effects of CHO mouth rinsing on performance appear to be limited. However, the use of CHO mouth rinsing is likely to not impede performance, by decreasing the amount of work/repetitions completed during a training session. The authors aimed to examine the potential implications of subjective fatigue and arousal levels with the use of RPE and FA. Similar to performance, there were no treatment effects and only time effects, signifying that RPE and FA increased as the training sessions progressed. Future CHO mouth rinsing investigations with higher intensity exercise protocols should continue to examine the effects of subjective measurements.

This investigation was one of the first to investigate a RE protocol that would be practical for a recreational active individual to complete within a training program. Based on the use of only upper body exercises, using larger muscle groups (i.e., lower body exercises) would potentially see benefits from CHO mouth rinsing. Several investigations have examined the neurological activity of the muscle with CHO mouth rinsing and high-intensity fatiguing exercise and observed enhancements in neurological activity (Bailey et al., 2019; Bazzucchi et al., 2016; Jensen et al., 2015). The current investigation was limited to subjective measurements and performance; however, with the lack of increase in repetitions and session volume, CHO mouth rinsing provides no enhancement in performance. Furthermore, although the participants were in a fatigued state, the potential threshold for enhancements with CMR to the neurological system was not strong enough to outweigh the fatigue accumulated during RE.

Carbohydrate mouth rinsing has been shown to be a successful strategy with aerobic exercise (Pottier et al., 2010; Rollo et al., 2010), but it is difficult to fully elucidate the potential effects of CHO mouth rinsing on RE performance. This study was limited by measurements of performance and no measurements of neurological activity. However, with the lack of performance increases, measured in repetitions, the authors concluded that no meaningful changes occurred with CMR. The lack of a control condition was also a limiting factor; however, the investigators wanted to avoid a potential order effect from adding another trial. Future investigations should examine the effects of CHO mouth rinsing during a traditional RE protocol with performance, subjective measurements, and neurological activity to fully understand the potential implications. Based on current and previous investigations, there is minimal research to conclude that CHO mouth rinsing is beneficial for acute RE performance. Individuals looking to gain an enhancement of performance during RE may look toward other ergogenic aids that are supported with current literature.

Acknowledgments

The authors would like to thank the participants for devoting their time to participate in the study. They would also like to acknowledge Malik Barakat and John Dodd, who assisted with the data collection.

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