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Effects of Supplemental Glucose and Bicarbonate for Promoting Recovery During Swim Training

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ABSTRACT

Swim athletes train at volumes that can lead to overtraining. Use of ergogenic aids, such as carbohydrate (CHO) and sodium bicarbonate (BC), have been proposed as methods to promote recovery in intense daily swim training. The purpose of the study was to assess the effectiveness of CHO and BC to support recovery when supplied over the course of two weeks of swim training**.** Eighteen collegiate swimmers, 12 males and 6 females, participated in a two-week study (age = 19.32 ± 1.16, height = 177.3 ± 11.23 cm, and mass = 75.55 ± 13.37 kg). Subjects were divided into three groups, receiving CHO beverage and placebo (PL) capsules (CHO+PL), receiving PL beverage and PL capsules (PL+PL), and receiving CHO beverage and BC capsules (CHO+BC). Subjects completed a 100 yd maximal swim, two-repeat Wingate bouts, hand-grip strength test, and Positive and Negative Affect Scale (PANAS) evaluation before and after the two week training period. No main group effect was observed for average Wingate power, peak Wingate power, swim performance, positive PANAS score, and negative PANAS score ($p = .32$, $p = .48$, $p = .98$, $p = .24$, and $p = .92$ respectively). A main time effect was observed in average power from the second pretest Wingate to the second posttest Wingate (4.36% increase) ($p < .01$). Significant improvement in average power and non-significant improvement (<1%) in swim performance were observed in all groups. However, no main group effects were observed for any variables. It was determined the dosage of CHO and BC administered did not enhance recovery during two weeks of swim training.

Keywords: Wingate; placebo-controlled; swim performance

INTRODUCTION

Many competitive swimmers train at high volumes that lead to risk of injuries involved with overtraining. To illustrate this point, one study applied a lower training volume vs. a higher training volume over 10 days in collegiate swimmers. Swimmers in the lower volume group swam 1.5 hours per day, averaging 4,266 m per day, whereas the higher volume group swam three hours per day, averaging 8,970 m per day (Costill et. al 1988). A substantial portion of the higher volume group (33%) was forced to reduce swim intensity during training and also experienced reduced muscle glycogen stores. These outcomes were proposed to be a potential factor in development of chronic muscle fatigue that may result from sustained over-reaching (Costill et. al 1988).

Two main overuse syndromes are of concern with high volume exercise: over-reaching and overtraining (Snyder 1998). Over-reaching is the milder, shorter-term form of the two, but could still take up to two weeks for the body to fully recover from (Snyder 1998). Overtraining is a more long-term effect and may take weeks to months to fully recover from (Snyder 1998). Both over-reaching and overtraining have an association with muscle glycogen depletion. Consecutive days of high levels of training (three days of ten or more miles of running, or the swimming volumes stated previously as examples) have been shown to lower muscle glycogen levels, which can impair performance (Snyder 1998). Achieving better maintenance of muscle glycogen levels over the course of training may be achieved by adopting proper CHO replenishment strategies; however, with high volume training, such strategies may not always prove successful. Muscle glycogen resynthesis is most effective when CHO is provided to the muscles immediately following exercise (Burke and Mujika 2014). The intent of CHO supplementation is to promote muscle glycogen resynthesis over the course of swim training (Costill et al. 1988).

In addition to muscle glycogen depletion, other mechanisms for fatigue exist, such as a lowering of muscle pH, which may be of greater prevalence in over-reaching and overtraining states. In an attempt to reduce the impact of these limiting factors, ergogenic aids such as carbohydrate (CHO) and sodium bicarbonate (BC) have been widely used in the sport of swimming. Researchers have investigated the effects of specific supplements consumed prior to or following swim training. Previous research has studied the effects of sodium bicarbonate (BC) and found its use led to improvements in 200 m freestyle times, due to the increase in buffering capacity (Lindh et al. 2008).

Repeated swim bout performance has also been shown to be improved as a result of BC supplementation. Mero et al. (2013) showed a significant improvement in 100 m swim performance in a group that loaded BC over a four-week period vs. a placebo group. Further, Campos et al. (2012) showed improved lactic acid tolerance for swimmers who loaded with BC, which could be beneficial to training.

Observing the limits of anaerobic energy generation can be accomplished with high intensity interval exercise, during which diminished capacity to generate adenosine tri-phosphate (ATP) becomes apparent. Much of the energy produced during swim performance comes through the anaerobic glycolysis pathway. This pathway rapidly generates energy; however, it also produces inhibiting factors for energy transfer. The leading factor that causes fatigue during high intensity interval training (HIIT) is lactic acid build up in the muscles. When lactic acid is produced, hydrogen ions accumulate which inhibit sarcoplasmic and neuromuscular function (Lindh et al. 2014). As a result, the performance of exercise will slow down due to the muscles not contracting as forcefully and fatigue will cause a reduction in work output. According to Jourkesh et al. (2011), there can be a significant increase in time to exhaustion during intense exercise with the ingestion of BC. BC can act as a buffering agent against the accumulation of hydrogen ions and delay the onset of fatigue, producing better work maintenance during HIIT. Researchers have proposed that BC supplementation can enhance the performance of HIIT, as well as increase muscle buffer capacity throughout a training period (Jourkesh et al. 2011).

The purpose of this study was to determine the effectiveness of post-exercise CHO and BC supplementation as means of promoting recovery from swim training. It was hypothesized that co-ingestion of CHO and BC over two weeks of daily swim training would provide the most benefit for swim performance and anaerobic work production (based on Wingate testing) vs. a CHO-only treatment group and a placebo group.

METHODS

Subjects

Twenty competitive swimmers from the University swim team, 13 men and 7 women (19.3 ± 1.16 yr.), originally volunteered to participate in the study. Subject descriptives are reported in Table 1. Prior to participation in the experiment all subjects signed an informed consent document and completed a health history questionnaire. Eighteen participants completed the entire two-week study. The study was approved by the Shippensburg University IRB.

After grouping by sex, subjects were randomly divided into three groups. The PL+PL group received the placebo drink and the placebo capsules. The CHO+PL group received the CHO drink and the placebo capsules. The CHO+BC group received the CHO drink and the BC capsules.

Table 1. *Descriptive Statistics for Study Participants (mean ± S.D.)*

Group	Height (cm)	Mass (kg)	BMI	Body Fat %
CHO+PL				
Male (n = 3)	183.18±9.74	80.78±10.59	24.10±2.76	9.90±2.85
Female (n = 3)	162.49±5.90	57.18±8.85	21.53±2.50	21.63±.92
Total (n = 6)	172.83±13.43	68.98±15.60	22.82±2.74	15.77±6.70
PL+PL				
Male (n = 4)	185.25±5.38	86.41±13.78	25.05±2.56	13.53±3.41
Female (n = 2)	167.64±16.16	67.68±12.02	23.95±.35	22.35±1.63
Total (n = 6)	179.38±12.34	80.17±15.38	24.68±2.07	16.47±5.32
CHO+BC				
Male (n = 5)	184.15±2.98	78.00±7.25	22.98±2.14	9.2±1.33
Female (n = 2)	167.61±1.82	75.25±13.79	26.75±5.44	26.10±5.23
Total (n = 7)	179.42±8.46	77.21±8.28	24.06±3.37	14.03±8.59

Procedures

Drink and Capsule Production. Subjects consumed their capsules and 300 ml beverage of their assigned treatment each day upon completion of practice. Placebo capsules contained maltodextrin (1.8 g in 3 capsules) and treatment capsules contained sodium bicarbonate (3.6 g in 3 capsules).

The CHO solution was prepared with 70 g of glucose and 5 g Kool-Aid® per 300 ml. The PL drink was prepared with 5 g of maltodextrin and 5 g of Kool-Aid per 300 ml serving. Capsules and beverages were labeled by Shippensburg University faculty. The treatments were administered in a double-blind fashion.

Swim Performance. Subjects reported to the University's six lane, 25 yd. pool during their respective practice time (based on sex). At the beginning of the pool session, subjects completed a 25 min warm up of their choice in the pool. After completion of the warm up, subjects reported to the starting blocks to begin the testing. The subjects completed a 100-yard freestyle swim at maximum effort. The men swam in four heats. The women swam in two heats. Three timers were assigned to each swimmer. The times were recorded using Accusplit brand stopwatches. All three times for each swimmer were recorded and averaged.

Laboratory Tests. Upon arrival to the lab subjects completed a Positive and Negative Affect Schedule (PANAS) (Watson et. al 1988). Subjects were instructed to complete the PANAS based on how they had felt over the previous week. After completing the PANAS, subjects' height and mass were measured (SECA, Germany). Then, body composition was assessed using a bioelectrical impedance analyzer (Omron, Model HBF-306, Bannockburn, IL). Hand grip strength (Baseline Dynamometer, Irvington, NY) was tested, having the subjects perform three trials with each hand, recording the best trial for each hand.

Next, the subjects completed the repeated Wingate protocol (WinPre1 and WinPre2). Prior to the Wingate, subjects completed a 3 min warm up on one of two designated warm up cycle ergometers (Monark Ergomedic 874E, Sweden). The subjects were instructed to pedal at 70 to 80 rpm, with a resistance of 1.0-1.5 kp. Subjects were also instructed to perform short sprints on the ergometer to prepare themselves for the quick pedaling of the Wingate protocol.

Upon completion of the warm-up, subjects were briefed on the protocol and were given time to ask any questions. Seat height for the Wingate ergometer (Monark Ergomedic 894E, Sweden) was adjusted and recorded. The resistance load was then determined for each subject using mass and sex (7.5% of female mass and 8.3% of male mass). Once the subject was ready they were instructed to pedal as fast as they could against no resistance. Once the subject reached 125 rpm, the basket containing the load automatically dropped. The subject continued to pedal as fast as possible against the resistance for 30 s.

After completion of the first bout, the Monark Anaerobic Test Software timed a 3 min recovery period for the subjects. Researchers encouraged the subjects to keep their lower body active in some form during the recovery period. After the completion of the 3 min recovery subjects immediately started the second Wingate following the same protocol.

Following the second bout subjects were instructed to cool down on the warm up ergometers or by walking at their own discretion. Subjects were monitored throughout the Wingate to minimize any potential health complications.

Recovery Intervention. The supplementation intervention lasted 2 weeks. During that time the subjects participated in an afternoon swim workout averaging two hours Monday through Friday, and a swim workout averaging one and a half hours Saturday morning. Each subject was randomly assigned to a group corresponding to the drink and capsules. Three beverage coolers were labeled A, B, and C. Each subject received three capsules per day. Capsule storage bags were labeled according to group, A, B, and C. Subjects in the A group received the CHO+PL treatment. Group B received the PL+PL treatment. Group C received the CHO+BC treatment.

Prior to each swim workout, all materials were placed in the pool area to be accessible following the workout. Upon completion of the swim workout subjects were instructed to use a Nalgene bottle to measure 300 ml of the respective group drink. The subjects then poured their 300 ml into a disposable plastic cup. Then, subjects consumed three treatment capsules. Subjects rated the difficulty of practice using a 10 cm scale provided to them and then placed the completed scale into a manila envelope. The subjects were asked to finish ingestion of their treatment within fifteen minutes of completing the workout and to dispose of their plastic cup once completed.

Post-testing. All posttests were completed in the same order as the pretests 24-48 hours after the last training session. Posttest Wingate tests identified as WinPost1 and WinPost2. In addition, subjects completed a three-question, post-experiment questionnaire for the researchers.

Data Analysis

A two-way ANOVA (IBM SPSS Statistics 23.0, Chicago, Illinois) was used to determine main group effects and time effects for the dependent variables, Anaerobic power, swim time performance, left handgrip strength, right handgrip strength, practice scales, positive PANAS score, and negative PANAS score across the three groups CHO+PL, PL+PL, CHO+BC. $P \leq .05$ was the selected level for statistical significance.

RESULTS

Using a two-way ANOVA (pretest Wingate 1, pretest Wingate 2, posttest Wingate 3, posttest Wingate 4 x CHO+PL, PL+PL, CHO+BC) with repeated measures there was no significant interaction ($p > .05$) and no main group effect yielded for average or peak power, $p = .32$ and $p = .48$ respectively. However, a main time effect was observed for average power and peak power across time for the four Wingate trials at the .05 confidence level, $p < .01$ and $p < .01$ respectively. The LSD *post hoc* test identified main time effects for average power between WinPre1 and WinPost2 ($p < .01$), WinPre2 and WinPost2 ($p < .01$), and WinPost1 and WinPost2 ($p < .01$). There was no time effect between the WinPre1 and WinPost1 ($p = .14$). For peak power, a main time effect was observed between WinPre1 and WinPre2 ($p < .01$), WinPre2 and WinPost1 ($p < .01$), and between WinPost1 and WinPost2 ($p < .01$). Mean peak and average powers derived from Wingate testing for each group are displayed in Table 2.

Table 2. *Comparison of Average and Peak Power across Time and Between Groups*

Average Power (W)				
Group	WinPre1	WinPre2	WinPost1	WinPost2
CHO+PL	509.96 ± 196.49	475.80 ± 185.65	532.90 ± 218.58	489.67 ± 195.71
PL+PL	605.65 ± 117.13	547.77 ± 112.10	614.02 ± 122.05	566.63 ± 110.83
CHO+BC	653. 02 ± 113.40	566.50 ± 81.61	660.10 ± 98.54	603.04 ± 87.72
Peak Power (W)				
Group	WinPre1	WinPre2	WinPost1	WinPost2
CHO+PL	665.86 ± 250.32	617.02 ± 218.14	721.43 ± 305.53	650.40 ± 276.23
PL+PL	758.21 ± 141.55	729.22 ± 171.28	770.17 ± 163.28	732.58 ± 154.79
CHO+BC	863.88 ± 137.12	762.16 ± 144.82	856.24 ± 164.64	790.55 ± 125.44

There were no significant interaction ($p \leq .05$) or main group effects observed for swim performance, handgrip strength, positive PANAS score, or negative PANAS score ($p = .98$, $p = .50$, $p = .40$, $p = .24$, and $p = .92$, respectively) (Table 1). In addition, no main time effect was observed between pretest and posttest for swim time, left handgrip strength, right handgrip strength, and negative PANAS score at the $p \leq .05$ level ($p = .09$, $p = .44$, $p = .49$, and $p = .38$, respectively). However, a main time effect (decrease) was observed between the pretest and posttest for positive PANAS score ($p = .01$). Negative PANAS showed a decrease in scores across time, but this change did not meet statistical significance.

Table 3. *Comparison of Pretest and Posttest Swim Performance, Handgrip Strength, and PANAS Scores Across Groups (No Significant Treatment Effects)*

Swim Time (s)				
Group	Pretest		Posttest	
CHO+PL	59.94 ± 8.34		59.45 ± 7.87	
PL+PL	57.36 ± 4.36		57.00 ± 3.96	
CHO+BC	57.90 ± 7.79		57.46 ± 7.81	
	Left Handgrip Strength (kg)		Right Handgrip Strength (kg)	
Group	Pretest	Posttest	Pretest	Posttest
CHO+PL	36.83 ± 12.40	36.17 ± 14.52	38.17 ± 12.09	37.17 ± 15.78
PL+PL	41.00 ± 11.35	41.83 ± 12.38	43.17 ± 8.45	45.83 ± 14.73
CHO+BC	47.43 ± 20.58	40.43 ± 11.90	54.00 ± 26.74	44.57 ± 12.38
	PANAS Positive Score		PANAS Negative Score	
Group	Pretest	Posttest	Pretest	Posttest
CHO+PL	32.50 ± 4.51	30.00 ± 5.22	16.33 ± 3.88	14.67 ± 4.68
PL+PL	35.33 ± 2.42	32.83 ± 5.38	17.00 ± 4.20	16.17 ± 3.19
CHO+BC	32.43 ± 5.06	25.14 ± 9.48	19.00 ± 6.48	18.43 ± 4.12

A 10-cm visual analog scale was administered upon completion of each practice for participants to rate training session difficulty. Difficulty was measured in cm from left to right. Mean practice scale ratings (Figure 1) were reported for the first day of practice. In addition the highest mean rated practice and lowest mean rated practice for week 1 and week 2 of training were reported. Using a two-way

ANOVA no significant interaction ($p \leq .05$) or main group effect was observed in practice scale data across groups.

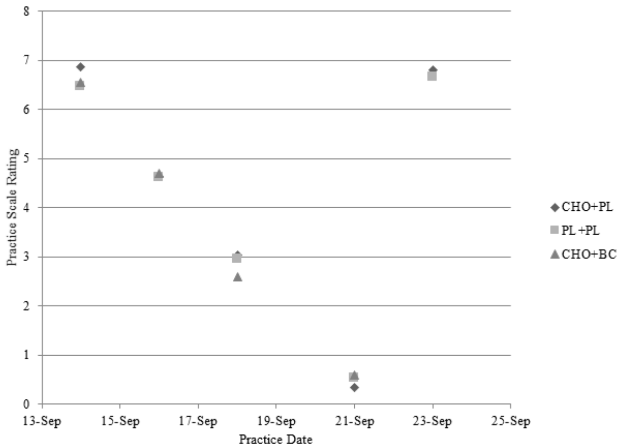

Figure 1. *Mean practice difficulty for selected swim training dates across groups.*

DISCUSSION

It was hypothesized that all groups would show improvement over the course of the two weeks, but with the CHO+BC group enabling more improvement than the CHO+PL group, and the PL+PL group showing the least improved. There was a significant time effect for average power from the second Wingate of pretest to the second Wingate of the posttest (4.3% improvement). Additionally, although not significant, a trend for improved swim performance time was observed (p = .09) (0.729% decrease in time). However, no main group effects were observed for any variables. Consequently, the results do not support the hypothesis.

CHO supplementation was expected to help swim training by promoting muscle glycogen resynthesis over consecutive days of hard swim training. Consumption of simple sugars immediately after glycogen depleting exercise benefits glycogen resynthesis due to its quick rate of appearance in the blood (Burke and Mujika, 2014). This procedure was practiced in the experiment; however, the total dosage may not have optimized the benefit as 1-1.5 g/kg body mass of CHO is recommended hourly two to four hours following depleting exercise to maximize glycogen storage (Burke and Mujika, 2014). This was not practiced in the experiment as only one dose of 75g of CHO was given to the experimental group immediately post-exercise, none in the following hours after exercise. However, the study's participants would move to their normal diet post-exercise, our post-study survey revealed that the supplementation and beverage did not affect their dietary practices.

Costill et al. showed in a study that those who struggled the most through intense training did not consume enough kilocalories (kcal) or CHO to maintain an energy balance throughout consecutive days of hard training. In addition these individuals showed significant reductions in muscle glycogen content in selected muscled tested (Costill et al. 1988). This shows the impact that insufficient energy replacement can have on effectiveness of training. With nutrition of subjects not regulated or reported other than the provided supplements, it is not known if nutrient deficits were met across groups. Yet, it is conceivable that with additional CHO supplementation and larger BC doses that significant performance effects may be identified.

In regards to performance variables of the Wingate protocol, Jourkesh et al. (2011) and colleagues saw an increase in work capacity in both BC supplementation (0.2 $g \cdot kg^{-1} \cdot d^{-1}$) and placebo groups over the six week period. However, BC supplementation was not associated with ergogenic benefit during exercise. BC supplementation in that study caused vomiting, nausea, and diarrhea after ingestion instead of promoting potential benefits. As a result, inferences can be made that an excessively large amount of BC can hinder or show no effect on performance (Jourkesh et al. 2011). Gastrointestinal problems and how an individual physiologically adapts to BC both play a role in performance outcome. Another study testing swimmers used a dosage of 0.3 g per kg of body weight one hour prior to swim performance and showed increased blood lactate levels without altering RPE (Campos et. al 2012). The low daily dosage of BC used in the current study avoided any gastrointestinal complications for the subjects, but did not support training recovery based on our results, perhaps a result of a shorter dosing duration of two weeks compared to six weeks and a substantially lower overall dose.

There are many factors that may influence the effectiveness of BC supplementation for performance enhancement. Examples include the method of administration of BC, timing of consumption, the total dose, and how the BC is administered over the course of the day. Several investigators have proposed that BC supplementation prior to swim performance would be beneficial. Lindh et al. (2008) administered BC based on each swimmer's body mass and the amount was consumed at three different times prior to their 200m swim. There were significant improvements found in each swimmer's time compared to placebo (Lindh et al. 2008). Campos et al. (2012) saw no change in repeat swim performance, but did see an increase in lactic acid levels without a change in RPE. Another study showed significant reductions in blood lactates after intense training (Costill et. al 1988). Perhaps the subjects experienced a similar phenomenon in the present study. The group supplemented with BC did not show significant improvements in swim performance, but it cannot be known for sure if lactate tolerance was improved as lactate was not assessed.

Griffen et al. (2015) studied the effects of BC supplementation on 6 x 10 second repeat Wingate tests performances. They administered a daily dosage of BC at four specific times during the day, each dose separated by three hours totaling 0.3 g BC per kg body mass. The BC treatment was found to show a significant increase in mechanical and peak power output during the repeated Wingate tests (Griffen et al. 2015). Using a longer dosing duration than two weeks, a higher dosage than 3.6g of BC, and consuming BC prior to performance testing may have potentially resulted in greater improvements in the CHO+BC group of the present study. However, in the present study, the investigators sought to avoid symptoms commonly associated with higher dose BC administration. Further, the dose that was supplied was not intended to impact a single bout of intense exercise, but was administered to potentially build total body bicarbonate stores over time.

Improvements seen in the current study were most likely the result of improved fitness independent of the supplementation strategy. With greater doses of CHO and BC it is possible that a main group effect could have been seen in both Wingate and swim performance. For future research diet should be controlled to ensure proper refueling for training. In addition, CHO supplementation should be given over the course of several hours following exercise and should be based on body weight to closer resemble the CHO refueling guidelines proposed by Burke and Mujika (2014), previously. In addition, dosing BC based on body weight would be appropriate. Administering several small doses would presumably afford a better chance to enhance the buffering system over days of administration.

Similar studies should be conducted deeper into the competition season where fitness improvement can be ruled out as a factor for performance gain. This could not be practically achieved with the current study due to competition and academic schedule conflicts. Additional limitations of the study include the small sample size and the improving fitness of the study subjects. Further, some subjects did not have consecutive years of swim training prior to participation in the study. Therefore, it would be ideal to match training status and fitness level among subjects to help in reducing individual variability. By having subjects do the swimming time trials in heats, competition and/or motivation could have played a factor in performance. In conclusion, supplemental BC and CHO administered daily following training was not associated with improved performance or enhanced recovery when contrasted against CHO alone or placebo treatment. Studying the benefits of increased doses or frequency of supplementation during recovery may be worthy of investigation.

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