Original Research

The Effect of a Moderately Low and High Carbohydrate Intake on Crossfit Performance

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ABSTRACT

International Journal of Exercise Science 9(4): 460-470, 2016. CrossFit is a metabolically demanding strength and conditioning method which performance may benefit from a carbohydrate (CHO)-rich diet. This study investigated the effect of three consecutive days of high CHO intake on CrossFit performance and corresponding metabolically -related variables in strength trained individuals. Eighteen subjects with a CHO intake of <6 g/kg/day were randomly assigned into a CHO (n = 9) or control (C) group (n =9) and underwent a 9-day training protocol. During days 1, 5, and 9, performance was measured as repetitions completed during a 12 minute CrossFit workout. Oxygen consumption (VO_2), respiratory exchange ratio (RER), and blood lactate (BL) were also measured. Days 6-8, the CHO group increased CHO intake from <6 g/kg/day to 6-8 g/kg/day; the C group maintained their current intake of <6 g/kg/day. On days 6 and 7 both groups performed CrossFit workouts followed by a day of rest prior to day 9. There was a significant increase in repetitions completed in both groups in day 9 (vs. means score of day 1 + 5) (p = 0.002), but no differences between C and CHO groups (p = 0.111). However, the CHO group displayed a 15.2 repetition increase (+10.9%) in day 9, compared to 5.7 (+4.2%) by the C group. VO_2, RER, and BL were not influenced by the experimental intervention. Our results suggest that the CrossFit-embraced practice of moderately-low CHO diets may be adequate in CHO during short periods of training, however, given the noted trend, extended training periods may be effected.

KEY WORDS: Nutrition, glycogen, resistance training, anaerobic exercise, power, strength training, high-intensity exercise

INTRODUCTION

CrossFit is a physically and metabolically demanding strength and conditioning method in which the ultimate training goal is often to maximize power output (32). This program has become increasingly popular as a mode of exercise as well as a competitive sport. Among others, CrossFit incorporates gymnastics, strength training (including Olympic lifts), anaerobic training, and high power cardiorespiratory activities in varying combinations, loads, and repetition schemes. Such bouts may range from 5 minutes or less to 30-45 minutes, and in rare cases, longer. Workouts of the day (WODs) are competition-based and scored based on the athlete's ability to complete a set amount of work as fast as possible or to complete as much work as possible within a given time period. Similar to other strength/power athletes, the aim of CrossFit athletes is to maximize power output, however whereas other power performances are intermittent in nature, CrossFit is unique in that training bouts and competitions require sustained expressions of power. The majority of CrossFit workouts lack prescribed rest periods, making their performance dependent on the athletes' ability to sustain a high power output (32). The expected and significant metabolic stresses of CrossFit bouts have been documented by Babiash et al.(3) who reported oxygen uptake (VO_2) of supra-anaerobic threshold intensities in two CrossFit workouts (in males and female athletes) along with substantial increments in blood lactate.

Training of such intense nature places a substantial demand on high and continuous glycogenolytic energy production (4, 20). In addition to a substantial amount of anaerobic-dominant activities, CrossFit athletes are also exposed to high power cardiorespiratory activities, furthering the degree of glycogen utilization and making availability of such substrate even more crucial to performance. Thus, it is possible that an inadequacy in CHO intake during a period of CrossFit training may compromise glycogen repletion and the performance of subsequent workouts and competitions.

Unlike endurance training (7, 13), there are no specific established guidelines for daily CHO intake for athletes whose primary mode of training is based on resistance training (9), such as strength athletes, bodybuilders, power lifters, and CrossFit athletes. Development of CHO intake guidelines for the above population seems warranted as, bouts of intense anaerobic exercise, including resistance training, results in substantial glycogen degradation (14, 18, 26, 34) even in those as short as 10 to 30 seconds (5, 6, 22). Repeated sessions of such intense training bear the potential of leading to compromised glycogen stores, and impaired performance in subsequent bouts if not repleted by sufficient CHO intake. Given this glycogenolytic response, current literature suggests a moderate to high daily CHO intake for strength/power-based athletes. For example, Pendergast, Meksawan, Limperasertkul, and Fisher (27) suggest that heavily training anaerobic athletes may need up to 8 – 10 g/kg/d or 60-70% of energy intake, whereas Lambert and Flynn (16) recommend 6 g/kg or 55%-60% of daily energy intake. Slater and Phillips (31) suggest a CHO intake range of 4 – 7 g/kg/d depending on the phase of training. Such recommendations are believed to mitigate the risk of compromised glycogen stores and, thus, maintain (or increase) the quality of training-induced adaptations (31). Empirically, however, this amount of daily CHO has not been conclusively established to be necessary for strength/power performance and a threshold of CHO need for these athletes has yet to be identified. Moreover, investigations of CHO intake on strength and anaerobic performance have produced less than consistent findings (4, 17, 19, 21, 24, 36) suggesting a CHO intake less than the aforementioned recommendations may be sufficient for such athletes, thus further inquiry is warranted.

To date there is a scarcity of literature pertaining to nutrition and CrossFit performance. In a study by Outlaw et al. (2014) (23), CrossFit-trained individuals consumed a post-exercise protein/carbohydrate supplement (20 g protein, 40 g CHO for females; 40 g protein, 80 g CHO for males) during 6 weeks of regular CrossFit training. The protein/CHO supplement was part of a larger 6 week supplementation intervention which also included ingestion of a pre-workout supplement prior to training. The investigators did not find a significant difference in CrossFit performance following the 6 weeks of supplementation. Presently, there is no literature pertaining exclusively to CHO intake and CrossFit performance.

Despite the fact that current research suggests a moderate to high CHO intake for training strength/power athletes (16, 27, 31), nutritional practices within the CrossFit community are largely based on anecdotal evidence and athletes are encouraged to adhere to the Paleolithic (Paleo) Diet and Zone Diet (40% CHO, 30% protein, and 30% fat) (12, 32). Given the metabolic (glycogenolytically-demanding) profile of CrossFit training, a moderately-low CHO diet may be less than optimal for performance and a diet richer in CHO may be necessary during periods of training.

To our knowledge, there is no published evidence addressing metabolic and performance variables following CHO manipulation during a CrossFit workout. Thus, the purpose of this study was to investigate the effect of three consecutive days of high CHO intake (6-8 g/kg/day) during a period of training on CrossFit performance and corresponding metabolically-related variables in strength trained individuals who have previously maintained a moderately-low CHO intake <6 g/kg/d.

METHODS

Participants

Eighteen subjects with a daily CHO intake less than <6 g/kg/day were randomly assigned into a CHO (n = 9) or control (C) group (n = 9) and underwent a 9-day exercise testing protocol. The primary investigators were blinded to group assignments. CrossFit performance was measured in repetitions completed during a 12 minute CrossFit workout (Rahoi) performed on days 1, 5, and 9. From days 6-8, the CHO group increased CHO intake from <6 g/kg/day to 6-8 g/kg/day whereas the C group maintained their current intake of <6 g/kg/day. Subjects performed prescribed CrossFit workouts on days 6 and 7, followed by a day of rest prior to the final performance test on day 9. The present design was aimed to mimic a mid-CrossFit-training period thereby investigating the effect of CHO intake and performance amidst a period of training. During performance tests (days 1, 5, 9), in addition to repetitions completed, oxygen consumption (VO_2), respiratory exchange ratio (RER), and blood lactate (BL) were measured.

Eleven females (mean age: 22.9 ± 2.8 yrs; mean body mass 61.1 ± 5.5 kg; height: 164.5 ± 5.4 cm) and 7 males (mean age: 26.1 ± 10.2 yrs; mean body mass 77.2 ± 8.8 kg; height: 178.7 ± 8.1 cm) with a strength and conditioning experience of ≥ 3 days per week for a minimum of one year participated in the study (Table 1). Given the broad spectrum of training adaptations that is present with the CrossFit community (due to the variety in programming and periodization), it is difficult to establish a common athletic "profile" with all CrossFit trainees. Thus, we believe that our criteria for subject selection introduced a valid representative sample of those who practice CrossFit. In addition, potential subjects must have been familiar with the movements of the exercise protocol and capable of meeting the demands of the associated stresses. To ensure the latter, a video illustrating the expected exercise mechanics was shown and a questionnaire was administered to further validate the criteria for inclusion. An additional eligibility requirement was a daily CHO intake of <6 g/kg/d. In order to measure this, potential subjects completed a three day dietary record using the MyFitnessPal mobile application. Prior to beginning the dietary record, subjects were shown examples of common serving sizes (1/2 cup, 1 cup, tablespoon, etc.) and given a measuring cup to facilitate accuracy of nutritional intake records. Additionally, subjects were given a tutorial on how to use the MyFitnessPal mobile application. The said records were completed within a seven day period and revealed a mean CHO intake of 3.55 g/kg/day (± 1.22). Eligible participants were also required to complete a Physical Activity Readiness Questionnaire (PAR-Q) to ensure a reasonable good health standing and physical preparedness. Once admitted, subjects refrained from any other training besides what was prescribed within the study and were randomly assigned into either a CHO or control group (C). Before the commencement of the study, ethical approval was obtained from the California State University, Fresno (CSUF) institutional review board committee. All subjects were informed of the possible risks and provided written informed consent before participating in any phase of the study.

Table 1. Mean and standard deviation for age, body mass, and height of subjects. (n = 18).

	Female (n = 11)	Male (n = 7)
Age (yrs)	22.9 ± 2.8	26.1 ±10.2
Body Mass (kg)	61.1 ± 5.5	77.2 ± 8.8
Height (cm)	164.5 ± 5.4	178.7 ± 8.1

* yrs = years, kg = kilograms, cm= centimeters

Protocol

Within a week following the completion of their dietary record, participants completed the first of three Rahoi performance tests (Pt1). As illustrated in Figure 1, Pt1 was followed by 3 days of complete rest (days 2, 3, 4). On day 5 subjects again reported to the laboratory and executed a second performance test (Pt2). The second Rahoi performance was intended to evaluate the level of consistency in the number of repetitions performed in Pt1 and therefore control for a possible learning effect on the performance of Pt3 (day 9). Given the expected familiarity of the subjects with the movements of the Rahoi workout, a learning effect was not anticipated. For all dependent measures (see below) the mean score obtained during Pt1 and Pt2 (i.e., pre-dietary intervention) was compared to that obtained during Pt3 (post- dietary intervention).

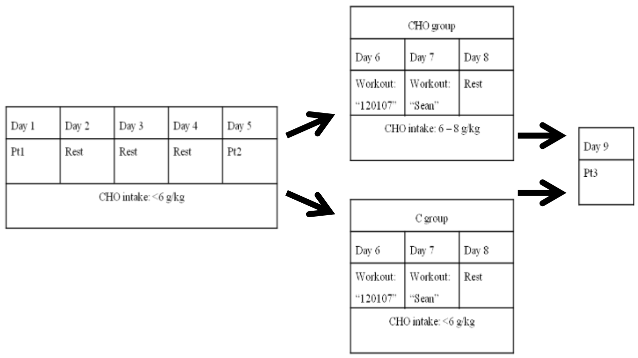

Figure 1. Timeline describing the experimental protocol.

According to the experimental protocol timeline (Figure 1), the day after Pt2 (day 6), all subjects performed CrossFit workout "120107"; CrossFit workout "Sean" was completed the day following (day 7). On day 8, participants were required to undergo a complete rest day before returning to the HPL for Pt3. Unlike the performance tests, the workloads of the 120107 and Sean workouts were fixed and the aim was to complete the set amount of work as fast possible. Therefore, these workouts were selected in order to control for the training volume and load prior to Pt3 and thus decrease variance in training stresses. This training schedule (Pt2→120107→Sean→rest) complied with the typical CrossFit prescription of 3 consecutive days of training followed by 1 day of recovery (12).

During all performance tests (Pt1, Pt2, Pt3), VO_2 and RER were measured using the ParvoMedics' True One 2400 Metabolic Measurement System (Sandy, Utah, USA) connected via a hose to a 2-way Hans-Rudolph Valve (Shawnee, Kansas, USA. In addition, blood lactate (BL) was assessed from the finger with a Scout lactate analyzer (Leipzig, Germany) according to procedures described by the manufacturer.

During days 6-8 the CHO group increased their daily CHO intake to 6-8 g/kg and the C group were instructed to maintain their current CHO intake of <6 g/kg. All participants recorded their nutritional intake during these 3 days using the MyFitnessPal mobile application to ensure adherence to the prescriptions. Mobile applications for dietary self-reporting have been used in previous studies (1, 35). The MyFitnessPal application is a database comprised of over 5 million foods derived primarily from food labels and the USDA National Nutrient database. To help comply with the CHO requirement, all participants were given a daily CHO prescription (in grams) and instructions. The CHO group was also given a list indicating the CHO content of common foods to ensure the daily CHO requirement was met. Low glycemic index CHO sources were recommended for the three day diet, as low glycemic CHO can enhance muscle glycogen stores, even in non-depleted states (29). CHO-rich foods (oatmeal, bread, pasta, granola, and cereal) were made available to the CHO group to assist them in meeting the prescription. Additionally, subjects were again shown examples of common serving sizes (1/2 cup, 1 cup, tablespoon, etc.) and instructed to continue to use the measuring cup given to them upon enrollment during the intervention period to facilitate accuracy of nutritional intake records. Foods not requiring measurement were readily listed on MyFitnessPal by serving size (i.e. 1 package, 1 slice, 1 piece, etc.). The number of daily meals, including CHO feedings and/or the amount per feeding was ad libidum as nutrient timing has been shown to be of little significance so long as overall intake of energy and respective macronutrients are sufficient (2, 15, 25, 28). Mean CHO intake during the intervention was 6.30 g/kg/d (± 0.34) for CHO group and 3.13 g/kg/d (± 0.18) for the control group (Table 2).

Table 2. Mean and standard deviations for CHO intake during the pre-intervention (Pre) and during days 6-8 (Int) for the CHO and control group (n = 18).

Macronutrient intake (g/kg/d)	CHO group (n = 9)	C group (n = 9)
Pre CHO	3.37 (± 1.27)	3.73 (± 1.21)
Int CHO	6.30 (± 0.537)[1,2]	3.13 (± 1.02)
Pre protein	1.64 (± 0.537)	1.43 (± 0.552)
Int protein	1.89 (± 0.437)	1.54 (± 0.314)
Pre fat	0.85 (± 0.336)	0.97 (± 0.547)
Int fat	1.16 (± 0.410)	0.94 (± 0.540)

[1]Significant difference between pre-intervention and days 6-8 in CHO group ($p < 0.001$); [2]Significant difference between CHO and C groups in days 6-8 ($p < 0.001$).

During all experimental sessions (Pt1, Pt2, Pt3), subjects were required to perform as many rounds as possible (AMRAP) in a 12-minute CrossFit workout which consisted of twelve 30″ box jumps (20″ for females), six 52.8 lb. thrusters (35.2 lb for females), and 6 bar-facing burpees in sequence. Based on the rounds completed and the repetitions associated with each round, a total repetition count was calculated for each testing session (Pt1, Pt2, Pt3). Consistent with the CrossFit training method there were no prescribed rest periods during the 12-minute bouts. Thus, our subjects were allowed to take self-selected rest periods of varying frequency and duration. This workout was selected to minimize a skill bias as the included movements are not highly technical or skill-dependent. In addition, such movements were expected to be familiar to most subjects. In order to collect expired blood gases during these non-traditional and more dynamic exercise bouts (Pt1, Pt2, Pt3), two 9′ gas collection hoses were connected with a cardboard mouthpiece (used for spirometry) and athletic tape. The hose extending from the Hans Rudolph valve was taped to the right side of the headgear and run down the back of the subject. The hose was held in place using a large resistance band, which was wrapped around the torso. A technician manually moved and adjusted the position of the hose during the trial in order to minimize interference. This setup required that the thrusters be performed with kettlebells, a practice commonly employed in CrossFit training, as the Hans Rudolph valve would interfere with the path of the barbell. The metabolic measurement system was calibrated to manufacture specifications prior to each trial.

As mentioned before, on day 6 participants completed CrossFit workout 120107; this workout consisted of 10 rounds of 15, 135 lb. deadlifts (75 lb. for females) immediately followed by 15 pushups (females were able to perform pushups on the knees). Day 7 CrossFit workout Sean consisted of 10 rounds of 11 pull-ups (females used resistance bands for assistance) immediately followed by twenty-two 75 lb. barbell front squats (35 lb. for females). Subjects were instructed to complete both workouts as fast as possible. As previously mentioned, these workouts were selected to control for training volume and thus decrease variation in training stresses prior to Pt3.

Statistical Analysis
The dependent variables in the study corresponded to those measured during the experimental exercise sessions (Pt1, Pt2, Pt3). The variables included: repetitions completed, mean VO_2 (ml/kg/min), mean RER, and BL (mmol/L) (pre, 4 min, 8 min, immediately post [12 min]). In order to probe the differences between the experimental groups (CHO vs. control) and experimental sessions (mean of Pt1 + Pt2 vs. Pt3) a 2 x 2 repeated measures analysis of variance (ANOVA) with repeated measures on the time (experimental sessions) factor was done. For all statistical tests, a significance of $p < 0.05$ was set *priori*. Means and standard deviations were also calculated for all dependent measures. All analyses were done with the Statistical Package for the Social Sciences (V.21; SPSS Inc., Chicago IL).

RESULTS

ANOVA revealed a main effect for time ($p = 0.002$) in repetitions completed but no main effect for group nor a time x group interaction ($p = 0.111$) (Figure 2). A small effect (0.354) (33) was found for the effect of CHO intervention on repetitions completed. This implies a change in repetitions in both groups at Pt3 (vs. mean of Pt1 + Pt2). ANOVA also indicated a significant time main effect ($p = 0.021$) for mean VO_2 which increased from 38.24 (mean of Pt1 + Pt2) to 39.99 ml/kg/min (Pt3) in the CHO group (Table 3). The corresponding scores for the C group increased from 35.88 (mean of Pt1 + Pt2) to 37.47 ml/kg/min (Pt3). No significant main effects for either experimental factors (time and group) or interaction were found for mean RER ($p > 0.05$) (Table 3). The same was true for BL except at the 8 min mark in which a significant main effect for time was found ($p = 0.025$) (Table 3).

Table 3. Mean and standard deviations for repetitions completed, mean VO_2, mean respiratory exchange ratio (RER), and blood lactate (BL) at pre-exercise, 4 min, 8 min, and immediately post (12 min) during the pre-CHO intervention (mean of baseline performance tests [Pt]; Pt1 + Pt2) and the post-CHO intervention (Pt3) for the CHO (n = 9) and control group. (n = 9).

	Group	Pre CHO	Post CHO
Repetitions completed	CHO	139.2 (± 28.0)	154.4 (± 29.0) *
	C	132.2 (± 23.8)	137.9 (± 24.9)*
Mean VO_2 (ml/kg/min)	CHO	38.2 (± 4.9)	40.0 (± 3.9) *
	C	35.9 (± 3.7)	37.5 (± 4.6) *
RER	CHO	1.04 (± 0.04)	1.01 (± 0.04)
	C	1.05 (± 0.07)	1.03 (± 0.05)
BL Pre (mmol/L)	CHO	2.8 (± 1.3)	3.3(± 3.2)
	C	3.2 (± 1.5)	3.1 (± 2.1)
BL 4 min (mmol/L)	CHO	10.8 (± 2.5)	9.1 (± 2.5)
	C	9.4 (± 2.7)	8.9 (± 2.6)
BL 8 min (mmol/L)	CHO	12.3 (± 3.5)	10.3 (± 2.3) *
	C	12.3 (± 2.6)	11.6 (± 3.8) *
BL 12 min (mmol/L)	CHO	13.3 (± 2.8)	12.6 (± 3.8)
	C	12.0 (± 3.6)	11.6 (± 3.6)

*Post CHO was significantly different from Pre CHO in both groups for repetitions completed ($p = 0.002$), mean VO_2 ($p = 0.021$), and BL at 8 minutes ($p = 0.025$).

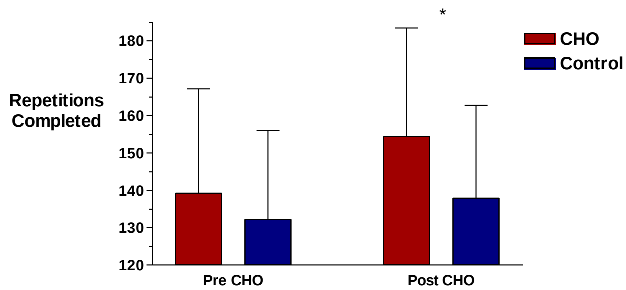

Figure 2. Repetitions completed (mean ± SD) during the pre-CHO intervention (mean of baseline performance tests; Pt1 + Pt2) and the post-CHO intervention (Pt3) by the CHO and control group. (n=18). *Post CHO was significantly different from Pre CHO in both groups (p = 0.002).

DISCUSSION

The purpose of this study was to investigate the effect of a high CHO intake (6-8 g/kg/day) during a period of training on CrossFit performance as evaluated by the repetitions completed during a 12 minute workout (Rahoi) in strength trained individuals with a chronic CHO intake of <6 g/kg/d. In addition, corresponding metabolic responses were also measured during said workout. The present CHO intervention was aimed to investigate the effect on performance during a period of intense exercise, rather than a traditional CHO loading protocol whereby diet and training are manipulated to peak on the day of performance. This was done in order to mimic the training stresses an athlete would encounter during regular CrossFit conditioning.

The main effect for time revealed by the ANOVA implies an increase in repetitions completed by both groups; however a more notable change was observed in the CHO group (+15.22; +10.9%) vs. that in the baseline sessions (mean of Pt1 + Pt2) compared to the C which displayed a (+5.67; + 4.2%). It is possible that the large standard deviations and the small effect size (.354) may have influenced the results of the ANOVA. In a time-based CrossFit competition where performance is dependent on work (repetitions) completed, a 15-repetition increase (as noted in the CHO group) in such a short duration bout (12 min) may be a substantial performance enhancement. Given the metabolic (glycolytically-demanding) profile of CrossFit conditioning, this trend towards increased performance may have been attributed to the three day increase of CHO in the experimental group. However, given the results of the ANOVA this may only be speculated. During days 6-8, the CHO group consumed 6-8 g/kg/day (6.30 ± .537) vs. < 6 g/kg/day (3.13 ± 1.02) by the C group. The high CHO intake might have promoted greater muscle glycogen repletion following workouts 120107 and Sean done during days 6 and 7, respectively. However, no muscle biopsies were taken in the present investigation to confirm this hypothesis. Nevertheless, the high CHO intervention during a period of repeated bouts of intense exercise may have resulted in pronounced glycogen reduction-restoration cycles. This is due to the fact that anaerobic exercise, including resistance training, results in substantial glycogen utilization (5, 6, 14, 18, 22, 26, 34). In addition, three days of a CHO-rich diet (as prescribed to the CHO group), is capable of increasing glycogen stores even without a depleting bout (8, 10, 11, 29, 30). The trend noted in the present study is consistent with the recommendation for training strength/power athletes to practice a moderate to high CHO intake (16, 27, 31) However, the lack of statistical significance makes it difficult to make any conclusions. It may plausible that a longer-duration intervention (> 3 days) may have allowed for the well-documented influence of CHO on high-intensity performance (16, 19) to fully manifest.

The noted VO_2 (Table 3) in all experimental sessions suggest considerable aerobic energy contribution during CrossFit exercise bouts and highlight the intense nature of this mode of training. Similarly, the high RER scores which exceed 1.0 may suggest the addition non-aerobic energy production, however, given the non-steady state nature of this exercise, the use of expired gasses to make inferences on substrate use (i.e. CHO metabolism), or energetic demands may not be made. These measures may only suggest that CrossFit training is that of intense nature.

Interestingly, a downward trend was noted in BL across time in both groups (Figure 3) despite an increased number of repetitions in CHO and C groups. This trend in the BL concentrations may be explained by the lack of steady and sustained performance. Consistent with the CrossFit training method there were no prescribed rest periods during any of the three testing bouts (Pt1, Pt2, Pt3). Thus, our subjects were allowed to take self-selected recovery periods of varying frequency and duration. Since BL was sampled at fixed time intervals (pre, minute 4, minute 8, and immediately post [minute 12]), it is possible that sampling occurred during a self-imposed rest period. Therefore, the timing of BL sampling may have come during a period of inactivity where lactate clearance exceeded its rate of accumulation thus, leading to a lower recorded (BL) score. This lack of sustained performance and its likely effect on the recorded BL concentrations is proposed as a plausible reason to explain the decrease in BL despite an increased repetition count. It is worth noting the sustained elevated BL (Pt1, Pt2, Pt3). From min 4-12, BL concentrations remained above 8.90 (±2.63) mmol/L. The peak concentration sampled was 22.1 mmol/L, followed by 21.4 mmol/L, and 19.4 mmol/L. These concentrations are indicative of fast and sustained glycolytic flux, sustained acidosis, and highlight the role of CHO as a substrate in CrossFit training.

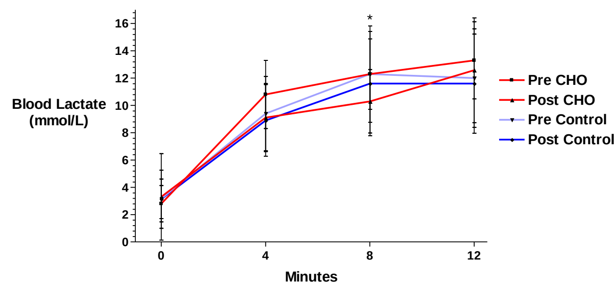

Figure 3. Blood lactate (mean + SD) at pre-exercise (0 mins), 4 mins, 8 mins, and post-exercise at 12 mins during Pre CHO intervention (mean of baseline performance tests; Pt1 + Pt2) and Post CHO intervention (Pt3) for CHO and control (C) groups. (n = 18). *Post CHO was significantly different from Pre CHO in both groups ($p = 0.002$).

The results from our study may suggest that the CrossFit-embraced practice of a moderately-low CHO diets such as the Paleolithic (Paleo) and Zone Diets (40% of daily energy intake), may be adequate in CHO intake during a short (3 day) training period. Given the lack of significant differences between groups, a conclusion regarding the superiority of a high CHO intake vs. a moderately-low CHO intake for enhancement of CrossFit training performance may not be made.

Considering the glycolytically-dependent profile of such training, as evidenced by the documented BL concentrations, however, it is plausible that over an extended period of training (i.e. weeks, months) an inadequacy of CHO resulting from a chronic moderately-low intake may manifest, potentially impairing performance, particularly considering the observed trend in the present study and the well-documented influence of CHO on repeated high-intensity performance. Therefore, future investigations should employ training/nutritional interventions of greater durations in order to elucidate the effect of CHO intake and CrossFit training performance.

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