The Effect of Pre-Exercise Carbohydrate Supplementation on Anaerobic Exercise Performance in Adolescent Males

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Carbohydrate (CHO) consumption before anaerobic exercise was studied in 13 adolescent boys (15.2 ± 0.9 yrs). A within subjects design was employed where subjects consumed a 22% CHO or volume-matched placebo (PL) beverage 30-min before anaerobic exercise on two separate days. Exercise consisted of a Wingate Anaerobic Test (WAnT), ten by 10-s-sprints, and a second WAnT. Fatigue index and peak power (PP) were similar while mean power (MP) was higher (p < .025) in CHO trial; however this difference was ascribed to initial WAnT performance. PP and MP for the 10-s sprints were similar between trials. Intravenous blood glucose and insulin concentrations were higher (p < .05) in the CHO trial while lactate and catecholamine concentrations were similar. Improved performance on a single WAnT was apparent with CHO consumption before exercise; however, this strategy did not attenuate fatigue over time in adolescent boys.

It is generally recognized that children and adolescents are less dependent on the glycolytic energy pathway for the synthesis of adenosine triphosphate (ATP) during exercise. Traditionally, this has been attributed to attenuated phosphofructokinase (PFK) activity (5), although diminished muscle glycogen concentration also has been reported (4,6), and would further affect the relative contribution of glycolysis to overall energetic profile during exercise. As a result children and adolescents, compared with adults, are more reliant on oxidative energy metabolism as further evidenced by lower blood lactate concentrations and respiratory exchange ratio values (12,23,26,28). This metabolic profile may serve as a means to preserve the limited glycogen stores in young individuals.

Recently the results of several studies have challenged the PFK limitation during submaximal aerobic exercise by examining the relative contribution of exogenous versus endogenous carbohydrate dependency in boys compared with men. During 60 min of exercise at 70% of VO2max, Timmons et al. (22) reported higher rates of exogenous CHO contribution in boys versus men (~22% versus

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~14%). Riddell et al. (16) reported that intermittent exogenous CHO ingestion spares endogenous CHO stores and contributes markedly to energy demands during prolonged exercise in adolescent boys. In addition, it has been shown that high intensity aerobic exercise performance following prolonged exercise is enhanced with CHO consumption before and during exercise compared with a placebo (14,17). Collectively, these results suggest that regardless of a substrate or enzymatic limitation, children and adolescents realize performance benefits when consuming CHO before and during extended bouts of exercise.

Anaerobic exercise, especially when repeated in an intermittent manner, will be dependent primarily on glycolytic energy metabolism. Thus, increasing CHO availability may enhance anaerobic exercise performance. To examine this premise Marjerrison et al. (11) had pre- and early-pubertal boys consume CHO before performing four Wingate Anaerobic Tests (WAnT) at 2-min intervals. Compared with a placebo trial, preexercise CHO ingestion had no effect on WAnT performance. It is possible that during low-intensity exercise the limited glycolytic activity observed in children is mostly a function of substrate (glycogen) availability whereas during high-intensity exercise the glycolytic limitation manifests as an enzymatic constraint.

At present it is not clear whether more mature children performing anaerobic exercise will benefit from consuming exogenous CHO beforehand. However, there are at least three considerations that would suggest anaerobic exercise performance may be enhanced with the use of exogenous CHO. First, although there is a puberty-induced decline in the reliance on exogenous CHO during exercise (21), reliance on exogenous CHO remains superior compared with adults (22). Second, the glycolytic enzymatic limitation may be abating during adolescence (7). Lastly, as noted above, high-intensity aerobic exercise performance in adolescent boys improves with exogenous CHO consumption (14,17). Therefore, the aim of this study was to assess the effect of preexercise CHO ingestion on anaerobic exercise performance in adolescent males. It was hypothesized that the consumption of exogenous CHO before exercise would lessen the decrement in WAnT performance before and after a series of high-intensity sprints compared with a placebo (PL) trial. Information obtained from this study may increase the understanding of effective nutritional strategies relative to exercise and sport performance for this age group, as well as gain insight into the dynamics of developmental exercise metabolism.

Methods

Subjects

Fourteen healthy and recreationally active 14- to 16-year-old adolescent boys, whose pubertal stage was $\geq 3$ according to Tanner (20), volunteered to participate in the study. Based on self-report information, the subjects participated in a variety of team sports (soccer, football, and basketball) and individual sports (martial arts, tennis and running) during the course of the school year. No separate provisions were made to assess sports drink consumption or sprinting activity before enrollment in the study. Parental permission and child assent were obtained for each subject. The protocol was approved by the Institutional Review Board at Ball State University.
Experimental Protocol

**Design** Each subject made four separate visits to the laboratory. The first two visits served as familiarization trials to acquaint the subjects with the testing procedures. The second two visits served as the experimental trials which examined the effects of preexercise CHO consumption on anaerobic exercise performance. This study employed a two-way, within subject, crossover design whereby drink administration was double-blinded and counter-balanced, but not random, by an individual independent of the research team. The experimental trials were separated by a minimum of 48 hr and a maximum of 15 days.

**Familiarizations Trials** The first visit included the following: completion of a health history questionnaire, self/parent-assessed maturation status using images of pubic hair development (20), the measurement of stature and mass, an explanation of the study, and performance of two WAnT’s separated by 15 min of passive rest. The second visit served to familiarize the subject with the experimental protocol and consisted of a WAnT followed by five, 10-s all-out sprints, and another WAnT with 60 s of active recovery. Preceding each exercise trial on both of these days, the subjects completed a 5–6 min warm-up with minimal resistance.

**Experimental Trials** Before the two experimental sessions of the study, the subjects were instructed to record the content and timing of a typical meal the evening before the day of the test. Subjects were asked to replicate both content and timing of their “day-before meal,” before the second experimental visit. The subjects were also given an assigned breakfast to be consumed 30 min before the arrival at the laboratory. The breakfast was a Carnation instant breakfast (Nestle Vevey, Switzerland), consisting of 5g of total fat, 15g of total CHO, and 12g of protein (150 total calories per serving).

Upon entering the laboratory a registered nurse inserted an intravenous catheter into an antecubital vein. The subject rested quietly for ~20 min after which a prebeverage blood sample was collected (approximately one hour postprandial). In the CHO trial, the subject consumed a volume of fluid that provided 1.5g glucose/kg of mass; a predetermined tolerable increase in glucose concentration based on our previously demonstrated procedures (11). The rationale for the higher glucose concentration was to provide more exogenous CHO than provided previously since a performance benefit was not realized (11). In the PL trial an equal volume of fluid similar in color, flavor (wild berry) and taste (artificial sweetness) was consumed (Gatorade Sports Science Institute, Barrington, IL). The average consumption of fluid in each trial was 488.9 ± 122.8 ml of fluid. Twenty minutes after finishing the drink the subject performed the warm-up exercise and a second blood sample (preexercise) was collected. The subject then performed the exercise protocol on a mechanically-braked cycle ergometer, approximately 30 min after drink administration. The protocol commenced with an initial WAnT followed by a series of ten, 10-s sprints and concluded with a second WAnT; 30 s of active rest pedaling against no resistance was provided between each repetition. The subjects were instructed to give a maximal effort for each WAnT and sprint and were verbally encouraged throughout the trials. A final blood sample (postexercise) was collected immediately following the second WAnT. A diagram of the exercise protocol is shown in Figure 1.
Figure 1 — Exercise Protocol (Day 3 & 4); 30 s of recovery between WAnT and sprints.
All exercise bouts (familiarization and experimental trials) were performed on a modified Monark cycle ergometer (818E Ergomedic, Sweden) interfaced to a personal computer programmed to record power output at 1-s intervals throughout the exercise (Sports Medicine Industries Power software: SMI V2.5.23, St. Cloud, MN, USA). WAiT and sprint resistance was set at a fixed load of 0.075 kiloponds/kilogram (kp/kg) of body mass (1) and commenced from a 70 rpm rolling start. WAiT peak power (PP) was considered the highest 5-s average, mean power (MP) was the average power across each bout, and fatigue index (FI), the percent decline from PP to the lowest 5-s average, was calculated. PP for the sprints was defined as the highest 1-s output and MP during the sprints was average power over the 10 s. HR and ratings of perceived exertion (RPE) were obtained after each exercise bout. HR was measured using a Polar Monitor (Polar USA, Inc., Stamford, CT) and RPE was assessed with the cycle version of the OMNI 0–10 RPE scale (18).

Blood Measures
Prebeverage, preexercise, and postexercise intravenous blood samples (~12–15 ml each) were collected using vacutainers containing EDTA (glucose, lactate, and insulin samples) and sodium heparin (catecholamine samples). Blood glucose concentration was determined from whole blood using a portable blood glucose monitor (BD Logic, Waltham, MA). Whole blood was lysed with perchloric acid, stored at -20 °C, and analyzed for lactate at a later time as previously described (13). After centrifugation, plasma samples for insulin and catecholamines were stored at -80 °C until analyzed. Plasma insulin concentration was determined using a Human Insulin ELISA kit (ALPCO Diagnostics, Salem, NH). Plasma epinephrine and norepinephrine analyses were measured by an independent analysis company (ARUP laboratories, Salt Lake City, UT) via high performance liquid chromatography (BIO-RAD Diagnostics Group, Hercules, CA). The intrasubject (within trial and time) CV for insulin was <8.0%. As glucose, lactate, epinephrine and norepinephrine were run (glucose) or reported as single measures (lactate, epinephrine and norepinephrine) intrasubject CV values are not available.

Statistical Analysis
A two-way trial (CHO vs. PL) by time ANOVA was used to determine the effect of the experimental treatment on the dependent variables (PP, MP, FI, blood lactate, blood glucose, catecholamines, insulin, HR and RPE). A Bonferroni post hoc test was used to identify specific differences. The average PP and MP across the ten, 10-s sprints were analyzed separately using a paired t test (CHO versus PL). All data are expressed as mean ± SD. Because of the related nature of the PP and MP responses, statistical significance was set at p < .025 for these analyses, otherwise comparisons statistical significance was set at p < .05.

Results
Of the fourteen boys recruited to participate in this study, thirteen completed all of the phases of the exercise portion of the protocol for data analysis; however, a complete set of blood samples were obtained from seven boys. Subject characteristics for all thirteen subjects are as follows: age 15.2 ± 0.9 y, stature 172.2 ± 9.1 cm, and mass 68.7 ± 14.6 kg.
WAnT PP data during the CHO and PL trials are displayed in Figure 2. In the CHO trial PP for the first WAnT was $442.9 \pm 130.4$ W and for the second WAnT PP was $322.2 \pm 86.5$ W. In the PL trial respective values for PP were $396.3 \pm 101.9$ W and $317.3 \pm 90.9$ W. PP decreased ($p < .025$) over time, but the trial and trial by time interaction effects were not significant. MP data during the CHO and PL trials are displayed in Figure 3. In the CHO trial, MP for the first and second WAnT was $330.5 \pm 112.2$ W and $229.1 \pm 69.8$ W, respectively. In the PL trial, MP was $293.8 \pm 82.3$ W and $220.5 \pm 68.5$ W at the two times of measurement. Between trials, MP was higher ($p < .025$) in the CHO condition and declined ($p < .025$) over time. The trial by time interaction was not significant.
The FI values in the CHO trial for the first WAnT were 46.5 ± 11.9 and 48.6 ± 14.2% for the second WAnT. In the PL trial, these values were 48.7 ± 12.0 and 54.2 ± 18.0%, respectively. There were no significant trial, time, or interaction effects.

PP and MP averaged across the ten, 10-s sprints in both the CHO and PL trials are shown in Figure 4. In the CHO trial, PP was 341.3 ± 98.4 W and in the PL trial, PP was 326.5 ± 95.0 W. MP was 283.9 ± 91.4 W in the CHO trial and 270.1 ± 79.2 W in the PL trial. There were no significant differences between trials.

HR in the CHO trial for the first and second WAnT was 178 ± 10 and 189 ± 8 bpm; in the PL trial these values were 173 ± 14 and 190 ± 8 bpm. RPE after the first and second WAnT for the CHO trial was 4.0 ± 1.7 and 9.1 ± 0.9. In the PL trial these values were 4.0 ± 1.4 and 8.8 ± 1.1. HR and RPE increased significantly across time; however, there were no significant trial or interaction effects.

Values for the venous blood measurements during each trial are displayed in Table 1. For blood glucose concentration there were significant main effects for trial and time. Glucose concentration was higher (p < .05) in the CHO trial and increased (p < .05) over time with the preexercise and postexercise concentrations higher than the prebeverage value; the preexercise was also higher versus postexercise. There also was a significant trial by time interaction for glucose. Specifically, the pre- and postexercise blood glucose concentration were significantly higher in the CHO trial compared with the PL trial; however, there were no differences (p > .05) between trials prebeverage. Within the CHO trial, blood glucose concentration was higher (p < .05) preexercise compared with prebeverage, and prebeverage was greater than postexercise; however, there was no difference between prebeverage and postexercise. In the PL trial, blood glucose concentration was unchanged (p > .05) over time.

For plasma insulin concentration there were significant trial, time, and trial by time effects. Insulin levels were higher (p < .05) in the CHO trial and changed over time (p < .05) such that the insulin concentration preexercise insulin level was higher than the other two measurements and postexercise insulin was higher than

![Figure 4](image-url) — Corrected average sprint PP and MP data (M ± SD) for CHO and PL trials (n = 13). There were no significant differences between trials.
prebeverage insulin concentration. The insulin analysis also indicated a significant interaction effect. Insulin concentrations preexercise and postexercise were higher \((p < .05)\) in the CHO trial compared with PL. Within the CHO trial, pre- and postexercise concentrations were higher \((p < .05)\) than prebeverage and preexercise was higher \((p < .05)\) than postexercise. In the PL trial, insulin concentration preexercise was higher \((p < .05)\) compared with prebeverage and postexercise.

Blood lactate concentration increased across time with the postexercise concentration higher \((p < .05)\) than both prebeverage and preexercise. However, there were no differences between trials, nor was there an interaction effect \((p > .05)\).

For epinephrine and norepinephrine only the time effect was statistically significant. Specifically, across time, postexercise epinephrine levels were higher \((p < .05)\) than the preexercise and prebeverage values. Similarly, norepinephrine increased across all three time points \((p < .05)\).

**Discussion**

In a previous study, the consumption of a CHO beverage 30 min before exercise failed to improve anaerobic exercise performance across 4 WAnT's in pre- and early-pubertal boys. It is not clear whether the failure to improve performance could be traced to an inability to use the exogenous glucose due to an enzymatic limitation or whether other factors causing fatigue, namely metabolic acidosis during this type of intense exercise, mitigated any benefit of exogenous CHO (11). However, given
evidence that high-intensity aerobic exercise performance immediately following prolonged exercise is enhanced with exogenous CHO (14,17) and that adolescents have a more developed glycolytic energy system than pre- and early-pubertal children (7), it was hypothesized that preexercise CHO consumption would improve anaerobic exercise performance in this population.

The results of this study indicated that MP was significantly higher in the CHO trial, whereas other measures of WAnT performance, PP and FI, were not significantly different between trials. The difference in MP between trials appears to be due to differences in the initial WAnT performance rather than an attenuation in fatigue over time as originally hypothesized. However, it may be worth noting that for both PP and MP, there were large effect sizes (f > 0.40) for both the trial and interaction effects suggesting that CHO supplementation enhanced performance on both of these measurements. Although the large effect size for the interaction effect would suggest that there was a greater, not lesser decline in performance with CHO, it could be argued that CHO enhances performance early on in repeated bouts of anaerobic exercise without creating more fatigue in the end. The fact that FI was similar between trials would support this latter point.

It is possible that the performance differences between trials, particularly on the first WAnT, reflect poor reliability; however there are several arguments against this notion. First, there was not a systematic day-to-day difference in performance. Second, pilot data using the same exercise protocol indicated moderate to good reliability for the performance measurements (9). Third, dietary intervention care was taken to ensure similar glycogen status between trials. Alternatively, the higher PP (based on the effect size) and MP (statistically significant difference) during the initial WAnT may indicate an ergogenic benefit of CHO before exercise. Indeed it has been shown that the mere presence of CHO in the mouth may activate specific brain regions and improve exercise performance (2). Although it is recognized that the phosphagen energy pathway is likely the primary energy contributor to PP and it is not clear how CHO ingestion could alter this pathway. CHO supplementation also did not affect sprint performances between WAnT’s, alter FI, or have any influence on HR or RPE.

The failure to observe an attenuated decrease in anaerobic performance concurs with previous studies involving adults (19,27) and children (11). Wouassi et al. (27) reported no performance effect of preexercise CHO supplementation on repeated maximal sprints of 6-s duration against increasing braking forces; however, hormonal and metabolic differences were observed between the two beverage trials. In pre- and early-pubertal boys preexercise CHO supplementation did not impact performance across four WAnT bouts performed over a ten minute period (11).

A number of factors could have contributed to the failure to observe a difference in the attenuation in subsequent anaerobic performance over time. The heavy reliance on glycolysis during this type of exercise has consequences that are known to inhibit continued muscle performance. These include a decrease in muscle pH and an accumulation in inorganic phosphate (25). As suggested by Marjerrison et al. (11) these factors may have alleviated any further benefit brought on by CHO consumption. Secondly, although substrate availability was increased in the CHO trial (as evidenced by the increase in blood glucose before exercise) it is not possible to determine whether this extra glucose was being used by the muscle. It is possible that while glucose availability increased, glycolytic flux was already at a
maximal rate given the intensity of the exercise and unable to benefit from more CHO. Alternatively it is possible that the “extra” glucose in the CHO trial was taken up by other tissues. However this does not seem plausible as the combination of an initially high plasma insulin concentration in the CHO trial combined with the effect of exercise would provide a potent synergistic stimulus for glucose uptake in the exercising muscle (8,24).

Given the intense nature of the repeated anaerobic exercise bouts the increases in postexercise blood lactate, in excess of 10mmol/L in this study, were anticipated (15,27). Comparable measures of blood lactate after similar exercise were reported by Ratel et al. (15) in nine adolescent boys who performed ten, 10s cycling sprints separated by 30s of passive recovery. However, with the addition of exogenous CHO, an increase in glycolytic metabolism might have been expected in the CHO trial. Although the lactate results of this study would indicate that the level of glycolytic activation was comparable between trials, more direct measures of lactate production or glycolytic intermediates would be required to verify this notion.

A significant increase in the concentrations of epinephrine and norepinephrine also was observed from prebeverage to postexercise. Specifically, epinephrine increased by more than tenfold, and norepinephrine increased eightfold, over time. This response was expected considering the intense exercise that was performed (10) and would contribute to the cardiorespiratory and metabolic responses during this type of exercise. The fact that there were no differences between trials is consistent with similar HR responses in both trials and the maintenance of blood glucose concentration at or above the euglycemic range.

In summary, the results of this study suggest that consumption of CHO 30 min before anaerobic exercise may enhance initial performance without necessarily having a negative impact on continued performance of an anaerobic and intermittent nature. The heart rate, lactate, perceptual and catecholamine response to this type of exercise were unaffected by the use of a preexercise CHO drink.

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References


