A reprint from

INTERNATIONAL JOURNAL OF
SPORT NUTRITION AND
EXERCISE METABOLISM

Human Kinetics
The Effects of a Pre-exercise Feeding With or Without Fungal Carbohydrases (Carbogen™) on Blood Parameters and Exercise Performance in Elite Cyclists: A Preliminary Study

Laura Lewis Frank, Janine T. Baer, Charles P. Lambert, and Mark L. Anderson

The effect of fungal carbohydrates (Carbogen™ [C]) consumed with a meal replacement bar (MRB) on glucose metabolism and exercise performance was determined in 5 male competitive cyclists. After a 12-hour fast, subjects performed two 60-min cycling bouts at 80% VO₂max followed by a time-to-exhaustion (TE) ride at 100% VO₂max. One hour prior to each cycling bout, subjects ingested a MRB + 160-mg C or 160-mg CaCO₃ placebo (PL) in a double-blind, counterbalanced fashion. Blood was drawn for determination of glucose, insulin, and lactate at fasting, 1 hour post-feeding, minutes 30 and 60 of exercise, and after TE. Two-way ANOVA revealed a significant (p < .05) treatment and time effect for glucose, with C being higher than PL. Interaction effects were observed for insulin and lactate. An increase in TE (min) at 100% VO₂max was observed in the C versus PL trial (6.3 ± 3.4 vs. 4.4 ± 2.9, p < .001). A MRB+C may benefit cyclists due to increased BG and improved exercise performance.

Key Words: meal replacement bar, cellulase, hemicellulase, amylase

Introduction

The depletion of endogenous carbohydrate stores (muscle and liver glycogen and blood glucose) contribute to fatigue during high-intensity (60–85% VO₂max) exercise (4, 6). Research has shown that when carbohydrate stores are diminished, exercise performance is reduced (7). Reduction in exercise performance may be seen as a decrease in exercise intensity and/or reduction in time-to-exhaustion (TE). Therefore, in order to delay fatigue and improve exercise performance, carbohydrates...
(CHO) have been ingested prior to exercise to promote liver and muscle glycogen synthesis, and/or to elevate blood glucose (BG) concentration for use during exercise (1, 6, 9, 11, 14–16, 18). Even when glycogen stores are low, maintaining euglycemia by supplying exogenous CHO feedings can allow endurance athletes to exercise at high intensities (e.g., 75% \( \dot{V}O_{2\text{max}} \)) (6). Moreover, repeated solid CHO feedings have been shown to maintain blood glucose concentrations, reduce muscle glycogen depletion during prolonged exercise, and enhance sprint performance (10).

Although many athletes supplement with glucose polymers, maltodextrin, or other carbohydrates prior to and/or during endurance exercise, athletes may benefit from additional increases in BG concentrations during the exercise bout. Commercially available fungal carbohydrases known to help digest starches and other polysaccharides resulting in soluble dextrins and oligosaccharides may be of benefit to the athlete to provide a more rapid and sustained release of BG and thereby increase endogenous carbohydrate stores. The purpose of this study was to investigate the effect of 160 mg of Carbogen™ (C) with a meal replacement bar (MRB) on glucose metabolism and endurance exercise performance during 60 min of high-intensity cycling (80% \( \dot{V}O_{2\text{max}} \)) followed by a TE ride at 100% of \( \dot{V}O_{2\text{max}} \). We hypothesized that ingestion of C with a MRB would result in a more rapid and sustained blood glucose concentration and, because of greater carbohydrate availability, TE would be greater after supplementation of MRB+C versus placebo.

**Methods**

**Subjects**

Five elite male competitive cyclists volunteered for this study. Prior to their participation, each of the subjects was informed of the purpose, methods, and possible risks associated with the study, and informed consent was obtained from each subject. The study was performed in accordance with the University of Dayton’s Institutional Review Board. The characteristics of the 5 subjects are presented in Table 1.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>( \dot{V}O_{2\text{max}} ) (ml/kg/min)</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>38</td>
<td>74.1</td>
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<tr>
<td>5</td>
<td>31</td>
<td>84</td>
<td>180</td>
<td>75</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>31.8 ± 3.9</td>
<td>78.2 ± 8.3</td>
<td>179.0 ± 4.2</td>
<td>70.0 ± 7.8</td>
</tr>
</tbody>
</table>
\( \dot{V}O_{2\text{max}} \) Assessment

Subjects arrived at the exercise physiology laboratory at the University of Dayton (Ohio) on three separate occasions after a 12-hour fast. The first visit to the laboratory was to determine the subjects’ body weight and to familiarize them with exercise protocol. In addition, subjects underwent a \( \dot{V}O_{2\text{max}} \) assessment via indirect calorimetry to establish the corresponding workload necessary for the 60-min exercise bout at 80\% \( \dot{V}O_{2\text{max}} \) and the time-to-exhaustion (TE) ride at 100\% \( \dot{V}O_{2\text{max}} \) using a mechanically braked Monark cycle ergometer (Model 864). All subjects were equipped with a mouth piece that was attached to a metabolic cart (Sensor Medics 2900 System, Sensor Medics, Anaheim, CA). Heart rate (HR) was determined by both the metabolic cart and by a chest-held Polar HR monitor (Polar\textsuperscript{TM} Vantage XL, Stamford, CT). All subjects exercised to exhaustion using a load-increment continuous protocol (3). The subjects performed a 5-min warm-up (50\% \( \dot{V}O_{2\text{max}} \)) at a pedal rate of 90 revolutions per min (RPM) with no resistance. A pedal rate of 90 RPM was used because it was similar to the rate used by cyclists during training and competition. Each stage of the test was 3 min; the first stage had a resistance of 1 kilopond (kp) and was increased by 0.5 kp with every subsequent 3-min stage until subject’s \( \dot{V}O_{2\text{max}} \) was reached.

Two of the three established criteria were used in order to determine when subjects reached \( \dot{V}O_{2\text{max}} \). A plateau or decrease in oxygen uptake with a concomitant increase in workload as evidenced by a rise less than 2.1 ml · kg · min\(^{-1}\) and a respiratory exchange ratio (RER) greater than 1.15 (12). Due to the subjects’ level of fitness, the criterion of “heart rate within 10 beats per min (bpm) of age-predicted maximum” (2) was not used (17).

The subjects visited the exercise laboratory a second and third time to perform the exercise protocol (described below). Experimental days 2 and 3 were exactly 1 week apart. Each subject served as their own control in a double-blind, counterbalanced design.

Dietary Protocol

Subjects followed a standardized diet 3 days prior to each test. Food records were kept by each subject for 3 days prior to each test. A registered dietitian evaluated the subjects’ diet to ensure that the subjects consumed 6 g CHO per kg body weight for 3 days prior to all tests.

Meal Replacement Bar (MRB)

Each subject ingested the “fudge brownie” flavored MRB (100 g) 60 min prior to exercise. This sports bar contained approximately 320 kcal, 2.5 g (7\%) fat, 52 g (65\%) CHO, and 27 g (34\%) Pro. Each bar contained a blend of milk protein isolates, caseinate, whey protein concentrate, egg white, glutamine, corn syrup, high fructose corn syrup, natural and artificial flavors, Dutch cocoa (alkali processed), vitamins, and minerals.

Exercise Protocol

After the preliminary testing, the subjects returned to the laboratory for the two experimental tests. The order of the trials were counterbalanced, and tests were
performed exactly 1 week apart. All subjects abstained from exercise prior to testing for 48 hours. Subjects began cycling at a workload corresponding to 50% $\dot{V}O_{2\text{max}}$ for 5 min in order to warm up on their respective bike. After the 5-min warm-up, subjects increased power output in order to sustain a workload corresponding to 80% $\dot{V}O_{2\text{max}}$ for 60 min. Immediately following the 60-min ride, subjects increased intensity and exercised at a workload corresponding to 100% $\dot{V}O_{2\text{max}}$ to exhaustion. Subjects returned to the laboratory the next week to repeat the exercise protocol. Subjects consumed $H_2O$ ad lib throughout the study to ensure adequate hydration. The amount of the $H_2O$ consumed on test day 1 was equivalent to that consumed on test day 2.

**Carbogen™ Supplementation**

Carbogen™ (C) is a maltodextrin-based, patented, proprietary blend of carbohydrates including amylase, cellulase, and hemicellulase (Triarco Industries, Inc., Wayne, NJ). During experimental trials 1 and 2, subjects’ blood was taken in order to establish baseline blood glucose (pre-Carbogen™/placebo). Subjects then ingested a MRB with or without C. Subjects received approximately 50 g CHO with or without the addition of 3 mg C per g CHO. Each subject consumed the MRB and received a 160-mg capsule of either the C or placebo (Calcium carbonate) with 8 oz. of water. The placebo (PL) was indistinguishable in taste and color compared to the C so that neither the investigators nor the subjects knew which supplement the subjects were receiving.

**Sampling Times**

Subjects’ blood was drawn prior to MRB+C/PL administration (T-baseline[B]), and 1 hour post-ingestion, immediately prior to exercise (time[T]-0). During the 60-min exercise bout, blood was drawn at minutes 30 (T-30), 60 (T-60), and at post-sprint (T-pS). Blood samples were used for the determination of serum glucose and insulin concentrations at T-B, T-0, T-30, and T-60, while samples were used to determine plasma lactate concentration at T-B, T-30, T-60, and T-pS.

**Sample Collection**

Whole blood samples (approximately 10 ml) were collected from an antecubital vein using a 1-in. needle. The samples were stored on ice until all data collection was complete. Blood samples were then centrifuged at 4 °C for 20 min at 1500 × g to obtain plasma for determination of lactate and serum for determination of glucose and insulin. Plasma lactate concentration was determined spectrophotometrically by the lactate dehydrogenase method using a COBAS Bio analyzer (Roche Diagnostica, Switzerland). Serum glucose and insulin was determined using a hexokinase/glucose-6-phosphate dehydrogenase method (Sigma 16-UV) and commercially available radioimmunassay kit (coat-A-count, Diagnostics Products Corp.), respectively. The intra-assay coefficient of variation for the glucose, insulin, and lactate procedures was < 1%, < 8%, and < 4%, respectively.

**Statistics**

Two-way ANOVAs (treatment × time) with repeated measures on both factors were performed on blood glucose, insulin, and lactate. When a significant interaction
was observed, a one-way ANOVA using the interaction error term in the denominator was performed between treatments at a given time point as a post hoc test. Time-to-exhaustion (min) was compared between treatments using a paired student's t test. Differences were considered significant at or below an alpha level of .05. Statistics were performed using a commercially available software program (Statistica for Windows, StatSoft®, v. 5.0, Tulsa, OK).

Results

All 5 subjects were included in the study analysis. After performing statistical analysis on the data collected during the two experimental trials, it was determined that there was a significant treatment effect \( (p = .022) \) with regard to blood glucose (BG) with C being higher than PL. In addition, a significant time effect \( (p = .0007) \) but no significant interaction \( (p = .115) \) effect was observed (Figure 1).

![Figure 1 — Mean serum glucose concentrations. PL = placebo; C = Carbogen™; T-0 = time at 60 min post PL or C and before exercise; T-30 = time at 30 min exercise; T-60 = time at 60 min exercise. *Significant treatment effect \( (p < .05) \).](image1)

![Figure 2 — Mean serum insulin concentrations (μU/ml). PL = placebo; C = Carbogen™; T-B = time at baseline; T-0 = time at 60 min post-PL or C and before exercise; T-30 = time at 30 min exercise; T-60 = time at 60 min exercise. *Significant treatment effect \( (p < .05) \).](image2)
There were significant treatment ($p = .000879$), time ($p = .000001$) and interaction ($p = .000000$) effects for serum insulin. Insulin levels (μU/ml) were higher in the C trial compared to PL trial at T-0 (24.4 ± 3.9 vs. 11.8 ± 2.0, $p = .000233$). Significantly lower insulin concentrations at T-30 (13.6 ± 5.8 vs. 20.2 ± 1.8, $p = .0425$) and T-60 (6.8 ± 1.6 vs. 24.0 ± 1.0, $p = .000000$) were observed for C vs. PL (Figure 2).

There were significant treatment, time, and interaction effects ($p = .000000$) for plasma lactate. Blood lactate values (mmol/L) were significantly higher at T-30 ($p = .000000$), T-60 ($p = .05$) and T-pS ($p = .000000$) for MRB+PL compared to the corresponding values for MRB+C (Figure 3). Subjects were able to maintain a workload corresponding to 100% $\dot{V}O_2_{max}$ significantly longer with C vs. PL (6.3 ± 3.4 min vs. 4.4 ± 2.9 min, $p < .001$; Figure 4). In addition, subjects reported a lower rate of perceived exertion (RPE) during exercise at T-30 when treated with C vs. PL (mean RPE 12.0 ± 1.0 vs. 13.0 ± 1.0, respectively; $p = .10$), although results were not significantly different.

**Figure 3**—Mean plasma lactate concentrations (mmol/L). PL = placebo; C = Carbogen™; T-B = time at baseline; T-30 = time at 30 min exercise; T-60 = time at 60 min exercise; T-pS = time at post-sprint. †Imputed values. *Significant treatment effect ($p < .05$).

**Figure 4**—Time to exhaustion at 100% $\dot{V}O_2_{max}$. PL = placebo; C = Carbogen™; Time at post-sprint (T-pS). *$p < .001$. 
Discussion

In this investigation, approximately 50 g of CHO consumed 1 hour before exercise with or without added Carbogen™ (C) was studied. Our results showed an increase in BG concentrations at all time points following consumption of MRB+C, with a significant treatment effect (C higher than PL). Specifically, there was a 20.5% and 26.4% higher BG concentration for the MRB+C compared to MRB+PL at T-30 and T-60, respectively. At these same time points, blood lactate levels were 175% and 17% lower, respectively, for the treatment versus placebo group. Our study suggests that BG concentrations remained significantly higher during exercise and TE was increased by 43% when a solid form of CHO (e.g., MRB) was given along with fungal carbohydrates. Therefore, where other researchers have shown that a solid CHO supplement increases BG and CHO oxidation, and improves cycling sprint performance when compared to a water placebo (8, 10), no published studies to date have compared a solid CHO supplement with or without added fungal carbohydrates.

Carbogen™ supplementation resulted in a significant decrease in blood lactate at T-30 min of exercise when compared to placebo. The decrease in lactate accumulation following C intake and associated increase in BG at T-30 min of exercise may be associated with a reduced rate of glycogen depletion. Evidence of selective glycogen-sparing in type 1 muscle fibers with CHO feedings and increased BG levels has been reported during high-intensity exercise (20). Although glycogen levels were not determined in the present study, BG levels were higher at all time points when subjects were given a MRB with C versus PL. Therefore, the reliance upon glycogenolysis may have been decreased due to the increased in BG concentration; however, because glycogen concentrations were not measured, this relationship is speculative.

Insulin concentrations presented an interesting trend when subjects were given C versus PL. At 1-hour post ingestion of the MRB with C or PL, significantly higher insulin concentrations were observed in the C versus PL trial. This trend was expected due to the higher BG concentrations in the C versus PL trial. We attribute the higher BG concentrations found in the C trial to the added fungal carbohydrates and their ability to breakdown polysaccharides into more easily digested oligosaccharides. However, despite significantly higher concentrations of BG observed in the C versus PL trial during the exercise bout, blood insulin concentrations were significantly lower. Again, we attribute this trend to the potentially faster digestibility of the MRB with C versus PL. Due to the stimulus of blood glucose and amino acids from the MRB (13), insulin concentrations may have peaked at T-0 with the C trial due to faster digestion/absorption caused by the addition of carbohydrates. At 60 min of exercise (T-60), the insulin data for the PL trial closely matches the insulin data found in the C trial at T-0. Hence, the C supplement may have caused the peak of insulin release earlier in the C versus PL trial. Because insulin data were not collected after T-60, however, it is not possible to know for certain whether this time-point was indeed the peak in insulin release for the PL trial. Previous researchers have shown that after an initial insulin peak due to various low and high fiber meals no more insulin peaks were observed up to 6 hours post-ingestion, despite elevations in blood glucose concentrations (5).

In conclusion, this study showed that Carbogen™ taken with a MRB increased BG an average of 23% during intense exercise and increased time-to-exhaustion by 43%. It also suggests that the combination of Carbogen™ with MRB may be responsible for a decrease in blood lactate and insulin levels during exercise. Cyclists, and
perhaps other endurance athletes, may benefit from supplementation of a MRB with Carbogen™ in order to increase blood glucose concentrations, time-to-exhaustion, and endurance exercise performance. Furthermore, supplementation of a MRB with added Carbogen™ may present an advantage for the cyclist or other athlete whose success is largely dependent upon a sprint phase at the race’s finish. Further research is needed to examine the effects of Carbogen™ on different variables of exercise including type, duration, and intensity as well as different forms of CHO supplements.

References