Carbohydrate intake during prolonged cycling minimizes effect of glycemic index of preexercise meal

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Burke, Louise M., Amanda Claassen, John A. Hawley, and Timothy D. Noakes. Carbohydrate intake during prolonged cycling minimizes effect of glycemic index of preexercise meal. J. Appl. Physiol. 85(6): 2220–2226, 1998.—We studied the effects of the glycemic index (GI) of preexercise meals on metabolism and performance when carbohydrate (CHO) was ingested throughout exercise. Six well-trained cyclists performed three counterbalanced trials of 2-h cycling at ~70% of maximal oxygen uptake, followed by a performance ride of 300 kJ. Meals consumed 2 h before exercise consisted of 2 g CHO/kg body mass of either high-GI potato (HGI trial) or low-GI pasta (LGI trial), or of a low-energy jelly (Con trial). Immediately before and throughout exercise, subjects ingested a 10 g/100 ml [U-14C]glucose solution for a total of 24 ml/kg body mass. Despite differences in preexercise CHO, insulin, and free fatty acids concentrations among trials, both total CHO oxidation for HGI, LGI, and Con trials, respectively, during steady-state exercise [403 ± 16, 376 ± 29, and 373 ± 24 (SE) g/h] and oxidation of the ingested CHO (65 ± 6, 57 ± 6, and 63 ± 5 g/h) were similar. There was no difference in time to complete the subsequent performance ride (946 ± 23, 954 ± 35, and 970 ± 26 s for HGI, LGI, and Con trials, respectively). When CHO is ingested during exercise in amounts presently recommended by sports nutrition guidelines, preexercise CHO intake has little effect on metabolism or on subsequent performance during prolonged cycling (~2.5 h).

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SUBJECTS AND METHODS

Subjects and preliminary testing. Six endurance-trained male cyclists (age 22.8 ± 2.3 yr, weight 72.0 ± 4.1 kg, VO2max 68.6 ± 3.8 ml·kg−1·min−1) volunteered to participate in this investigation, which was approved by the Research and Ethics Committee of the Faculty of Medicine of the University of Cape Town, South Africa. Because tracer amounts of [U-14C]glucose were ingested and blood samples were taken, the risks were carefully explained to the subjects before their written consent was obtained. The total radiation dose received by each subject was ~20 mrem. The radiation dose accepted as safe in South Africa is 500 mrem/yr or 130 mrem/13 wk (3).

Subjects were tested for VO2max on an electronically braked cycle ergometer (Lode, Groningen, The Netherlands) modified with clip-on pedals and racing handlebars. The incremental cycle test to exhaustion and the accompanying gas-collection procedures have been described in detail previously (20). Briefly, each subject started cycling at an exercise intensity of 3.33 W/kg body mass (BM) for 150 s, after which the work rate was increased by 50 W for a further 150 s.
Thereafter, the exercise intensity was increased by 25 W every 150 s up to the point of exhaustion.

The results of the initial maximal test were used to determine the exercise intensity that corresponded to 70% of each subject’s $\dot{V}_{\text{O}2\text{max}}$ for use in the three subsequently described experimental rides. Throughout the maximal test, subjects wore a face mask attached to an Oxycalc Alpha automated gas analyzer (Jaeger, The Netherlands). Before each test, the gas analyzer was calibrated by using a Hans Rudolf 5550 3-liter syringe and a 5% CO$_2$-95% N$_2$ gas mixture. Analyzer outputs were processed by an IBM computer, which calculated minute ventilation, oxygen consumption (V$\dot{O}_2$), and rates of CO$_2$ production (V$\dot{C}_2$O) using conventional equations.

Study design. Each subject undertook three trials in a randomized counterbalanced order, with each trial separated by a period of 7 days. On each occasion, one of the following test meals was consumed 2 h before cycling at 70% $\dot{V}_{\text{O}2\text{max}}$: an HGI CHO-rich meal (HGI trial) of instant mashed potato (GI = 87, where glucose = 100; Ref. 13), an LGI CHO-rich meal (LGI trial) of lightly cooked pasta (GI = 37, Ref. 13), or a control meal (Control trial) of low-energy jelly. The HGI meal provided 2 g CHO/kg BM, and the water content of all meals was standardized so that each provided ~1,100 ml of fluid (Table 1).

Food intake and training were standardized for the 24-h period before each trial. Subjects were provided with guidelines for CHO-rich meals and were requested to record their dietary intake on the day before the first trial. Identical food was consumed before the subsequent trials, with dietary records being continued to check compliance. Additionally, subjects were asked to abstain from alcohol, caffeine, and strenuous exercise for at least 24 h before each trial. On the morning of an experiment, subjects reported to the laboratory in an overnight-fasted state, and their food and training diaries were examined to ensure that all instructions had been followed. Thereafter, a flexible 18-gauge catheter was inserted into a forearm vein and attached to a three-way stopcock for the sampling of blood. The catheter was kept patent throughout the experiment with periodic injection of heparinized saline.

After a fasting blood sample was taken, the subjects were given 15 min to consume their test meal and rested for 2 h. Fifteen minutes before exercise, the subjects consumed 4 ml/kg BM of a 10 g/100 ml [U-14C]glucose solution (Amersham International, Buckinghamshire, UK) with a specific radioactivity of 0.17 µCi/g (6.3 kBq/g). The [U-14C]glucose label was added to the drink so that the rates of ingested glucose oxidation could be calculated. A total of 3.3 ml/kg BM of the labeled drink was ingested every 20 min during the steady-state ride, for a total of 24 ml/kg each trial (2.4 g of CHO/kg BM).

Immediately before the start of exercise, subjects voided, were weighed, and the cycle ergometer was set up to conform with their preferred cycling position. Exactly 2 h postprandially, the subjects started their steady-state ride at ~70% of $\dot{V}_{\text{O}2\text{max}}$ (245 ± 18 W). As part of the 2-h cycle, a warm-up period was allowed; exercise started at 100 W for 5 min, after which the workload was increased by 50 W/min until the final workload was attained. During the trials, the subjects were cooled with an electric fan while the laboratory was maintained at a constant temperature (−20°C) and relative humidity (−55%). On completion of the 2-h steady-state ride, the subjects were given 1 min to rest before they started the performance ride, which consisted of the time to complete 300 kJ. During the timed ride, subjects were kept blind to time; the only feedback given was the completion of each 50 kJ of work. After subjects had completed 275 kJ, they received information about each successive 5 kJ until the end of the ride. No performance results were provided to any subject until the completion of the entire study.

Blood sampling and analysis. A fasting blood sample was collected before ingestion of the experimental meal whereafter blood sampling was undertaken, 30, 60, 90, and 120 min postprandially. During the steady-state ride, blood was sampled at successive 20-min intervals, commencing after 20 min of the start of the ride. Approximately 6 ml of blood were drawn at each sampling, of which 2 ml were placed in a tube containing potassium oxalate and sodium fluoride for the later analysis of plasma glucose concentrations. The remaining 4 ml were placed in a tube containing gel and clot activator and allowed to clot for 15 min at room temperature for the later analyses of serum insulin and free fatty acid (FFA) concentrations. All samples were kept on ice during the duration of the trial before the plasma and serum were separated by centrifugation (2,000 revolutions/min) at 4°C and stored at −18°C until subsequent analyses.

Plasma glucose concentrations were determined by the glucose oxidase method (Glucose Analyzer 2, Beckman Instruments, Fullerton, CA). Serum insulin concentrations were determined by the use of a commercially available radioimmunoassay kit (Count-A-Coat Insulin, Diagnostic Products). Serum total FFA concentrations were determined by an enzymatic colorimetric assay (Half-micro test, Boehringer Mannheim, Germany).

$\dot{V}_{\text{O}2}$, $\dot{V}_{\text{CO}_2}$, and $^{14}$CO$_2$ measurements. Immediately after each blood sampling during the steady-state ride, gas exchange ($\dot{V}_{\text{O}2}, \dot{V}_{\text{CO}_2}$) was measured for 5 min. In addition, CO$_2$ was trapped by passing a sample of expired air, collected in an ambulatory bag, through a solution containing 1 ml of 1 N hyamine hydroxide in methanol (United Technologies, Parkard, IL), 1 ml of 96% ethanol (SAARCHEM, Krugersdorp, South Africa), and 2–3 drops of phenolphtalein (SAARCHEM). The expired air was bubbled through the trapping mixture until the solution became clear, at which point exactly 1 mmol of CO$_2$ had been absorbed (30). Liquid-scintillation cocktail (Ready Gel, Beckman Instruments) was added, and $^{14}$CO$_2$ radioactivity (in dpm) was counted in an Insorb 460C automatic liquid-scintillation counter (United Technologies).

Calculation of total and ingested drink CHO oxidation. Instantaneous rates of CHO oxidation during exercise were

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These meals were designed for a 70-kg subject. HGI, high glycemic index; LGI, low glycemic index; CHO, carbohydrate.
Total CHO oxidation during the 120 min of steady-state exercise was estimated from the area under the CHO oxidation vs. time curve for each subject. The rates of ingested CHO oxidation were calculated from the following equation
\[
\text{Glucose}_{\text{ox}} = \frac{[^{14}\text{CO}_2 \times 6] (\text{SA}_{\text{CHO}}/\text{CHO}_{\text{d}}) \times 180}{\text{VCO}_2 \times 1.35}
\]
where glucose_{ox} is the amount of ingested CHO oxidized, in g/min; $^{14}\text{CO}_2 \times 6$ is the $^{14}\text{CO}_2$ dpm/mmol value multiplied by 6 (as there are 6 carbon atoms per molecule of $^{14}$C glucose tracer added to the ingested solution); SA_{CHO} is the specific activity of the ingested solution, in dpm/ml; CHO_d is the CHO content of the drink, in g/l; 180 is the molecular mass of glucose; VCO_2 is the volume of expired CO_2, in l/min; and 1.35 is the number of grams of glucose oxidized to produce 1 liter of CO_2.

During all three trials, subjective ratings of perceived exertion (RPE) were obtained by using the modified Borg scale (2). At the end of the study, subjects were asked by questionnaire which of the preexercise meals provided their best performance and which they would choose to consume before a competition.

Statistical analyses. Data from the three trials were compared by using a two-factor (diet and time) ANOVA with repeated measures. Simple main-effects analyses and Schef-fe’s post hoc tests were undertaken when ANOVA revealed a significant interaction. CHO oxidation over the 2 h of steady-state exercise and time trial performances were compared by using one-way ANOVA with Schef-fe’s post hoc tests. Significance was accepted when $P < 0.05$. All data are reported as means ± SE. Statgraphics (STSC, version 6.0, 1992) was used for all statistical analyses.

RESULTS

Records kept by each subject during the 24 h before each trial indicated compliance with the standardized preparation protocol; reported CHO intakes on the day before the three trials were 479 ± 51, 465 ± 62, and 460 ± 52 g for the HGI, LGI, and Con trials, respectively (not significant), and all subjects refrained from exercise during that day.

Figure 1 shows plasma glucose, serum insulin, and serum FFA concentrations for the 2-h period following ingestion of each test meal and for the subsequent 120 min of steady-state exercise. There was a significant interaction of diet and time for all parameters ($P < 0.05$). Thirty minutes after ingestion of the HGI meal, plasma glucose concentrations were significantly increased above fasting values (Fig. 1A). At this time point, plasma glucose concentrations were greater in both HGI and LGI trials (7.9 ± 0.6 and 6.6 ± 0.5 mmol/l) than in the Con trial (4.4 ± 0.3 mmol/l). Plasma glucose concentrations returned to baseline 60 min after each of the CHO meals but did not fall below fasting values in any of the trials. Plasma glucose concentrations rose slightly with the ingestion of the CHO drink (starting 15 min before the start of exercise) and at the onset of exercise, and remained at euglycemic levels (4.5–6.0 mmol/l) throughout the steady-state ride in all trials. Plasma glucose concentrations during exercise did not differ among trials (Fig. 1A).

The rise in serum insulin after the HGI meal was significantly greater and persisted for longer than for the LGI meal (Fig. 1B). Serum insulin concentrations at 30 min were higher in the HGI trial than in the LGI trial (74.1 ± 10.1 vs. 43.9 ± 8.9 uU/ml) and remained
Serum insulin concentrations remained at fasting values (≤10 uU/ml) in the Con trial until 90 min; however, at 120 min, there was an increase in insulin concentration in response to the ingestion of the glucose drink 15 min before the start of exercise. In the LGI trial, serum insulin concentration peaked at 30 min after the meal and then declined thereafter, with the feeding of the bolus of the glucose drink causing a small rise. During the bout of steady-state exercise, despite the intake of significant amounts of CHO, serum insulin fell to fasting concentrations in all trials. Insulin concentrations in the HGI trial were still elevated above those in the Con trial at 20 min of exercise; thereafter, there were no differences in the serum insulin concentrations during exercise among any of the trials.

The intake of CHO from both the HGI and LGI meals caused a suppression of serum FFA concentrations to <0.1 mmol/l, which persisted until the start of the exercise bout (Fig. 1C). During the Con trial, FFA concentrations were maintained at fasting levels throughout the preexercise phase. However, intake of CHO at the onset of exercise caused a small drop in FFA concentration after 20 min of exercise. Nevertheless, at this time point, FFA concentrations in the Con trial were significantly greater than in the HGI trial. Thereafter during exercise, despite the continued intake of CHO, there was a gradual rise in serum FFA in all trials. After 120 min of exercise in the HGI and LGI trial, FFA concentrations were significantly greater than at the beginning of exercise, and in all trials FFA concentrations had returned to fasting values (≤0.25 mmol/l) by this time. From 20 min of exercise onward, there were no differences in FFA concentrations among the three trials.

Metabolic data from 120 min of steady-state exercise are presented in Fig. 2. There was no significant interaction of diet and time for RER (Fig. 2A), total CHO oxidation (Fig. 2B), and oxidation of the ingested glucose drink (Fig. 2C). The decline in RER over the 120 min of steady-state exercise was not significant. Oxidation of CHO from the glucose drink increased throughout exercise from ~0.3 g/min after 20 min to ~0.8 g/min at 120 min across all trials. After 20 min, oxidation of the ingested CHO drink was significantly lower in the LGI trial than in Con; however, there were no differences at any other time points. Overall, the drink provided ~16% of total CHO oxidation for the 120 min of exercise, and this contribution was similar for all trials (Fig. 3). Total CHO oxidation was ~380 g during the 120 min of steady-state exercise and did not differ among trials.

Subjects' RPE rose steadily throughout the steady-state exercise and did not differ among trials. The fluid deficits accumulated during exercise (estimated from changes in BM) were 1.2 ± 0.4, 1.3 ± 0.2, and 1.2 ± 0.1 kg for HGI, LGI, and Con trials, respectively. Performance during the time trial undertaken at the end of the 120 min of steady-state exercise did not differ among trials. Time to complete 300 kJ was 947 ± 23, 953 ± 36, and 970 ± 26 s, respectively, for HGI, LGI, and Con trials.

Although subjects were kept blind to their time trial performances until completion of the study, all were able to correctly identify the trial in which they performed best (HGI, n = 2; LGI, n = 3; Con, n = 1). When asked to choose the meal they would prefer to consume before an important competition, all subjects nomi-
cause widespread warnings to avoid CHO intake fed 30 min before exercise, and publicity of this study caused widespread warnings to avoid CHO intake during the hour before endurance exercise. These fears have persisted despite evidence from at least a dozen subsequent studies that CHO intake during the hour before exercise enhances, or at least fails to affect, work capacity and performance of prolonged moderate-intensity exercise (for reviews see Refs. 8, 18). Furthermore, the intake of substantial amounts (~200 g) of CHO, which offset any increase in exercise CHO oxidation, enhances work capacity and performance (27, 31, 35).

The recent application of the GI to sports nutrition (33) has revived the prejudice about metabolic perturbations associated with preexercise CHO intake. Thomas and co-workers (33) reported enhanced work capacity when subjects consumed 1 g of CHO/kg BM from an LGI food (lentils), 1 h before cycling at 67% of VO_{2max}, compared with an equal amount of CHO eaten as an HGI food (potatoes). This benefit was attributed to lower glycemic and insulimemic responses to the LGI trial compared with the HGI meal, maintaining blood glucose concentrations during exercise, increasing FFA concentrations, and reducing exercise RER values.

Although this study (33) has led to widespread advice that endurance athletes should choose preexercise meals based on LGI CHO-rich foods and drinks (4), other investigations have failed to find that metabolic alterations translate into performance effects. A second study conducted by the same group (34) utilized the same prefeeding and exercise protocol; on this occasion, the test meals consisted of an LGI and an HGI powdered food, and an LGI and an HGI breakfast cereal. They reported a correlation between the meal GI and the subsequent depression of blood glucose and FFA concentrations during exercise; LGI meals were associated with higher glucose and FFA concentrations after 90 min than the HGI meals. Thus LGI meals appeared to provide a sustained source of CHO throughout the exercise bout and later recovery (34). However, there were no differences in exercise time to exhaustion among trials, and no correlation between exercise time and the GI of the meal (34). It should be noted that the measurement of performance used in both Thomas studies (33, 34) (cycling time to exhaustion at a fixed submaximal work rate) has a high (~25%) coefficient of variation (25), which increases the possibility of errors.

Febbraio and Stewart (11) found no differences in the performance of a time trial conducted after 2 h of cycling at 70% VO_{2max} when preexercise meals con-

**DISCUSSION**

The major finding of this investigation was that when large amounts (~170 g) of CHO were ingested during prolonged (~2.5 h) cycling, there were minimal differences in the metabolic and performance responses to the choice of preevent meal. Preexercise meals and CHO intake during exercise were chosen to balance current guidelines for optimal sports nutrition practice with strategies that are realistic for competitive cycling. Specifically, subjects ate a meal 2 h before the exercise bout, which in the case of the CHO trials provided 2 g of CHO/kg BM. Just before exercise, a bolus of fluid was ingested to promote a rapid rate of nutrient delivery from the subsequent feedings (29). CHO was consumed throughout exercise (26) to provide a total intake of ~1 g/min; this is the maximal rate at which ingested CHO is oxidized during prolonged moderate-intensity exercise (19). This fluid and energy intake was achieved by consuming a 10 g/100 ml glucose drink at a rate of ~700 ml/h, a compromise between fluid intake recommendations (1) and rates typically achieved by athletes in competitive situations (28). Subjects tolerated their pre- and during-exercise feeding schedules; there were no reports of gastrointestinal discomfort.

This study was carried out in view of the historical controversy regarding CHO intake before prolonged submaximal exercise and the lack of application of preexercise feeding studies to the practices of competitive athletes. With regard to the former, there has been considerable focus on the metabolic disturbances caused by the rise in insulin concentration that accompanies preexercise CHO intake (12, 14, 17, 24). Even small elevations in plasma insulin suppress lipolysis during subsequent exercise (22); this effect is mostly likely to occur when CHO is consumed 30–60 min before exercise and insulin concentrations are raised at the onset of the bout. However, metabolic alterations have been observed when feedings were given 4 h before exercise, persisting even though glucose and insulin concentrations had normalized by the onset of exercise (9). Increased CHO oxidation during subsequent exercise may lead to a decrease in plasma glucose and/or an accelerated rate of muscle glycogen utilization. Indeed, Foster et al. (12) reported impaired cycle time to exhaustion at 80% of VO_{2max} when 75 g of glucose were fed 30 min before exercise, and publicity of this study caused widespread warnings to avoid CHO intake during the hour before endurance exercise. These fears have persisted despite evidence from at least a dozen subsequent studies that CHO intake during the hour before exercise enhances, or at least fails to affect, work capacity and performance of prolonged moderate-intensity exercise (for reviews see Refs. 8, 18). Furthermore, the intake of substantial amounts (~200 g) of CHO, which offset any increase in exercise CHO oxidation, enhances work capacity and performance (27, 31, 35).

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Although this study (33) has led to widespread advice that endurance athletes should choose preexercise meals based on LGI CHO-rich foods and drinks (4), other investigations have failed to find that metabolic alterations translate into performance effects. A second study conducted by the same group (34) utilized the same prefeeding and exercise protocol; on this occasion, the test meals consisted of an LGI and an HGI powdered food, and an LGI and an HGI breakfast cereal. They reported a correlation between the meal GI and the subsequent depression of blood glucose and FFA concentrations during exercise; LGI meals were associated with higher glucose and FFA concentrations after 90 min than the HGI meals. Thus LGI meals appeared to provide a sustained source of CHO throughout the exercise bout and later recovery (34). However, there were no differences in exercise time to exhaustion among trials, and no correlation between exercise time and the GI of the meal (34). It should be noted that the measurement of performance used in both Thomas studies (33, 34) (cycling time to exhaustion at a fixed submaximal work rate) has a high (~25%) coefficient of variation (25), which increases the possibility of errors.

Febbraio and Stewart (11) found no differences in the performance of a time trial conducted after 2 h of cycling at 70% VO_{2max} when preexercise meals con-

**Fig. 3.** Total and ingested CHO oxidation during 2 h of steady-state exercise calculated from area under oxidation curves. Values are means ± SE for 6 subjects. Differences were not significant.
sisted of either an LGI CHO-rich food (lentils), HGI
CHO-rich (potatoes), or a placebo (low-energy jelly). The meals were eaten 45 min before exercise and, in the
case of the CHO meals, provided an intake of 1 g of
CHO/kg BM. One point of difference in this study lies in
the definition and measurement of “performance.” The
advantage of the exercise protocol employed by Feb-
braio and Stewart is that it provides a more sports-
specific and reliable measurement of performance (co-
efficient of variation = 4%) (23), preceded by a period of
steady-state exercise during which comparison of the
metabolic responses to treatments can be made. Data
from that study showed no differences in total CHO
oxidation between the two CHO treatments and similar
muscle glycogen utilization in all trials (11). The find-
ings of that study are consistent with the view that
glycemic differences at the onset of exercise are short
lived and unimportant for the performance of most
athletes.

Regardless of any effects of preexercise feedings on
subsequent metabolism, the most effective and com-
mon strategy used by endurance athletes to promote
CHO availability during exercise is to ingest CHO-rich
drinks or foods during the event. CHO ingestion during
exercise is important for endurance performance be-
cause it maintains euglycemia and high rates of CHO
oxidation when endogenous CHO stores have become
limited (6). This study has examined the effect of
various preexercise CHO feedings and CHO intake
during exercise on metabolism and subsequent per-
formance. In agreement with other studies, we found that
the ingestion of an HGI CHO-rich meal produced a
greater glycemic and insulnemic response compared
with an LGI CHO-rich meal (11, 32–34). However, the
rise in insulin concentration after both CHO-rich meals
caulsed a suppression of FFA concentrations. Insulin
increases CHO oxidation (11) and suppresses lipolysis
(22), even at very low concentrations; this appears to be
an absolute rather than a dose-dependent effect.

Nevertheless, CHO feedings throughout exercise
minimized any potential differences in either circulat-
ing blood metabolites or substrate oxidation during the
bout. Blood glucose concentrations were maintained
throughout exercise in all trials; there was no transient
decine at the beginning of the bout as is typically seen
with the preexercise intake of glucose (5, 10, 12, 16,
17, 24) or medium-GI and HGI CHO-rich foods (21, 22,
32, 33). High rates of CHO oxidation were sustained
throughout the exercise bout; there was no difference at
time point among trials or over 2 h of exercise. The
tracer-determined rates of oxidation of the ingested
sugar were similar to those reported in other studies
that have used a preexercise bolus feeding and serial
feedings throughout exercise (for review, see Ref. 19).
The LGI meal may have caused slower gastric empty-
ing of the ingested drink. After 20 min of exercise, the
rate of oxidation of the ingested glucose was lower in
the LGI trial compared with the Con trial. However,
this difference was short lived, and there were no dif-
fences among trials in the total oxidation of in-
gested glucose drink during 2 h of steady-state exercise.
Irrespective of the choice of the preexercise meal, the
ingested drink contributed ~60 g, or ~16%, of the total
CHO oxidized. Given similar patterns of substrate
utilization and availability among the three trials, it
was not surprising to find similar performances during
the timed rides that followed the steady-state exercise.

Wright et al. (35) examined the interaction of CHO
intake before and during exercise. They found that,
compared with no CHO intake at all, cycling time to
exhaustion and total work output at 70% of VO_{2max}
were improved by the ingestion of 5 g of CHO/kg BM 3 h
before exercise or by intake of 2.6 g of CHO/kg BM in
serial feedings during the trial. Enhancement of the
performance measures was ~18 and 33% (P < 0.05) for
the preexercise CHO and during exercise CHO intake,
respectively. When undertaken together, the two strat-
egies improved performance by ~45%. Whereas this
suggests that the combination of CHO-intake strate-
gies was superior to either of the feeding strategies
alone, performances during the combined trial were not
significantly different to the preexercise CHO trial or
the during-exercise CHO trial (35). Similarly, in the
present investigation, whereas there was no significant
difference in ride time among trials, five of the six
subjects achieved their best performance with a combi-
nation of CHO before exercise (HGI or LGI trial) and
glucose intake during exercise, compared with the Con
trial (CHO intake during exercise alone).

Finally, although subjects were able to correctly
identify the trial in which they performed best, all
reported that for an important competition they would
choose to eat the preexercise meal that was most
familiar. We conclude that the ingestion of CHO during
prolonged moderate-intensity cycling according to cur-
rent sports nutrition guidelines minimizes any differ-
ences in the metabolic and performance responses
arising from the choice of preexercise meal. Contrary to
some advice that LGI CHO-rich foods are the preferred
preexercise choice (4), endurance athletes are guided
that when significant amounts of CHO are consumed
during exercise they may choose their preexercise meal
strategies in accordance with their personal prefer-
ences and previous experience.

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