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Section: Original Research

Article Title: The Ingestion of 39 or 64·g·h^{-1} of Carbohydrate is Equally Effective at Improving Endurance Exercise Performance in Cyclists

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Running Head: Carbohydrate and endurance performance: how much is enough?

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The ingestion of 39 or 64 g·h^{-1} of carbohydrate is equally effective at improving endurance exercise performance in cyclists.

Original Investigation

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ABSTRACT

In an investigator-blind, randomised cross-over design, male cyclists (mean±SD) age 34.0 (± 10.2) years, body mass 74.6 (±7.9) kg, stature 178.3 (±8.0) cm, peak power output (PPO) 393 (±36) W, and VO_{2max} 62 (±9) ml·kg^{-1}·min^{-1} training for >6h/wk for >3y (n=20) completed four experimental trials. Each trial consisted of a 2h constant load ride at 95% of lactate threshold (185 ± 25W) then a work-matched time trial task (~30min at 70% of PPO). Three commercially available carbohydrate (CHO) beverages, plus a control (water), were administered during the 2h ride providing 0, 20, 39 or 64g·h^{-1} of CHO at a fluid intake rate of 1L·h^{-1}. Performance was assessed by time to complete the time trial task, mean power output sustained, and pacing strategy used. Mean task completion time (min:sec ± SD) for 39g·h^{-1} (34:19.5 ± 03:07.1, p=0.006) and 64g·h^{-1} (34:11.3 ± 03:08.5 p=0.004) of CHO were significantly faster than control (37:01.9 ± 05:35.0). The mean percentage improvement from control was -6.1% (95% CI: -11.3 to -1.0) and -6.5% (95% CI: -11.7 to -1.4) in the 39 and 64g·h^{-1} trials respectively. The 20g·h^{-1} (35:17.6 ± 04:16.3) treatment did not reach statistical significance compared to control (p = 0.126) despite a mean improvement of -3.7% (95% CI -8.8 to 1.5%). No further differences between CHO trials were reported. No interaction between CHO dose and pacing strategy occurred. 39 and 64g·h^{-1} of CHO were similarly effective at improving endurance cycling performance compared to a 0g·h^{-1} control in our trained cyclists.

KEY WORDS: Nutrition, metabolism, Time trial

INTRODUCTION

Carbohydrate (CHO) intake during exercise has consistently been shown to improve exercise performance (Smith et al., 2013; Smith et al., 2010) and extend exercise capacity (Galloway & Maughan, 2000; Watson, Shirreffs, & Maughan, 2012). CHO is thought to act in many ways to enhance performance: sparing of muscle glycogen (Bjorkman, Sahlin, Hagenfeldt, & Wahren, 1984; Stellingwerff et al., 2007); enhancing and maintaining elevated CHO oxidation rate; maintenance of blood glucose concentration (Coyle, Coggan, Hemmert, & Ivy, 1986); elevated exogenous CHO oxidation rate (Galloway, Wootton, Murphy, & Maughan, 2001); and central and peripheral neural up-regulation (Carter, Jeukendrup, & Jones, 2004; Chambers, Bridge, & Jones, 2009; Nikolopoulos, Arkinstall, & Hawley, 2004). As a result, CHO feeding strategies are now widely employed in the exercise setting as a means to support athletic performance.

Although the provision of CHO has been shown to improve exercise performance/capacity, the optimal dose of CHO required to maximise athletic performance remains a topic of debate. Currently, guidelines from the ACSM state an optimal dose of CHO during exercise to be within the range of 30 - 60g.h^{-1}. However, significant improvements in performance and exercise capacity have been reported with ingestion rates as low as 22g.h^{-1} (Galloway & Maughan, 2000; Maughan, Bethell, & Leiper, 1996) and as high as >100 g.h^{-1} (Currell & Jeukendrup, 2008) highlighting a beneficial impact of CHO ingestion over a much broader range of feeding rates, when compared with water or placebo solutions. Smith et al (2010) indicated that 15, 30 and 60g.h^{-1} were all 'very likely' to improve power output sustained (7.4, 8.3 and 10.7% respectively) during a 20km TT when compared to a 0g.h^{-1} placebo, with 60g.h^{-1} providing the largest effect. Furthermore, 30g.h^{-1} was 'very unlikely' to further improve performance over 15g.h^{-1} whilst 60g.h^{-1} was 'likely' to improve performance over the 30g·h^{-1} with a mean percentage improvement of only 2.3%.

However, following post hoc power calculations, the authors indicated that a sample size of 15 to 22 was required to confidently conclude there were no differences in performances across the three doses. In contrast, Watson et al (2012) reported no further improvements in time to exhaustion when feeding a 6% (~47g·h^{-1}) mixed CHO solution when compared to a 4% (~27g.h^{-1}) mixed solution, though a small increase of 20 g·h^{-1} may have missed any potential increase. Nevertheless, the absence of an additional improvement with the higher CHO dose is surprising considering the improvements in performance reported with higher ingestion rates (Smith et al., 2010). As such, it seems a range of CHO feeding doses increases performance over a 0g·h^{-1} condition. However, any additional increases in CHO provision above feeding rates of ~30g·h^{-1} do not appear to have a clear significant improvement on performance.

To provide clarity to the optimal dose of CHO for performance additional studies with greater sample sizes have followed up these initial reports. In a recent study Smith et al (2013) expanded on these data and examined fifty five participants spread across four sites. The participants consumed CHO during a 2h submaximal ride followed by a 20km TT task. Each participant completed 4 trials, one placebo and three CHO treatments, between 10 and 120g·h^{-1} (10g·h^{-1} increments) which consisted of a 1:1:1 ratio of glucose, fructose and maltodextrin. Following some statistical modelling of their data the authors reported an optimal dose of 78g·h^{-1} for performances during the TT. However, they reported only a small 1.7% improvement in performance from 30 to 80g·h^{-1}, and a rather trivial 0.7% improvement in performance from 40 to 80g·h^{-1}. In addition, the linear regression model used for the determination of the optimal feeding strategy utilised was not significant. Taken together, these studies indicate that the largest gains in performance occur between 0 and 40g·h^{-1} of

CHO ingestion with only relatively small increases in performance with ingestion rates up to 80 g·h^{-1}.

These data, coupled with those of Smith et al (2010) and Watson et al (2012), indicate a divide between the optimal feeding rates and compositions reported by investigators and the subsequent measurable and meaningful improvement in performance obtained from increasing amounts of CHO, particularly in the 30 to 60g·h^{-1} range. Similarly, the range of responses reported across the feeding rates provided in these studies considered this individual variability. Accordingly, the aim of the current study was to determine the dose response relationship between CHO feeding and exercise performance in the 0 to 64g·h^{-1} range in 20 male cyclists. We hypothesize that performance gains compared to a 0g·h^{-1} will be smaller with increasing doses of CHO administered.

METHODOLOGY

Twenty trained male cyclists were recruited from regional cycling and triathlon clubs. The mean (± SD) characteristics of the participants were: age 34.0 (± 10.2) years, body mass 74.6 (± 7.9) kg, stature 178.3 (± 8.0) cm, peak power output (PPO) 393 (± 36) W, and VO_{2max} 62 (± 9) ml·kg^{-1}·min^{-1}. Participants were required to have been training for >6 h / wk for >3 y. Each individual had the procedures and associated risks explained prior to providing written informed consent to participate in the study, which was approved by the local research ethics committee in accordance with the Declaration of Helsinki.

Design

In an investigator blind, placebo controlled, randomised cross-over study design participants visited the laboratory 6 times (2 preliminary and 4 intervention) over a six week period. They completed one visit per week commencing each trial on the same day at the same time of day on each visit. The laboratory was maintained at a constant 19±1℃ for all

visits. Following pre-screening, participants completed a preliminary assessment where lactate threshold, VO_{2max}, and, peak power output were determined. Following a 20min break participants then completed the first familiarisation of the performance task to be used in subsequent visits. On the second visit participants completed a full familiarisation trial. The familiarisation trial and four subsequent intervention trials involved a 120 min steady state submaximal cycle at 95% lactate threshold (185 ± 25W, 59 ± 7% VO_{2max}) followed by a time trial performance task, whereupon the participants were instructed to be complete their set work target as quickly as possible. The steady state intensity was set at 95% lactate threshold to ensure a similar metabolic demand of the exercise for all participants. Water was ingested for the familiarisation trial and consumed at a rate of 1 L·h^{-1}. Thereafter, on the intervention trials participants consumed in a random order either: a control (water) 0%, 2%, 3.9% or 6.4% CHO solutions, in counter balanced randomised order, at a fluid ingestion rate of 1L·h^{-1}, thus providing carbohydrate at 0, 20, 39 or 64g·h^{-1}. Performance was determined as the time to complete a work matched simulated time trial task designed to last ~30min. Pacing strategy was assessed from taking time splits and average power output sustained for each 10% of work competed during the performance task.

Preliminary testing

On week 1 of 6, following a 10h overnight fast, participants performed a two section incremental cycle test (Lode Excalibur Sport, Netherlands) to determine maximal oxygen uptake (VO_{2max}, lactate threshold, and peak power output. Section 1 commenced at 120W and each stage increased 30W every 3 min. The wattage continued to increase until the blood lactate concentration increased more than 2mmol·L^{-1} from the previous stage. The lactate threshold was defined as an increase of >1mmol·L^{-1} between stages (Aunola & Rusko, 1984). In the last 30 s of each stage, heart rate (Polar Electro, Finland) was recorded and a capillary

blood sample (fingertip) was obtained for blood lactate concentration analysis by micro-assay (LactatePro LT-1710, ArkRay Inc., Kyoto, Japan). The reliability and validity of this device has been previously determined (Pyne, Boston, Martin, & Logan, 2000). This initial stage was followed by a 10 min recovery period. Individual lactate responses were examined independently by two researchers to ensure validity and consistency of the analysis. The mean ± SD lactate concentration at LT was 2.1 ± 0.4 mmol·L corresponding to an intensity of 52 ± 6% of PPO for LT which is typical of other studies utilising a similar protocol (Neal et al., 2013).

Participants commenced section 2, starting at an intensity of the penultimate stage of section 1, with each stage lasting 1 min and increased by 30 W until volitional exhaustion. The end time and power output of the stage was used to calculate peak power output (PPO) using the following equation (Kuipers, Verstappen, Keizer, Geurten, & Van Kranenburg, 1985):

$$PPO = W_{final} + ([t/60] \cdot PI)$$

Where, W_{final} = the power output of the final completed stage in (watts), t = the time spent in the final uncompleted stage (seconds), 60 = the duration of each stage (seconds) and PI = the increase in power output between each stage (W). Maximal oxygen uptake (VO_{2max}) was also measured during this protocol via an automated online gas analysis machine (Oxycon Pro, Jaeger, Wuerzerberg, Germany). VO_{2max} was determined as the highest average VO_2 captured in a 30sec period.

Familiarisation and Experimental trials

Participants were asked to record their dietary intake for 2 days prior to the full familiarisation, and were asked to replicate their diaries for all subsequent visits. Additionally, participants were asked to refrain from intense exercise for 48h, and to rest

completely 24h before any laboratory visit. On arrival to the laboratory participants emptied bladder and bowel prior to nude body mass measurements. Individuals then changed into cycling attire which was kept consistent throughout all trials to reduce thermoregulatory variability. Participants then completed a 2h submaximal ride at 95% LT (185 ± 25 W, cadence 80-95 rpm) during which one of four beverages were consumed: 0% water (familiarisation and control); 2.0%; 3.9%; or 6.4% glucose (single carbohydrate, glucose monomers and polymers) based commercially available CHO beverage. All beverages were maintained at 10°C and were consumed at a rate of 1L·h^{-1} providing 0, 20, 39 and 64g·h^{-1} of CHO respectively. The 20g.h^{-1} solution contained 37mg of sodium per 100mL and the 39 and 64g·h^{-1} solutions both contained 50mg per 100mL. Such a small difference in sodium content is unlikely to have had any effect on the subsequent exercise performance. Each beverage was provided with an initial bolus ingestion of 240 mL two minutes prior to the start of exercise. Subsequently, 220mL was consumed every 15 min with the final drink provided at 120min of exercise. Following the 2h ride, a 5min recovery period allowed a toilet break and for the equipment to be set up for the performance task. The performance task was a work target simulated time trial specific to the individual (531 ± 48KJ). A linear factor, 70% W_{max} (275.4 ± 24.8W) divided by preferred cadence (rpm^2), was entered into the cycle ergometer. The formula used to determine the work target value was:

$$\text{Work target} = (0.7 \cdot \text{PPO}) \cdot 1800$$

The time trial protocol employed has previously been validated and has been shown to be highly reliable (A. Jeukendrup, Saris, Brouns, & Kester, 1996). Participants did not receive any verbal encouragement throughout the time trial task and the task was completed in silence.

Data Presentation and Statistical Analysis

All data are presented as mean (±SD) unless otherwise stated. Total time to complete the performance task and average power output sustained throughout were compared across all trials. The magnitude of difference from the water control was examined with a one-way ANOVA with Dunnet's post hoc comparisons made. The mean differences between two variables are presented as the mean with associated 95% confidence limits and Cohen's size effects (mean difference; confidence intervals; Cohen's size effects). Cohen's sizes effects can be interpreted as 0.2 = small, 0.6 = moderate, 1.2 = large, 2.0 = very large and 4.0 = extremely large. Performance task time and average power output was compared between treatments using repeated measures regression models. The null hypothesis of no differences between any of the treatments groups was tested using ANOVA with all values compared back to the water control condition. A difference from the control of 3.5% in either time to complete the task or mean power output sustained was considered a large and meaningful difference.

RESULTS

Performance time and mean power output

Mean task completion time (min:sec ± SD) for 39g·h^{-1} (34:19.5 ± 03:07.1, $p<0.01$) and 64g·h^{-1} (34:11.3 ± 03:08.5, $p<0.01$) CHO solutions were significantly faster than control (37:01.9 ± 05:35.0) (Figure 1). Corresponding percentage change from the 0g·h^{-1}condition was similar at 6.1% (95% CI 1 to 11.3%; $p=0.02$) for the 39g·h^{-1} trial, and 7% (95% CI 1 to 12%, $p=0.01$) for the 64g·h^{-1} trial (Figure. 2). The 20g·h^{-1} (35:17.6 ± 04:16.3) treatment did not reach statistical significance compared to control ($p=0.13$) despite a mean improvement of 3.7% (95% CI -1.5 to 8.8%). Furthermore, the 20 g·h^{-1} treatment did not differ significantly from the 39 or 64g·h^{-1} treatments. The Cohen's size effect in comparison to the

control was 0.6 (95% CI -0.1 to 1.4), 1.0 (95% CI 0.2 to 1.7), and 1.0 (95% CI 0.3 to 1.8) for 20, 39 and 64g·h^{-1} treatments respectively indicating moderate and large effects on performance improvement.

In conjunction, there was a significant effect of treatment on mean power output sustained during the time trial between the four experimental trials ($p<0.01$). There were significant increases of 17W (95% CI 5-30; $p<0.01$) and 19W (95% CI 6-31; $p<0.01$) in mean power output sustained throughout the 39g·h^{-1} and 64g·h^{-1} treatments, respectively. Corresponding percentage improvements compared to the 0g·h^{-1} trial were similar at 8% (95% CI 1-15%; $p=0.02$) for the 39g·h^{-1} trial, and 9% (95% CI 2-16%; $p=0.01$) for the 64g·h^{-1} trial. There was no statistical difference reported between the 20g·h^{-1} treatment and the 0g·h^{-1} control ($p=0.12$) despite a 5.7% (95% CI: -1.2 to 12.6) mean increase in power output sustained. The Cohen's size effect compared to the control was 0.7 (-0.1 to 1.4), 1.1 (0.3 to 1.8), and 1.1 (0.4 to 1.9) for 20, 39 and 64g·h^{-1} reflecting moderate and large effects respectfully.

Pacing strategy

The assessment of pacing strategy revealed no interaction between time and treatment ($p=0.80$). This suggests no evidence of any differences in the slopes of the lines between the treatments in the incremental trends of performance time or mean power sustained (Figure 3).

DISCUSSION

This study was designed to determine the optimal dose of CHO to maximise endurance exercise performance. We show that CHO provided at rates of 39 and 64g·h^{-1} were equally effective at improving performance in 20 trained male participants compared to a 0g·h^{-1} water control. The 20g·h^{-1} treatment did not, on average, show evidence of a significant improvement in participants' performance, despite demonstrating a mean

improvement in both performance task time and mean power output of 3.7% over the 0g·h^{-1} treatment. As such, our data demonstrate that a plateau in performance gain occurs when consuming a single source CHO beverage at rates between 39 to 64g·h^{-1} during endurance tasks lasting less than 3hrs.

Previous studies investigating a dose-response relationship between CHO feeding and endurance exercise performance/capacity have reported somewhat conflicting results. Smith et al (2010) provided evidence of a dose-response relationship when feeding glucose in the range of 15 to 60g·h^{-1}. These authors showed that all trials significantly improved performance of 12 cyclists over the placebo condition, with only the 60g·h^{-1} 'likely' to improve performance over the 15g·h^{-1}. However, the authors highlighted that 15-22 participants would be required to make meaningful comparisons between solutions, leaving no clear picture into the optimal dose of CHO. In a follow up investigation, Smith et al (2013) reported that optimal performance gains with CHO ingestion were likely to occur at rates as high as 78g·h^{-1} when consuming multiple forms of CHO. However, the optimal dose for the greatest improvement in performance was unclear in the 40 to 80g·h^{-1} range and interpretation is limited by the choice of study design. In contrast, Watson et al (2012) observed no further improvement in exercise capacity when 46g·h^{-1} was consumed compared to 31g·h^{-1} during prolonged exercise in cool conditions. We add to these data by demonstrating that the vast majority of the performance gains occur when ingesting 39g·h^{-1} with greater amounts of CHO ingestion (64g·h^{-1}) providing negligible additional performance gains. As such, these results support the hypothesis that a ceiling in performance gains exists when consuming CHO above 40g·h^{-1} during exercise < 3 h. However, any mechanistic explanation for the outcome would only be speculative due to the limited measures taken throughout the trial: though increased neural drive through oral sensors in the mouth; better maintenance of blood glucose due to greater exogenous glucose availability; enhanced

maintenance of exogenous glucose oxidation; and endogenous glycogen sparing within the liver; are all potential explanations.

Consuming 20g·h^{-1} of CHO in the present study had a less easily interpretable outcome. When participants consumed 20g·h^{-1} performance did not significantly improve over the water control, while 39 or 64g·h^{-1} of CHO did not significantly differ compared to 20g·h^{-1}. Other investigations have reported a significant improvement in performance and/or exercise capacity with quite modest (~15g·h^{-1}) amounts of CHO when compared to a 0g·h^{-1} condition (Galloway & Maughan, 2000; Karelis et al., 2010; Maughan et al., 1996; Murray, Seifert, Eddy, Paul, & Halaby, 1989). Consuming 20g·h^{-1} in the present study still produced a mean improvement in performance time of 3.7% compared to 0g·h^{-1}, which corresponds to a ~58s reduction in time trial task time. The variance in response is a likely explanation for lack of statistical significance, but it is noteworthy that there is considerable variation in performance responses in all CHO conditions, not just at the 20g·h^{-1}. Additionally, some individuals (n=2) did not respond positively to any of the CHO ingestion trial, with the control condition being the fastest trial completed. No gastrointestinal discomfort was reported by any participant when consuming any of the beverages raising an interesting research question regarding the non-response of some individuals when consuming CHO during exercise. The variability in performances, along with some negative responses to CHO ingestion, highlights the individual nature of CHO feeding as an ergogenic aid.

The range of responses measured in the present study highlights that, for the majority of individuals, there is a ceiling in the performance gains achieved when feeding rates are higher than 40g·h^{-1}. Any additional performance gains reported appear to result in a minimal increase in performance. However, in elite level athletes, there is evidence there is an enhanced ability to utilise CHO and have a subsequent meaningful improvement in

performance (Stellingwerff, 2012). In support of this enhanced intake Prof. Louise Burke (personal communication) has recently presented a case study describing a nutritional intervention which enabled an Olympic walker to ingest as much as 90g·h^{-1} of multiple transportable CHO. Furthermore, there may be further additional improvements in exercise performance with multiple transportable CHO with increasing exercise duration i.e. bouts >3h (Stellingwerff & Cox, 2014). Thus, when providing feeding recommendations, the degree to which an increase in performance translates into a worthwhile change should be considered.

One potential limitation of the current investigation is that participants completed the trial following an overnight fasted to best control and replicate the metabolic state in which they arrive at the laboratory. Overnight fasting is not the current practice for optimal performance for athletes as liver glycogen is reduced following glycogen breakdown in the liver to maintain blood glucose concentration overnight. However, the glycogen storage capacity of the liver is enhanced following endurance training therefore reducing the impact an overnight fast has on liver glycogen content. Casey et al (2000) reported athletes had an overnight liver glycogen content of 386mmol·L^{-1}, which is considerably higher than values reported in healthy untrained individuals (~120 to 210mmol·L^{-1}) (Magnusson, Rothman, Katz, Shulman, & Shulman, 1992; Stadler et al., 2013; Taylor et al., 1996). Therefore, the liver glycogen content of athletes following an overnight fast is unlikely to vastly affect subsequent exercise performance. In studies examining the effect of CHO on performance following a shorter (~3h) fast, where liver glycogen content is unlikely to be compromised, Hulston and Jeukendrup (2009) reported a significant improvement in performance when consuming a CHO beverage compared to water. Additionally, a recent meta-analysis indicated the pre exercise nutritional status of participants (fed or fasted) appears to have no effect on the subsequent exercise performance/capacity achieved (Temesi, Johnson,

Raymond, Burdon, & O'Connor, 2011). As such, the findings of this study are still likely to be applicable to those looking to perform in the fed state.

The current investigation only measured performance responses up to feeding rates of 64g·h^{-1} and we are therefore unable to determine responses to higher feeding rates. The upper feeding rate was based on research showing a maximal absorption rate of ~1g·min^{-1} of a single source CHO solution (A. E. Jeukendrup et al., 1999). Nevertheless, we cannot be certain that CHO feeding rates above 64g·h^{-1} do not significantly alter subsequent performances as others have reported (Currell & Jeukendrup, 2008; Smith et al., 2013). The lack of any further substantial improvement in performance with rates >39g·h^{-1} in the present study, in addition to reports of a negative impact on performance with higher rates of CHO ingestion, suggests that performance is unlikely to improve with higher rates of single source CHO ingestion during exercise < 3h. Future studies should focus on utilising measures and techniques to try and ascertain explanations as to why some feeding rates are more beneficial than others, and which factors contribute to the individual variability in response.

Finally, we decided to use water as a control solution as athletes are likely to be consuming water rather than a colour sweetened matched placebo in their current practice. Some individuals may have preconceived ideas that a flavoured drink alone would have a beneficial effect on performance. The non-significant increase in performance when consuming the 20 g.h^{-1} treatment compared to control may simply be due to a placebo effect, if participants felt they had something, rather than nothing. Similarly, the increases in performance with CHO feeding in light of the water control could be artificially elevated. Nevertheless, if athletes are utilising water as their main hydration strategy then the performance gains are likely to be realistic.

CONCLUSIONS

The 39g·h^{-1} and 64g·h^{-1} CHO solutions were equally effective in improving the cycling performance of 20 trained male cyclists over a 0g·h^{-1} water placebo during an exercise task <3h. For most trained individuals, an optimal feeding rate for maximising the ergogenic effect of CHO for endurance performance is likely to occur at around 40g·h^{-1}. There is a wide range of responses to all rates of CHO ingested highlighting the individual nature of the responses observed in individuals using CHO to aid performance. However, the results of this study highlight that most individuals will respond most positively to CHO ingestion rates around 39 and 64g·h^{-1}.

NOVELTY STATEMENT

The vast majority of performance improvement with CHO ingestion occurred when ingesting 39g·h^{-1}, with any additional CHO intake (64g·h^{-1}) providing a minimal additional performance gain. As such, both 39 and 64g·h^{-1} of carbohydrate, ingested during 2 hours of endurance exercise, are equally effective at improving subsequent TT task performance in comparison to a water control.

PRACTICAL APPLICATION

Cyclists performing tasks lasting between 2-3 hours should consider consuming around 40-60g·h^{-1} of single source carbohydrate and increase their intake within this range depending on individual comfort and experience.

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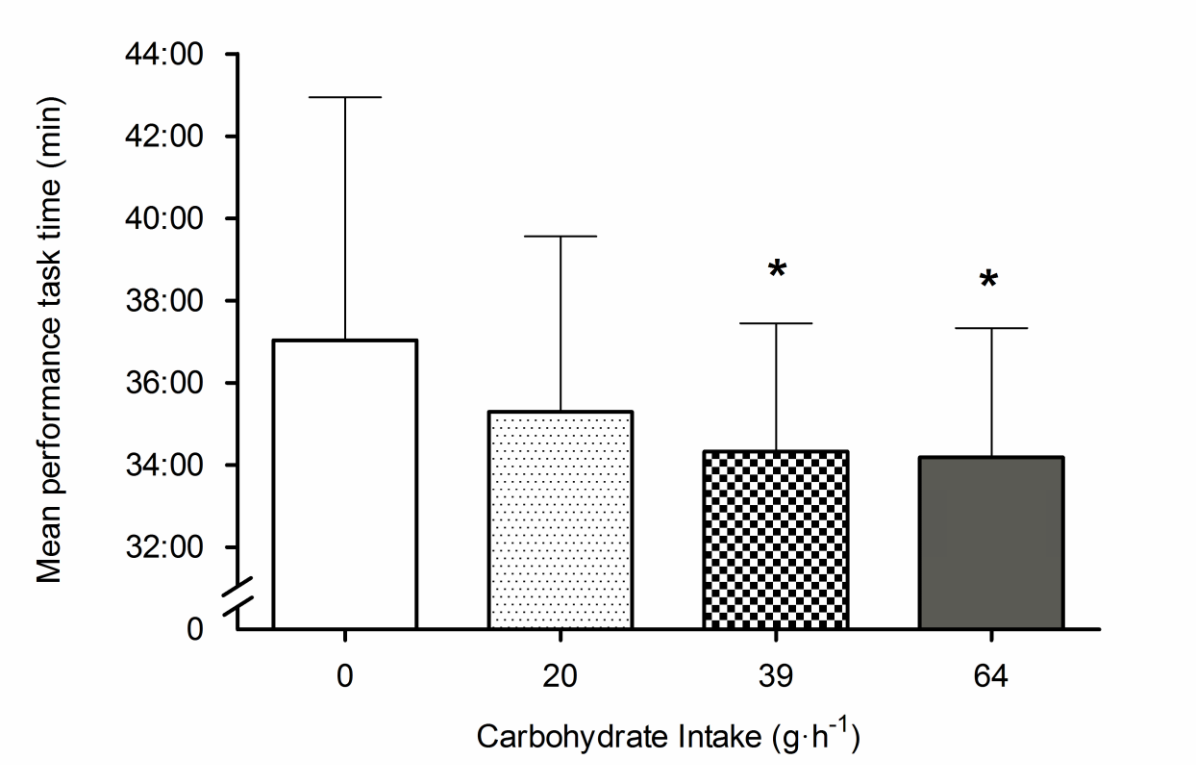


Figure 1: Mean performance task time when 0, 20, 39, and 64g·h^{-1} of carbohydrate were consumed with and arbitrary finish line denoting the fasting mean time. Data presented as mean ± standard deviation. Statistical significance is (*$p < 0.05$)

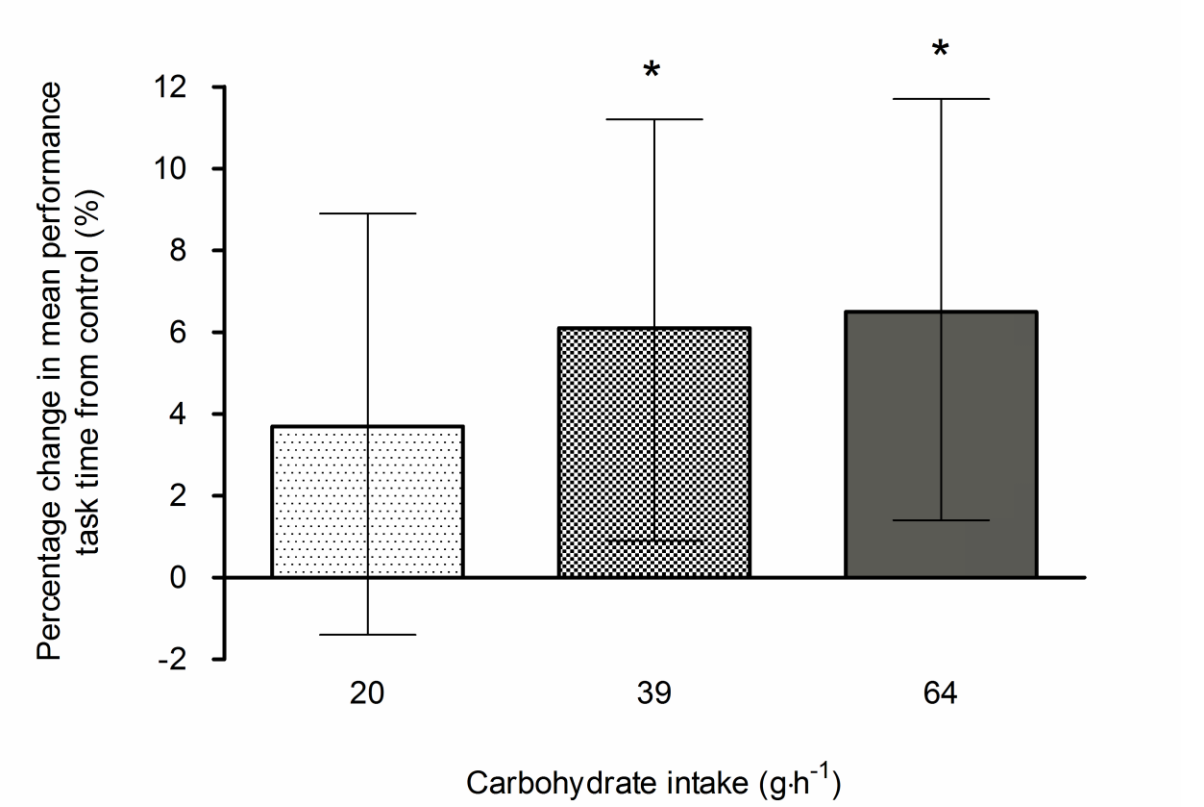
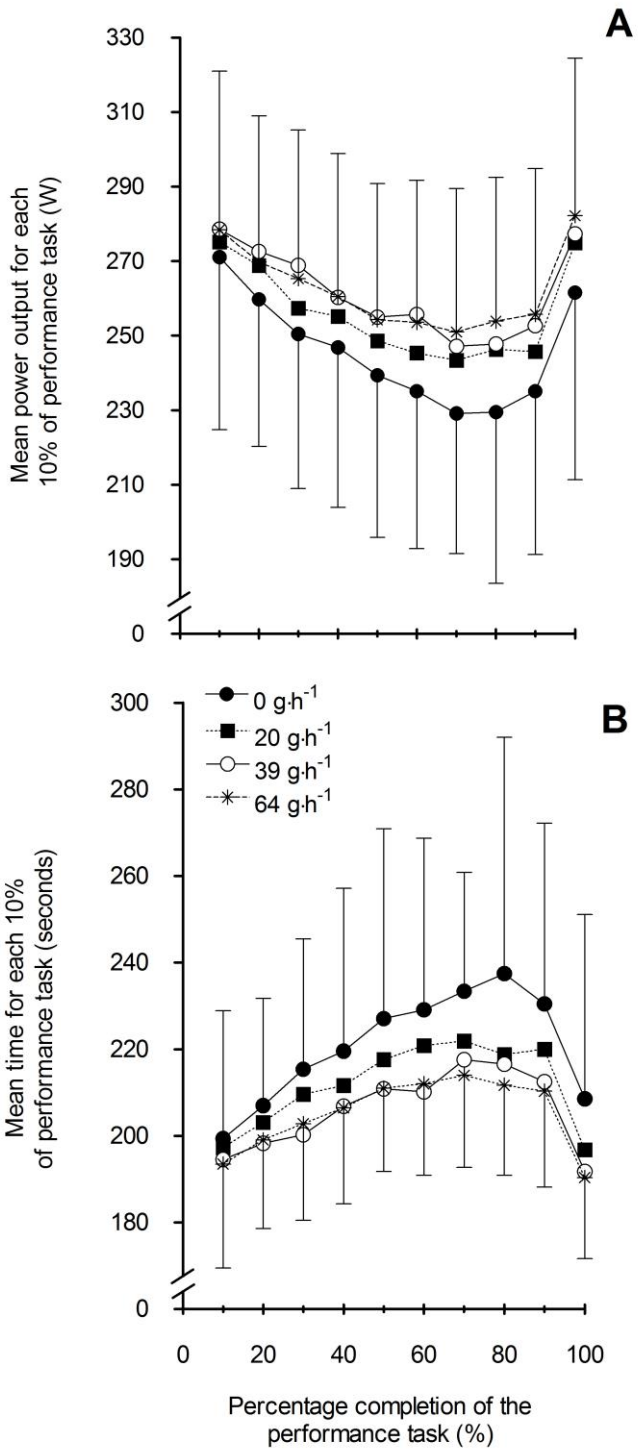


Figure 2. Percentage change in mean performance task time from the 0g·h^{-1} treatment for 20, 39, and 64g·h^{-1} carbohydrate ingestion rates. The percentage change in performance task time was significantly greater in the 39g·h^{-1} and 64g·h^{-1} (*$p < 0.05$). Date presented as mean ± 95% confidence intervals.

"The Ingestion of 39 or 64·g·h^{-1} of Carbohydrate is Equally Effective at Improving Endurance Exercise Performance in Cyclists" by Newell ML et al.
International Journal of Sport Nutrition and Exercise Metabolism



Mean power output (A) and time to complete each 10% of the performance task (B) when 0g·h^{-1}, 20g·h^{-1}, 39g·h^{-1}, and 64g·h^{-1} of carbohydrate was consumed. Data presented as mean and standard of deviation.