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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

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1 The ingestion of 39 or 64 g·h⁻¹ of carbohydrate is equally effective at improving endurance
2 exercise performance in cyclists.

3 Original Investigation

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25 **Abstract and key words**

26 In an investigator-blind, randomised cross-over design, male well-trained cyclists (n=20) completed four
27 experimental trials. Each trial consisted of a 2h constant load ride ($185 \pm 25\text{W}$) followed by a work-matched
28 time trial task (~35min). Three commercially available CHO beverages, plus a control (water), were
29 administered during the 2h ride providing 0, 20, 39 or $64\text{g}\cdot\text{h}^{-1}$ CHO/h at a fluid intake rate of $1\text{L}\cdot\text{h}^{-1}$.
30 Performance was assessed by time to complete the time trial task, mean power output sustained, and pacing
31 strategy used. Mean task completion time (min:sec \pm SD) for $39\text{g}\cdot\text{h}^{-1}$ ($34:19.5 \pm 03:07.1$, $p=0.006$) and
32 $64\text{g}\cdot\text{h}^{-1}$ ($34:11.3 \pm 03:08.5$ $p=0.004$) of CHO were significantly faster than control ($37:01.9 \pm 05:35.0$). The
33 mean percentage improvement from control was -6.1% (95% CI: -11.3 to -1.0) and -6.5% (95% CI: -11.7
34 to -1.4) in the 39 and $64\text{g}\cdot\text{h}^{-1}$ trials respectively. The $20\text{g}\cdot\text{h}^{-1}$ ($35:17.6 \pm 04:16.3$) treatment did not reach
35 statistical significance compared to control ($p = 0.126$) despite a mean improvement of -3.7% (95% CI -8.8
36 to 1.5%). Mean power output differences mirrored the performance time. There was no interaction between
37 CHO dose and pacing strategy. 39 and $64\text{g}\cdot\text{h}^{-1}$ of CHO were similarly effective at improving endurance
38 cycling performance compared to a $0\text{g}\cdot\text{h}^{-1}$ control in our well trained cyclists.

39 **Key words:** Carbohydrate, performance, cycling

40

41 **Introduction**

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

51 Although the provision of CHO has been shown to improve exercise performance/capacity, the optimal
52 dose of CHO required to maximise athletic performance remains a topic of debate. Currently, guidelines
53 from the ACSM state an optimal dose of CHO during exercise to be within the range of 30 - 60g.h⁻¹.
54 However, significant improvements in performance and exercise capacity have been reported with
55 ingestion rates as low as 22g.h⁻¹ (Galloway & Maughan, 2000; Maughan, Bethell, & Leiper, 1996) and as
56 high as >100 g.h⁻¹ (Currell & Jeukendrup, 2008) highlighting a beneficial impact of CHO ingestion over a
57 much broader range of feeding rates, when compared with water or placebo solutions. Smith et al (2010)
58 indicated that 15, 30 and 60g.h⁻¹ were all 'very likely' to improve power output sustained (7.4, 8.3 and
59 10.7% respectively) during a 20km TT when compared to a 0g.h⁻¹ placebo, with 60g.h⁻¹ providing the largest
60 effect. Furthermore, 30g.h⁻¹ was 'very unlikely' to further improve performance over 15g.h⁻¹ whilst 60g.h⁻¹
61 was 'likely' to improve performance over the 30g.h⁻¹ with a mean percentage improvement of only 2.3%.
62 However, following post hoc power calculations, the authors indicated that a sample size of 15 to 22 was
63 required to confidently conclude there were no differences in performances across the three doses. In
64 contrast Watson et al (2012) reported no further improvements in time to exhaustion when feeding a 6%
65 (~47g.h⁻¹) mixed CHO solution when compared to a 4% (~27g.h⁻¹) mixed solution. The absence of an
66 additional improvement with the higher CHO dose is surprising considering the improvements in
67 performance reported with higher ingestion rates (Smith et al., 2010). As such, it seems a range of CHO
68 feeding doses increases performance over a 0g.h⁻¹ condition. However, any additional increases in CHO
69 provision above feeding rates of ~30g.h⁻¹ do not appear to have a clear significant improvement on
70 performance.

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

82 These data, coupled with those of Smith et al (2010) and Watson et al (2012), indicate a divide between the
83 optimal feeding rates and compositions reported by investigators and the subsequent measurable and
84 meaningful improvement in performance obtained from increasing amounts of CHO, particularly in the 30
85 to 60g·h⁻¹ range. Similarly, the range of responses reported across the feeding rates provided in these studies
86 highlights considerable individual variability. Accordingly, the aim of the current study was to determine
87 the dose response relationship between CHO feeding and exercise performance in the 0 to 64g·h⁻¹ range in
88 20 male cyclists. Furthermore, pacing strategies used during a performance task were investigated to
89 provide insight as to where any changes in performance may be the greatest.

90

91 **Methods**

92 Twenty well-trained male cyclists were recruited from regional cycling and triathlon clubs. The mean (\pm
93 SD) characteristics of the participants were: age 34.0 (\pm 10.2) years, body mass 74.6 (\pm 7.9) kg, stature
94 178.3 (\pm 8.0) cm, peak power output (PPO) 393 (\pm 36) W, and VO_{2max} 62 (\pm 9) ml·kg⁻¹·min⁻¹. Participants
95 were required to have been training for >6 h / wk for >3 y. Each individual had the procedures and
96 associated risks explained prior to providing written informed consent to participate in the study, which
97 was approved by the local research ethics committee in accordance with the Declaration of Helsinki.

98 **Design**

99 In an investigator blind, placebo controlled, randomised cross-over study design participants visited the
100 laboratory 6 times (2 preliminary and 4 intervention) over a six week period. They completed one visit per
101 week commencing each trial on the same day at the same time of day on each visit. Following pre-
102 screening, participants completed a preliminary assessment where lactate threshold, VO_{2max} , and peak
103 power output were determined and for the first familiarisation of the performance task to be used in
104 subsequent visits. On the second visit participants completed a full familiarisation trial. The familiarisation
105 trial and four subsequent intervention trials involved a 120 min steady submaximal cycle at 95% lactate
106 threshold ($184 \pm 25W$) followed by a time trial performance task, whereupon the participants were
107 instructed to be complete their set work target as quickly as possible. Water was ingested for the
108 familiarisation trial and consumed at a rate of $1 L \cdot h^{-1}$. Thereafter, on the intervention trials participants
109 consumed in a random order either: a control (water) 0%, 2%, 3.9% or 6.4% CHO solutions, in random
110 order, at a fluid ingestion rate of $1L \cdot h^{-1}$. Performance was determined as the time to complete a work
111 matched simulated time trial task designed to last ~30min. Pacing strategy was assessed from taking time
112 splits and average power output sustained for each 10% of work competed during the performance task.

113 **Preliminary testing**

114 On week 1 of 6, following a 10h overnight fast, participants performed a two section incremental cycle test
115 (Lode Excalibur Sport, Netherlands) to determine maximal oxygen uptake (VO_{2max} , lactate threshold, and
116 peak power output. Section 1 commenced at 120W and each stage increased 30W every 3 min until blood
117 lactate increased more than $2mmol \cdot L$ between stages (lactate threshold defined as the final point before the
118 blood lactate concentration increased distinctly from the baseline concentration (Aunola & Rusko, 1984).
119 In the last 30 s of each stage, heart rate (Polar Electro, Finland) was recorded and a capillary blood sample
120 (fingertip) was obtained for blood lactate concentration analysis by micro-assay (LactatePro LT-1710,
121 ArkRay Inc., Kyoto, Japan). The reliability and validity of this device has been previously determined
122 (Pyne, Boston, Martin, & Logan, 2000). This initial stage was followed by a 10 min recovery period.
123 Individual lactate responses were examined independently by two researchers to ensure validity and
124 consistency of the analysis. The mean \pm SD lactate concentration at LT was $2.1 \pm 0.4 mmol \cdot L$ corresponding
125 to an intensity of $52 \pm 6\%$ of PPO for LT which is typical of other studies utilising a similar protocol (Neal
126 et al., 2013).

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

$$131 \quad \text{PPO} = W_{\text{final}} + ([t/60] \cdot \text{PI})$$

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

137 **Familiarisation and Experimental trials**

138 On arrival to the laboratory participants emptied bladder and bowel prior to nude body mass measurements.
 139 Individuals then changed into cycling attire which was kept consistent throughout all trials to reduce
 140 thermoregulatory variability. Participants then completed a 2h submaximal ride at 95% LT (185 ± 25 W)
 141 during which one of four beverages were consumed: 0% water (familiarisation and control); 2.0%; 3.9%;
 142 or 6.4% glucose (single carbohydrate) based commercially available CHO beverage. All beverages were
 143 maintained at 10°C and were consumed at a rate of 1L·h⁻¹ providing 0, 20, 39 and 64g·h⁻¹ of CHO
 144 respectively. The 20g·h⁻¹ solution contained 37mg of sodium per 100mL and the 39 and 64g·h⁻¹ solutions
 145 both contained 50mg per 100mL. Each beverage was provided with an initial bolus ingestion of 240 mL
 146 two minutes prior to the start of exercise. Subsequently, 220mL was consumed every 15 min with the final
 147 drink provided at 120min of exercise. Following the 2h ride, a 5min recovery period allowed a toilet break
 148 and for the equipment to be set up for the performance task. The performance task was a work target
 149 simulated time trial specific to the individual (531 ± 48 KJ). A linear factor, 70% W_{max} divided by preferred
 150 cadence (rpm²), was entered into the cycle ergometer. The formula used to determine the work target value
 151 was:

$$152 \quad \text{Work target} = (0.7 \cdot \text{PPO}) \cdot 1800$$

153 The time trial protocol employed has previously been validated and has been shown to be highly reliable
 154 (A. Jeukendrup, Saris, Brouns, & Kester, 1996).

155

156 Data Presentation and Statistical analysis

157 All data are presented as mean (\pm SD) unless otherwise stated. Total time to complete the performance task
158 and average power output sustained throughout were compared across all trials. The magnitude of
159 difference from the water control was examined with a one-way ANOVA with Dunnet's post hoc
160 comparisons made. The mean differences between two variables are presented as the mean with associated
161 95% confidence limits and Cohen's size effects (mean difference; confidence intervals; Cohen's size
162 effects). Cohen's sizes effects can be interpreted as 0.2 = small, 0.6 = moderate, 1.2 = large, 2.0 = very
163 large and 4.0 = extremely large. Performance task time and average power output was compared between
164 treatments using repeated measures regression models. The null hypothesis of no differences between any
165 of the treatments groups was tested using ANOVA with all values compared back to the water control
166 condition. A difference from the control of 3.5% in either time to complete the task or mean power output
167 sustained was considered a large and meaningful difference.

168

169 **Results**

170 **Performance time and mean power output**

171 Mean task completion time (min:sec \pm SD) for 39g·h⁻¹ (34:19.5 \pm 03:07.1, $p < 0.01$) and 64g·h⁻¹ (34:11.3 \pm
172 03:08.5, $p < 0.01$) CHO solutions were significantly faster than control (37:01.9 \pm 05:35.0) (Fig 1).
173 Corresponding percentage change from the 0g·h⁻¹ condition was similar at 6.1% (95% CI 1 to 11.3%;
174 $p = 0.02$) for the 39g·h⁻¹ trial, and 7% (95% CI 1 to 12%, $p = 0.01$) for the 64g·h⁻¹ trial (Fig. 2). The 20g·h⁻¹
175 (35:17.6 \pm 04:16.3) treatment did not reach statistical significance compared to control ($p = 0.13$) despite a
176 mean improvement of 3.7% (95% CI -1.5 to 8.8%). The Cohen's size effect in comparison to the control
177 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
178 treatments respectively indicating moderate and large effects on performance improvement.

179 In conjunction, there was a significant effect of treatment on mean power output sustained during the time
180 trial between the four experimental trials ($p < 0.01$). There were significant increases of 17W (95% CI 5-
181 30; $p < 0.01$) and 19W (95% CI 6-31; $p < 0.01$) in mean power output sustained throughout the 39g·h⁻¹ and
182 64g·h⁻¹ treatments, respectively. Corresponding percentage improvements compared to the 0 g·h⁻¹ trial
183 were similar at 8% (95% CI 1-15%; $p = 0.02$) for the 39 g·h⁻¹ trial, and 9% (95% CI 2-16%; $p = 0.01$) for
184 the 64g·h⁻¹ trial. There was no statistical difference reported between the 20g·h⁻¹ treatment and the 0g·h⁻¹
185 control ($p = 0.12$) despite a 5.7% (95% CI: -1.2 to 12.6) mean increase in power output sustained. The
186 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
187 20, 39 and 64g·h⁻¹ reflecting moderate and large effects respectfully.

188

189 **Pacing strategy**

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

193

194 Discussion

195 This study was designed to determine the optimal dose of CHO to maximise endurance exercise
196 performance. We show that CHO provided at rates of 39 and 64g·h⁻¹ were equally effective at improving
197 performance in 20 well trained male participants compared to a 0g·h⁻¹ water control. The 20g·h⁻¹ treatment
198 did not, on average, show evidence of a significant improvement in participants' performance, despite
199 demonstrating a meaningful mean improvement in both performance task time and mean power output over
200 the 0g·h⁻¹ treatment. As such, our data demonstrate that a plateau in performance gain occurs when
201 consuming a single source CHO beverage at rates between 39 to 64g·h⁻¹ during endurance tasks lasting less
202 than 3hrs.

203 Previous studies investigating a dose-response relationship between CHO feeding and endurance exercise
204 performance/capacity have reported somewhat conflicting results. Smith et al (2010) provided evidence of
205 a dose-response relationship when feeding glucose in the range of 15 to 60g·h⁻¹. These authors showed
206 that all trials significantly improved performance of 12 cyclists over the placebo condition, with only the
207 60g·h⁻¹ 'likely' to improve performance over the 15g·h⁻¹. However, the authors highlighted that 15-22
208 participants would be required to make meaningful comparisons between solutions, leaving no clear picture
209 into the optimal dose of CHO. In a follow up investigation, Smith et al (2013) reported that optimal
210 performance gains with CHO ingestion were likely to occur at rates as high as 78g·h⁻¹ when consuming
211 multiple forms of CHO. However, the optimal dose for the greatest improvement in performance was
212 unclear in the 40 to 80g·h⁻¹ range and interpretation is limited by the choice of study design. In contrast,
213 Watson et al (2012) observed no further improvement in exercise capacity when 46g·h⁻¹ was consumed
214 compared to 31g·h⁻¹ during prolonged exercise in cool conditions. We add to these data by demonstrating
215 that the vast majority of the performance gains occur when ingesting 39 g·h⁻¹ with greater amounts of CHO
216 ingestion (64 g·h⁻¹) providing negligible additional performance gains. As such, these results support the
217 hypothesis that a ceiling in performance gains exists when consuming CHO above 40g·h⁻¹ during exercise
218 < 3 h. However, any mechanistic explanation for the outcome would only be speculative due to the limited
219 measures taken throughout the trial: though increased neural drive through oral sensors in the mouth; better
220 maintenance of blood glucose due to greater exogenous glucose availability; enhanced maintenance of
221 exogenous glucose oxidation; and endogenous glycogen sparing; are all potential explanations.

222

223 Consuming 20g·h⁻¹ of CHO in the present study had a less easily interpretable outcome. When participants
224 consumed 20g·h⁻¹ performance did not significantly improve over the water control, while 39 or 64g·h⁻¹ of
225 CHO did not significantly differ compared to 20g·h⁻¹. Other investigations have reported a significant
226 improvement in performance and/or exercise capacity with quite modest (~15g·h⁻¹) amounts of CHO when
227 compared to a 0g·h⁻¹ condition (Galloway & Maughan, 2000; Karelis et al., 2010; Maughan et al., 1996;
228 Murray, Seifert, Eddy, Paul, & Halaby, 1989). Consuming 20g·h⁻¹ in the present study still produced a
229 mean improvement in performance time of 3.7% compared to 0g·h⁻¹, which corresponds to a ~58s reduction
230 in time trial task time. The variance in response is a likely explanation for lack of statistical significance,
231 but it is noteworthy that there is considerable variation in performance responses in all CHO conditions,
232 not just at the 20g·h⁻¹. Additionally, some individuals (n=2) did not respond positively to any of the CHO
233 ingestion trial, with the control condition being the fastest trial completed. The variability in performances,
234 along with some negative responses to CHO ingestion, highlights the individual nature of CHO feeding as
235 an ergogenic aid.

236

237 The range of responses measured in the present study highlights that, for the majority of individuals, there
238 is a ceiling in the performance gains achieved when feeding rates are higher than 40g·h⁻¹. Any additional
239 performance gains reported appear to result in a minimal increase in performance. However, in elite level
240 athletes, there is evidence there is an enhanced ability to utilise CHO and have a subsequent meaningful
241 improvement in performance (Stellingwerff, 2012). In support of this enhanced intake Prof. Louise Burke
242 (personal communication) has recently presented a case study describing a nutritional intervention which
243 enabled an Olympic walker to ingest as much as 90g·h⁻¹ of multiple transportable CHO. Thus, when
244 providing feeding recommendations, the degree to which an increase in performance translates into a
245 worthwhile change should be considered.

246

247 One potential limitation of the current investigation is that participants completed the trial following an
248 overnight fasted to best control and replicate the metabolic state in which they arrive at the laboratory.
249 Overnight fasting is not the current practice for optimal performance for athletes as liver glycogen is
250 reduced following glycogen breakdown in the liver to maintain blood glucose concentrations overnight.
251 However, the glycogen storage capacity of the liver is enhanced following endurance training therefore
252 reducing the impact an overnight fast has on liver glycogen content. Casey et al (2000) reported athletes

253 had an overnight liver glycogen content of $386\text{mmol}\cdot\text{L}^{-1}$, which is considerably higher than values reported
254 in healthy untrained individuals (~ 120 to $210\text{mmol}\cdot\text{L}^{-1}$) (Magnusson, Rothman, Katz, Shulman, &
255 Shulman, 1992; Stadler et al., 2013; Taylor et al., 1996). Therefore, the liver glycogen content of athletes
256 following an overnight fast is unlikely to vastly affect subsequent exercise performance. In studies
257 examining the effect of CHO on performance following a shorter ($\sim 3\text{h}$) fast, where liver glycogen content
258 is unlikely to be compromised, Hulston and Jeukendrup (2009) reported a significant improvement in
259 performance when consuming a CHO beverage compared to water. Additionally, a recent meta-analysis
260 indicated the pre exercise nutritional status of participants (fed or fasted) appears to have no effect on the
261 subsequent exercise performance/capacity achieved (Temesi, Johnson, Raymond, Burdon, & O'Connor,
262 2011). As such, the findings of this study are still likely to be applicable to those looking to perform in the
263 fed state.

264

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

276

277 **Conclusions**

278 The $39\text{g}\cdot\text{h}^{-1}$ and $64\text{g}\cdot\text{h}^{-1}$ CHO solutions were equally effective in improving the cycling performance of 20
279 well trained male cyclists over a $0\text{g}\cdot\text{h}^{-1}$ water placebo following a 2 h submaximal ride. For most well
280 trained individuals, an optimal feeding rate for maximising the ergogenic effect of CHO for endurance
281 performance is likely to occur at around $40\text{g}\cdot\text{h}^{-1}$. There is a wide range of responses to all rates of CHO

282 ingested highlighting the individual nature of the responses observed in individuals using CHO to aid
283 performance. However, the results of this study highlight that most individuals will respond most positively
284 to CHO ingestion rates around 39 and 64g.h⁻¹.

285

286 **Novelty statement**

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

291

292 **Practical application**

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

296

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302

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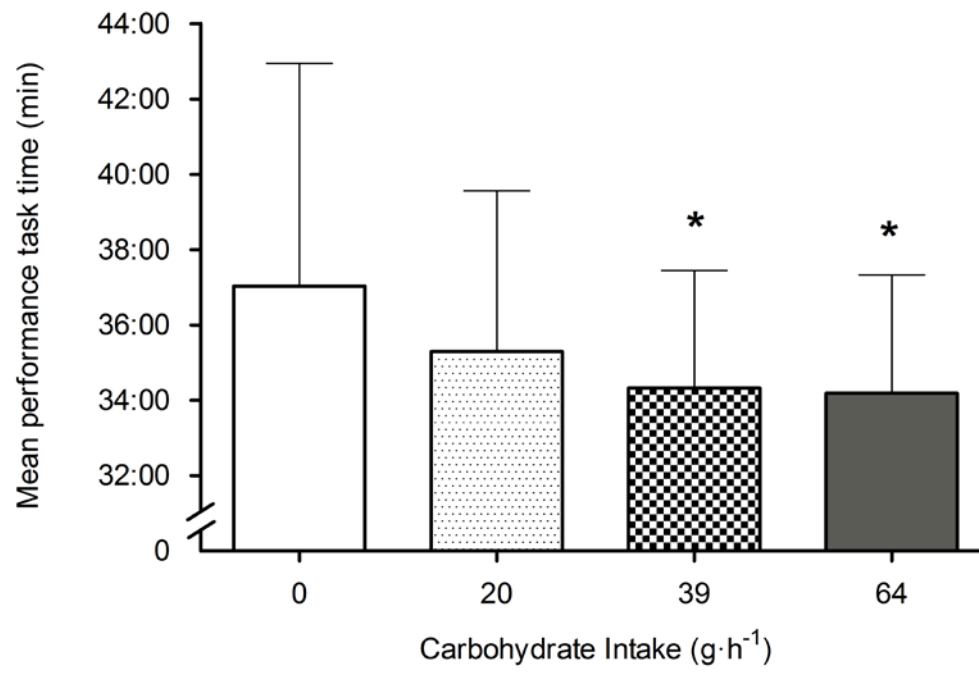
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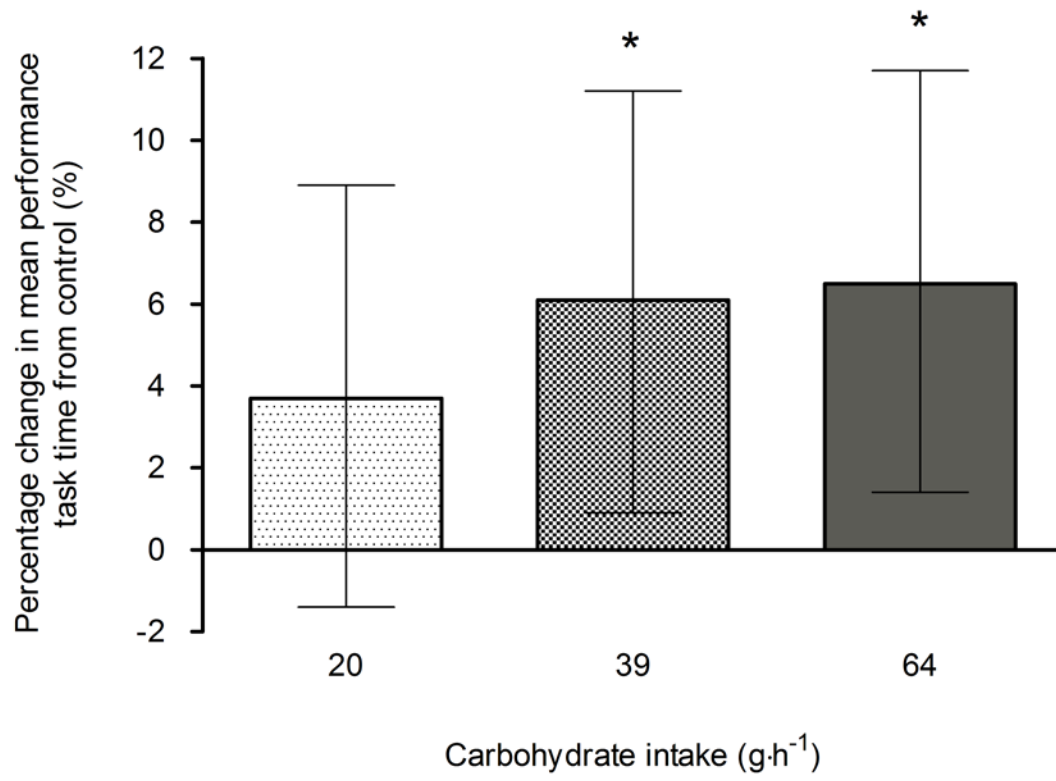
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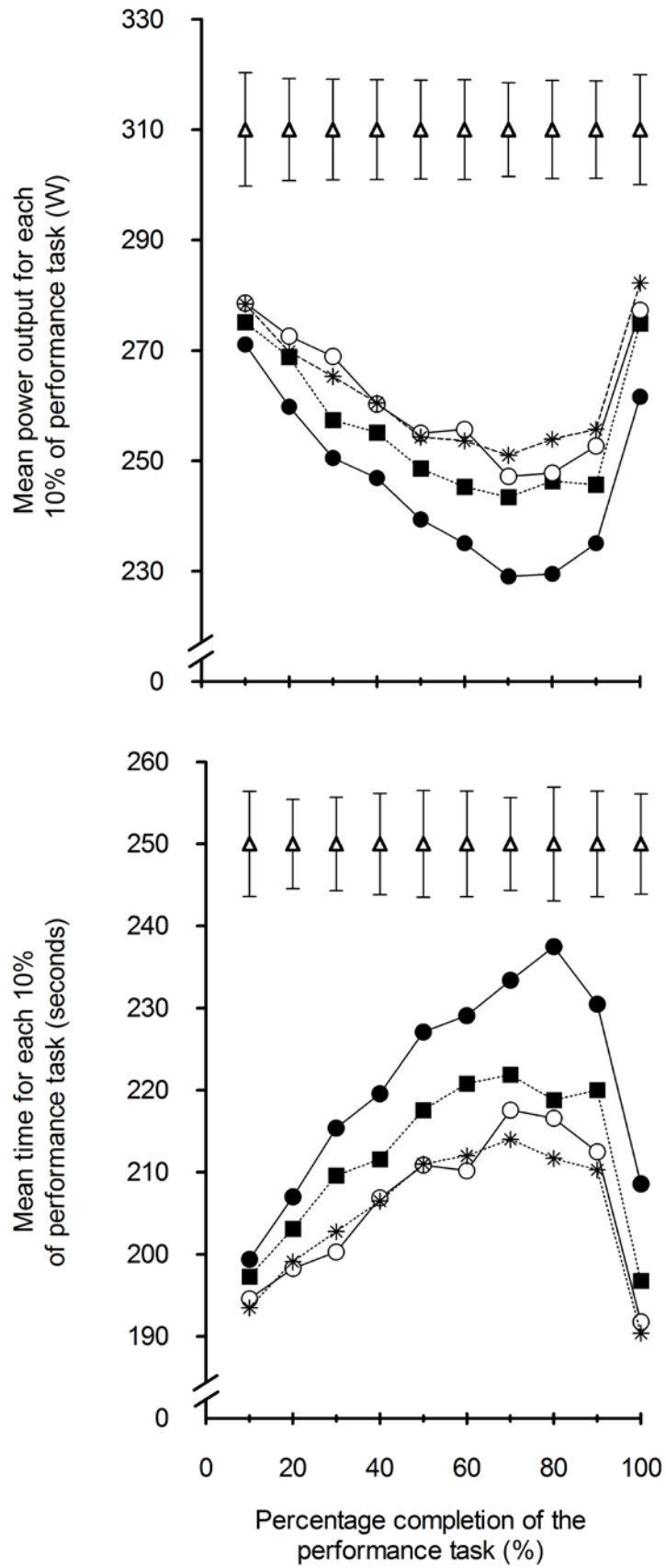
402 **Figure 1**

403

404 **Figure 2**

405

406 **Figure 3**



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

411

412 Figure 2. Percentage change in mean performance task time from the 0 g·h⁻¹ treatment for
413 20, 39, and 64 g·h⁻¹ carbohydrate ingestion rates. The percentage change in performance
414 task time was significantly greater in the 39 g·h⁻¹ and 64 g·h⁻¹ trials when compared to 0
415 g·h⁻¹ (*p < 0.05). Data presented as mean ± 95% confidence intervals.

416

417 Figure 3. Mean power output (A) and time to complete each 10% of the performance
418 task (B) when 0 g·h⁻¹ (-●-), 20 g·h⁻¹ (-■-), 39 g·h⁻¹ (-○-), and 64 g·h⁻¹ (-*-) of
419 carbohydrate was consumed. Data presented as means with the pooled standard error of
420 the mean (open triangle) on an arbitrary value of 310 (Power) and 250 (Time) for ease
421 of viewing.

422

423