

Mixed drink increased carbohydrate oxidation but not performance during a 40 km time trial

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Background: The present study aimed to determine whether consuming a glucose polymer (GP) and fructose would result in increased carbohydrate oxidation rates and improve 40 km time trial performance compared with an isocaloric GP-only drink.

Methods: Eight well-trained male competitive cyclists (VO_{2max} 62.7 ± 9.4 ml/kg/min, power output 5.1 ± 0.6 Watts/kg) participated in three visits consisting of a peak power output (W_{max}) and VO_{2max} test and two separate visits of a 105 minute steady state ride (at 65% W_{max}), followed by a 40 km time trial. Participants received 1.2 g/min of either a GP or mixed drink every 15 min.

Results: No differences were found in the 40 km performance between GP (69:14 min \pm 4.12, mean \pm SD) and the mixed drink (66:58 min \pm 4.51, mean \pm SD) trials ($p = 0.289$). There were no differences in blood glucose or lactate between the trials. No differences in total oxidation were found in either carbohydrate or fat oxidation rates; however, exogenous carbohydrate oxidation was significantly different between the GP drink trials at $t=90$ min (GP: 0.96 ± 0.36 g/min; mixed drink: 1.53 ± 0.48 g/min; $p = 0.041$, mean \pm SD).

Conclusion: The present study found no improvement in 40 km time trial time between an isocaloric GP-only or a GP and fructose drink, and no differences in any of the measured variables other than exogenous carbohydrate oxidation at 90 minutes during the pre-time trial steady state ride.

Keywords: multiple carbohydrate, cycling, endurance, glucose, fructose

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It is well-established that consuming exogenous carbohydrate during prolonged physical activity improves performance.^[1,2] The role of exogenous carbohydrate intake is hypothesised to provide additional substrate for oxidation^[3] specifically influencing performance by decreasing endogenous liver glycogen utilisation and preventing hypoglycaemia.^[4,5]

Early research cited the maximum rate of exogenous carbohydrate oxidation to be ~ 1 g/min.^[1] It was hypothesised that oxidation rates higher than 1 g/min were achieved by overcoming a limitation of a single carbohydrate at the intestinal absorption sites (SGLT-1)^[6,7] by utilising alternative carbohydrate transporters located in the intestine, such as GLUT5 for fructose.^[5] This suggests the potential for

improved performance.

However, to date, only a handful of studies have investigated the effects of multiple carbohydrate (glucose or maltodextrin and fructose) ingestion on cycling performance parameters and whether the difference in exogenous carbohydrate oxidation between a multiple carbohydrate drink and single carbohydrate drink results in an improved performance.^[7,8] In the first of these studies, a laboratory trial by Currell and Jeukendrup,^[7] a marked improvement in cycling performance was attained when a multiple carbohydrate drink, containing mixed carbohydrates, was ingested compared to that of a single carbohydrate drink which contained a GP only. The authors concluded that the mechanism for the improvement in performance was due to the increased exogenous carbohydrate oxidation rate, which allowed a greater amount of carbohydrate to enter systemic circulation for subsequent oxidation by the working muscles. Similarly, O'Brien and Rowlands^[9] have shown that higher rates of exogenous carbohydrate oxidation with a multiple carbohydrate drink result in an improvement in performance over and above that of when an isocaloric single carbohydrate with concomitant lower oxidation rate is ingested. Furthermore, the studies by Rowlands et al.^[10] and Currell and Jeukendrup^[7] measured endogenous a carbohydrate oxidation rates in addition to performance parameters, however, exogenous oxidation rates were not measured and it was assumed that the oxidation rate of the multiple CHO drink ingested was higher.

The present study aimed to determine if a superior performance is attained when a multiple carbohydrate drink is ingested. Specifically, time trial performances were compared in a single group of highly trained cyclists to determine whether a multiple carbohydrate drink (glucose: fructose in a 2:1 ratio) confers a performance advantage over that of a single carbohydrate drink (glucose-polymer only), the physiological parameters of lactate, insulin and glucose concentrations, substrate oxidation (total, endogenous and exogenous) and respiratory exchange, will be measured, which may explain the underlying mechanisms that relate to any performance differences.

Methods

Study Design

A double-blind randomised crossover design was employed in the study. The drink order was randomised to ingest either the glucose-polymer only (GP) or a multiple carbohydrate (Mixed) drink during the first trial, while the alternative drink was ingested in the second trial. Prior to participation in the trial, all participants completed a physical activity readiness and training history questionnaire to assess eligibility. Informed consent for the study was obtained from the participants, which was approved by the Human Research Ethics Committee of the Faculty of Health Sciences, University of Cape Town, South Africa. The testing for each participant took place over three

weeks and consisted of an anthropometry and peak power output test on the first visit, followed by a three-five day recovery period. The second visit (Fig.1) to the laboratory was the first performance trial. Seven to 14 days later, participants returned for the second performance trial, using the alternate carbohydrate drink.

Participants

Eight (n=8) well-trained male cyclists were recruited for the study from local cycling clubs. Descriptive data of the participants is summarised in Table 1. Participants ate a standardised breakfast (comprised of Kellogg's Corn Flakes and skim milk) two hours before each trial as previously described in^[11].

Peak power output test

Anthropometry, including height, weight and body fat percentage were obtained through skinfold measurements of the cyclists. Skinfold measurements were taken from the bicep, tricep, calf, subscapular, suprailiac, abdominal and thigh. Subsequent to the anthropomorphic measures, participants performed a Peak Power Output test (PPO) using their own bicycle attached to a Computrainer (Computrainer™ Pro 3D Ergometer, RacerMate, Seattle, USA).

Performance testing

Lamberts and Lambert Sub-maximal Cycle Test (LSCT) and Peak Power Output (PPO)

Prior to commencement of the LSCT, a cannula (20 Gauge, NIPRO, OSAKA, JAPAN) was inserted into the antecubital vein of the arm and a baseline blood sample of 5 ml was drawn for subsequent biochemical analysis. Immediately after ingesting one of the test drinks, participants completed a LSCT to calculate standardised HR-based workload data for each cyclist. RPE, power and heart rate for each of the LSCT stages were recorded for subsequent analysis. A detailed description of the LSCT and PPO protocol can be found in Lamberts et al^[12].

Pre time trial steady state ride (PTSS) and 40 km time trial

After the start of the preliminary analysis, a thematic framework was constructed in which to consolidate similar themes and perceive the differences from others. The themes identified in the data set were categorised as: psychosocial barriers and professional and programme-related barriers to progress in the programme.

Carbohydrate drink and ingestion schedule

Each participant ingested either glucose-polymer only (GP) (Refuel cc, Muizenberg, South Africa) or a glucose-polymer:fructose mixed drink. The type of carbohydrate drink ingested was randomised for each participant's first trial and the alternative drink was given at the subsequent trial. The mixed drink contained GP and fructose (Lifestyle Food Crystalline Fructose, Dis-Chem (PTY) Ltd, Midrand, South Africa) in a 2:1 ratio. Both ingested drinks had a concentration of 12% (12 g/100 ml) to deliver 1.2 g/min of

carbohydrate. The drinks were artificially flavoured and coloured with a sugar-free, flavoured cordial.

The participants ingested 400 ml of the selected drink immediately before the commencement of the PTSS. One hundred and fifty ml was ingested every 15 minutes throughout the 105 min PTSS (t= 0, 15, 30, 45, 60, 75, 90 and 105 mins). During the subsequent time trial, 150 ml of one of the test drinks was consumed at the start (0%) and then at 25%, 50% and 75% respectively during the completion of the time trial distance.

Biochemical analyses

Blood samples (for plasma, glucose and lactate analysis) were collected using vacuette tubes (4 ml Vacuette, Greiner Bio-One, Kremsmunster, Austria) and were stored on ice until analysed. RER and Respiratory calculations were done according to Faryn.^[13] and ¹³C calculations were done according to Pimay et al.^[14]

Performance and heart rate measures

During the time-trial, in addition to time to complete the 40 km, 1 km split times were recorded. Average power output (W) was calculated for each of the 1 km intervals during the 40 km, as well as the average power output (mean ± SD) for the entire time trial. Heart rate was monitored during the entire experiment and then averaged for 5 min intervals using a Suunto T6 heart rate monitor (Suunto®, Oy, Vantaa, Finland).

Statistical analyses

Statistical analyses were performed using Statistica 10 (Statsoft Inc.) and significance was accepted at $p < 0.05$. Data are presented as Means ± SD. Comparison between the GP and mixed drink's completion time of the 40 km time-trial, as well as the 1 km interval splits, peak power output, insulin, glucose and lactate concentrations, RER and oxidation rates calculations were performed using repeated measures analysis of variance (ANOVA).

Results

Participant characteristics

Participant characteristics are summarised in Table 1

Respiratory measurements

None of the measured variables (Table 1) were found to be significantly different between trials. Total carbohydrate oxidation, fat oxidation and RER during the PTSS were not significantly different between the two trials (Fig. 2).

Biochemical analysis

Glucose concentrations (Fig. 3), insulin concentrations and blood lactate concentrations were shown to change over the course of the PTSS, but were not significantly different between trials.

Carbohydrate oxidation

Endogenous carbohydrate (Fig. 4A) oxidation was not found to be significantly different between drinks trials at any of the time points; however, the data showed a trend towards

Table 1. Summary of participant results (n=8), PPO test (visit 1) and Respiratory measures during the PTSS

Participant Characteristics							
Anthropometry	Age (y)	Height (cm)	Weight (kg)	Body fat %	Cycling history (y)	Training load (hours/week)	
	26.1 ± 5.4	179.6 ± 6.8	75.6 ± 10.1	8.6 ± 1.7	7.0 ± 3.6	17.6 ± 5.2	
PPO Test							
	PPO (Watts)	RPO (Watts/kg)	Absolute VO ₂ (l/min)	Relative VO ₂ (ml/kg/min)			
	406 ± 38	5.1 ± 0.6	4.7 ± 0.4	62.7 ± 9.4			
Respiratory measurements (PTSS)							
	VO ₂ (L/min)	VCO ₂ (L/min)	VO ₂ (ml/kg/min)	% VO ₂ max	RER	CHO Ox	Fat Ox
(p) Trial	0.932	0.977	0.923	0.748	0.639	0.787	0.665
(p) Time	0.102	p<0.05	0.259	p<0.05	p<0.05	p<0.05	p<0.05
(p) Interaction	0.661	0.839	0.720	0.352	0.970	0.834	0.522
Effect size	0.106	0.046	0.014	0.098	0.533	0.427	0.538

PPO, Peak Power Output; RPO, Relative Power Output; RER, Respiratory Exchange Ratio; PTSS, Pre Time Trial Steady State; CHO, Carbohydrates; Ox, Oxidation; y, years; p, p-value

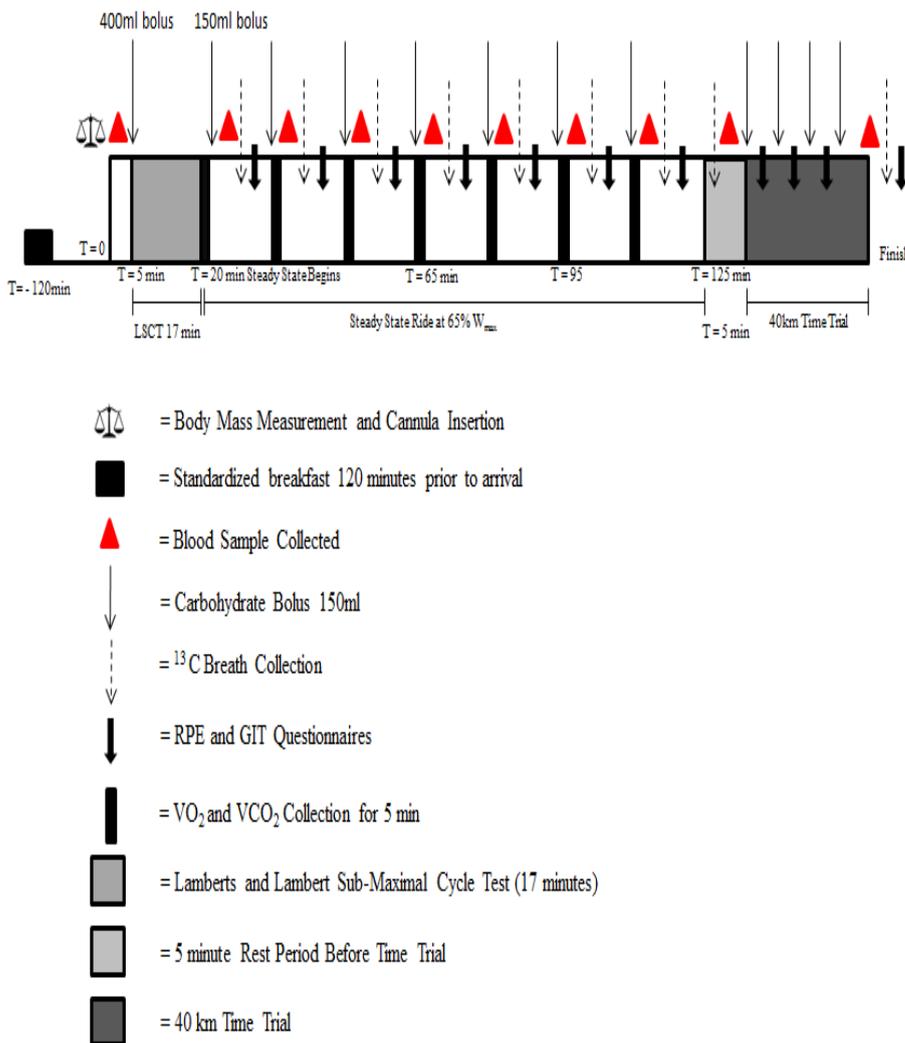


Fig. 1. Schematic representation of protocol for performance trials

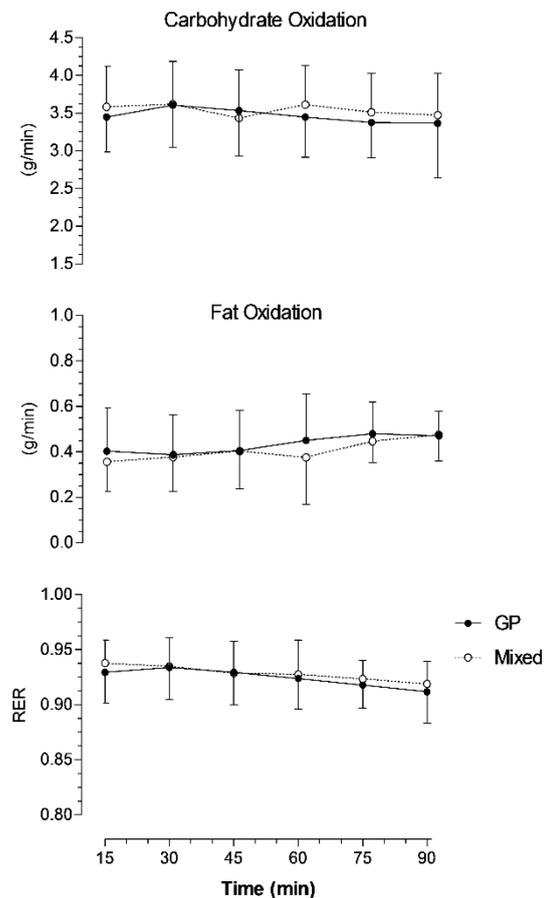


Fig. 2. Total carbohydrate oxidation, fat oxidation and RER during the PTSS (T=0 – 90 min). Mean values of VO₂ and VCO₂ were measured for 5 min every 15min. These were used to calculate RER, total CHO and total fat oxidation. GP trial (black circles) and mixed drink trial (white circles); no significant differences were found. Error bars indicate 95% Confidence Interval.

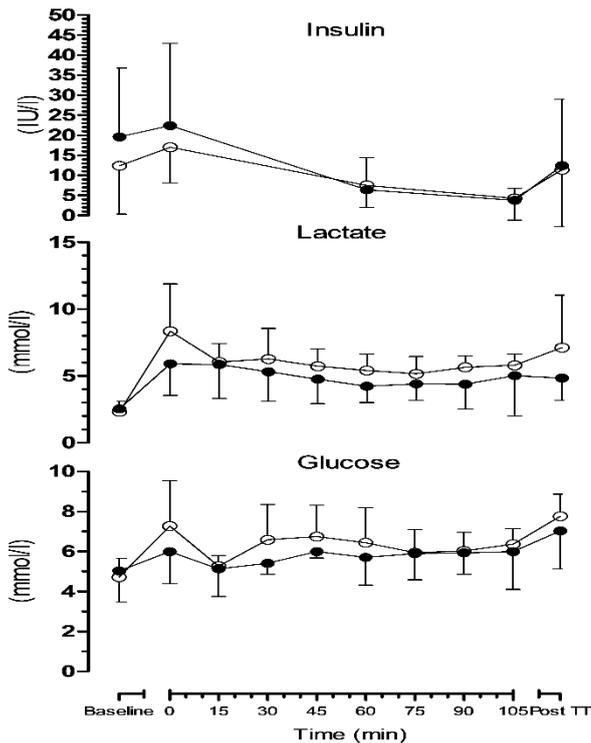


Fig.3. Plasma insulin, lactate and glucose concentrations during the time trial. GP (black circles) or mixed drink (white circles). No significance difference was found between the drink trials. Error bars indicate 95% Confidence Interval.

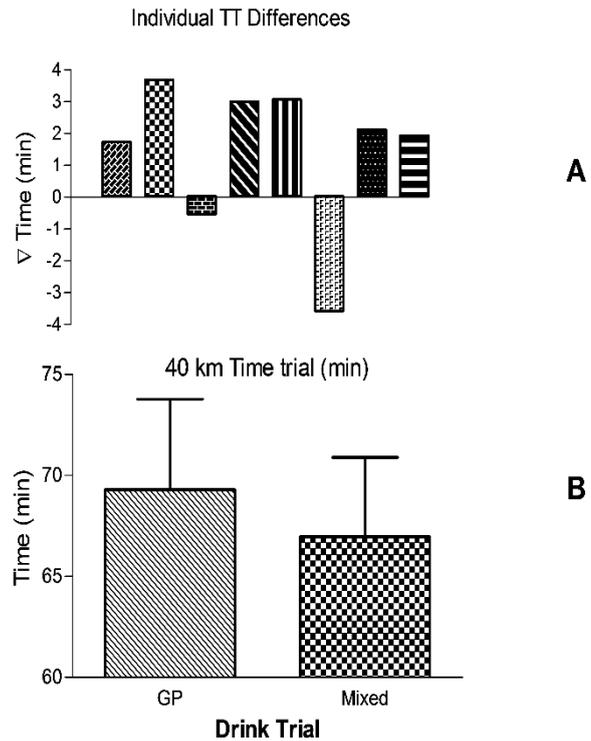


Fig. 5A. Individual time trial differences of participants (Each bar represents an individual participant). A positive Δ Time indicates faster time to completion in mixed drink trial compared to GP.

Fig. 5B. Final time trial completion for the GP (69:14min \pm 4.12, mean \pm SD) and the mixed drink (66:58min \pm 4.51, mean \pm SD) trials were not significantly different between trials ($p=0.289$).

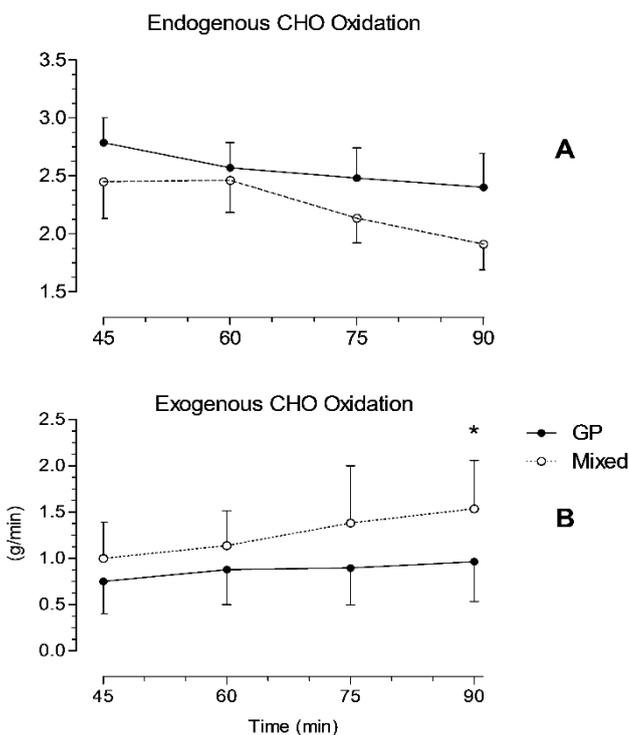


Fig. 4. Endogenous and exogenous carbohydrate oxidation during PTTSS ($T=45-90$ min). Endogenous oxidation was not significantly different at any of the intervals ($p=0.275$); however, the data show a trend toward significance at the 90 minute interval ($p=0.078$). No statistical difference was found at 45-, 60- and 75 minute intervals for exogenous CHO oxidation but a significant difference was found at the 90 minute interval ($p=0.041$). Error bars indicate SD.

significance at the 90 minute time point (GP: 2.38 ± 0.77 g/min; mixed drink: 1.99 ± 0.12 g/min; $p=0.078$, mean \pm SD). Exogenous carbohydrate oxidation (Fig. 4B) determined from expired air samples (^{13}C abundance in breath samples) from the PTTSS was significantly different between the mixed drink and GP trials at 90 minutes (GP: 0.96 ± 0.36 g/min; mixed drink: 1.53 ± 0.48 g/min; $p=0.041$, mean \pm SD). No differences were found at the 45-, 60- and 75 minute time points respectively ($p=0.083$).

Time trial performance measures

40 km time trial

Total time to completion for the 40 km time trial and each of the individual 40 km performances are shown in Fig. 5A. No significant differences were found in the 1 km split times (GP: 1 min 43sec \pm 7.3 sec ; mixed drink: 1 min 41sec \pm 6.5 sec; $p=0.696$, mean \pm SD), 1 km average RPM (GP: 88 ± 9 RPM; mixed drink: 91 ± 9 RPM; $p=0.731$, mean \pm SD) and 1 km average power output (GP: 230 ± 38 W; mixed drink: 242 ± 41 W; $p=0.611$, mean \pm SD); neither was there any significant change during the 40 km time trial (Fig. 5A). There was no significant difference in time to complete the time trial (Fig. 5B) between GP (69:14 min \pm 4.12, mean \pm SD) and mixed drink (66:58 min \pm 4.51, mean \pm SD) performance trials ($p=0.289$).

Heart rate and Rating of Perceived Exertion (RPE)

No significant differences were found in heart rate (GP: 161 ± 5 bpm; mixed drink: 161 ± 6 bpm; $p=0.845$, mean \pm SD) between the trials in both the PTTSS and 40 km time trial rides (GP: 165

± 2 bpm; mixed drink: 166 ± 2 bpm; $p=0.956$, mean \pm SD). RPE (Borg Scale Units) increased significantly over the course of the PTTSS and 40 km time trial but was not significantly different between drink trials during the PTTSS ($p=0.373$) and 40 km time trial rides ($p=0.223$).

Discussion

In contrast to previous research,^[7,8,10,15] no improvement in performance was recorded during a 40 km laboratory time trial between the GP and the mixed drinks ($p=0.289$). Triplett et al.^[8] showed an 8.1% improvement in time trial performance when participants ingested approximately 144 g (or 2.4 g/min) of drinks containing either GP only, or a GP and fructose (1:1 ratio) mixed drink. The improvement in performance was attributed to maintenance of a significantly higher average power output during the ingestion of the mixed drink as compared to the GP trial. Similar results were reported by Currell and Jeukendrup^[7] in which cyclists, ingesting 1.8 g/min, improved by 8% in a time trial in which a set amount of work was to be completed as quickly as possible following a period of steady state exercise for 120 min at 55% W_{max} . However, Rowlands et al.^[10] obtained similar findings to those of the present study, observing only a modest improvement in performance in both a race ($1.8\% \pm 1.8\%$, mean \pm SD) and laboratory trial ($1.4\% \pm 0.8\%$, mean \pm SD) with participants ingesting 1.2 g/min. This is further supported by Bauer et al.^[15]

The present study's objective was to determine whether a more modest concentration of mixed carbohydrate drink (12%) can increase carbohydrate oxidation above 1 g/min and thereby improve performance. Besides not finding any improvement in cycling performance, the present study also found no difference in total carbohydrate oxidation between the GP and mixed drink trials. However, a significant difference in exogenous oxidation (Fig. 4B) was found after 90 minutes during the PTTSS ($p=0.041$). In the study by Jentjens and Jeukendrup^[5], participants ingested a drink that contained 2.4 g/min of mixed carbohydrates during a 150 min of cycling exercise at 60% of VO_2 max which resulted in a peak exogenous oxidation rate of 1.75 g/min at the 150 minute time point. The GP drink resulted in a significantly lower exogenous oxidation rate of 1.06 g/min. This is in agreement with this present study as only a significant difference in CHO oxidation at the 90 minute time point during the PTTSS was detected suggesting that the effects of ingesting an exogenous carbohydrate may only become prevalent after 60 minutes of prolonged exercise.

The increase in oxidation rates in a mixed carbohydrate drink is hypothesised to be as a result of the increased uptake of mixed carbohydrates by GLUT4 and GLUT5 transporters respectively in the brush border of the gut.^[5,7,10] It is theorised that when GPs are ingested alone, the SGLT-1 transporters become saturated, ultimately limiting the uptake of glucose into the body. The ingestion of a multiple carbohydrate drink is suggested to overcome

this limitation by utilising alternative carbohydrate transporters, specifically the GLUT5 transporters which function to absorb other sugar isomers such as fructose.^[6,7,12] However, in the present study, the nature of the protocol utilised was particularly intense (participants exercised at 65% W_{max} for 105 minutes during the pre-time trial steady state ride before completing a 40 km time trial, resulting in participants exercising at 76-82% of VO_2 max and 85-90% of HR_{max}) compared to a number other performance trials, in which moderate exercise intensities were employed. These authors can only stipulate that the absence of significant differences between the GP and mixed drinks can be attributed to the demanding study design, the participants may have experienced fatigue and near muscle glycogen depletion^[1,4] before the commencement of the performance component, masking a potential effect of the additional exogenous carbohydrate. The rationale behind the utilisation of such a demanding protocol was an attempt to simulate as closely as possible the physiological stress that would be encountered during a prolonged cycling road race.

Although the present study failed to find a statistical improvement in performance over the 40 km between the two drink trials, it was found that the ingestion of the mixed drink resulted in a faster time trial completion than the GP drink. This research also demonstrated that there was a significant more exogenous carbohydrate oxidation at $t=90$ min in the mixed drink trial compared to the GP drink in the PTTSS, supporting previous studies findings.^[7,15] Therefore this study contributes to the growing scientific body of the importance of CHO ingestion during prolonged and often intense exercise, such as can be seen in events such as the Tour de France. However, the study is not without limitations. The sample size was small, and therefore including more participants in the future may produce clearer results.

Conclusion

As far as the authors can ascertain, this is the first study to utilise the well-established laboratory-based time trial as a measure of endurance performance, in conjunction with pre-time trial steady state exercise in order to reassess the potential performance-enhancing effect of ingesting a multiple carbohydrate drink compared to a single carbohydrate drink. The present study found no improvement in a 40 km time trial time between an isocaloric GP only or a GP and fructose drink, and no differences in any of the measured variables other than exogenous carbohydrate oxidation at 90 minutes during the pre-time trial steady state ride.

Conflict of interest: There are no conflicts of interest to report.

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