Title: Perception of breakfast ingestion enhances high intensity cycling performance

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Abstract

Purpose: To examine the effect on short duration, high intensity cycling time trial performance when a semi-solid breakfast containing carbohydrate or a taste and texture matched placebo is ingested 90 minutes pre-exercise compared to a water control.

Methods: Thirteen well trained cyclists (25 ± 8 years, 71.1 ± 5.9 kg, 1.76 ± 0.04 m, 383 ± 46 W_{max}, VO_{2peak} 4.42 ± 0.53 $L \cdot min^{-1}$) performed three experimental trials examining breakfast ingestion 90 minutes before a 10 minute steady state cycle (60% W_{max}) and a ~20 minute time trial (to complete a workload target of 376 ± 36 kJ). Subjects consumed either water (WAT), a semi-solid carbohydrate breakfast (2 g carbohydrate$\cdot kg^{-1}$ body mass; CHO) or a taste and texture matched placebo (PLA). Blood lactate and glucose concentrations were measured periodically throughout the rest and exercise periods.

Results: The time trial was completed quicker in CHO (1120 ± 69 s; P=0.006) and PLA (1112 ± 50 s; P=0.030) compared to WAT (1146 ± 74 s). Ingestion of carbohydrate caused an increase in blood glucose concentration throughout the rest period in CHO (peak at 30 minutes rest: 7.37 ± 1.10 $mmol \cdot l^{-1}$; P<0.0001) before dropping below baseline levels after the steady state cycling.

Conclusion: A short duration cycling time trial was completed quicker when subjects perceived that they consumed breakfast (PLA or CHO) 90 minutes prior to the start of exercise. The improvement in performance is likely attributable to a psychological rather than physiological effect.

Key words: carbohydrate, exercise, time trial, fasted, placebo

Introduction

The benefits of carbohydrate feeding prior to prolonged bouts of endurance exercise are well established[1-6]. When exercise duration is longer than 60 minutes it is generally advised that athletes consume carbohydrate in the 1-4 hours before exercise[7]. For exercise lasting less than 45 minutes there appears to be little evidence, if any, to suggest pre-exercise carbohydrate ingestion will enhance performance. It is generally perceived that muscle glycogen depletion is not the limiting factor for short duration exercise and therefore prior ingestion of carbohydrate will serve little benefit[7,8]. However, for many athletes common practice often dictates consumption of carbohydrate prior to training sessions and competition regardless of the duration and particularly if the training is at a high intensity.

Endurance athletes will regularly train in the morning, but for many, the logistics of consuming carbohydrate 1 to 4 hours prior to exercise may be difficult and therefore result in some sessions completed in a fasted state. Training in a fasted state and thereby reducing carbohydrate availability has been shown to potentiate cellular and molecular adaptations to endurance training[9]. This may be of advantage to endurance athletes if correctly integrated into a periodised training programme[10], however, other methods of reducing carbohydrate availability (i.e. 'sleep low' and 'train low' paradigms) have resulted in reduced self-selected intensity, which might attenuate the training stimulus[11,12]. From a physiological standpoint, despite small decreases in liver glycogen stores overnight[13], fasted exercise should not impair short duration performance, and therefore any influences on performance or self-selected intensity may be as a result of a placebo effect.

The placebo effect has been commonly observed in exercise performance settings, arising from the belief that one is receiving a treatment or product that will result in a favourable outcome[14]. In exercise lasting approximately 1 hour, Clark and collegues[14] observed a 4% improvement in cycling performance when a placebo drink thought to be containing carbohydrate was consumed during exercise, yet for longer periods of exercise (~3h), no placebo effect has been reported[15]. Although these results are based on feeding during exercise, it appears that there is more likely to be a placebo effect when the exercise bout is short in duration and muscle glycogen use is not the limiting factor. For a cycling time trial lasting ~20 minutes (i.e. comparable to a 10-mile time trial), a placebo effect may therefore be of substantial significance, with those consuming carbohydrate or breakfast potentially perceiving this to be advantageous and increasing self-selected intensity.

Therefore the aim of this study was to examine the effect of pre-exercise carbohydrate intake (i.e. breakfast) on cycling time trial performance compared to a taste and flavour-matched placebo and a water control. A semi-solid breakfast was used to enhance the perception of energy/ nutrient intake and facilitate blinding. It was hypothesised that a carbohydrate breakfast would have no effect on performance compared to the placebo, but both would be advantageous compared to water.

Methods

Thirteen well-trained male cyclists (age 25 ± 8 years, body mass (BM) 71.1 ± 5.9 kg, height 1.76 ± 0.04 m, maximum power output 383 ± 46 W, VO_{2peak} 4.42 ± 0.53 $L \cdot min^{-1}$) were recruited to take part in three trials, undertaken in a randomised order. The study protocol was explained to all subjects both verbally and in writing before they provided written informed consent. The study was approved by the Loughborough University Ethics Approvals (Human Participants) Sub-Committee and conformed to the Declaration of Helsinki. It was estimated that 12 subjects were required to detect a 2.5% (30 sec) difference between trials based on an α of 0.05 and a statistical power of 0.8. Thirteen were recruited to provide adequate power and account for dropouts.

Subjects visited the laboratory on 5 occasions: a VO_{2peak} test, a time trial familiarisation and three experimental trials (water (CON), placebo (PLA) and carbohydrate (CHO); figure 1). Subjects were recruited on the premise that the investigation was examining two breakfast drinks. Trials were performed in a randomised cross-over design. The PLA and CHO trials were administered in a double-blind manner, although it was impossible to blind the WAT trial from either experimenters or subjects.

During the first visit, subjects performed a VO_{2peak} test using a continuous incremental protocol on an electronically braked cycle ergometer (Lode Excalibur; Lode BV, Groningen, Netherlands). Commencing at 95 W, subjects completed three minutes stages increasing by 35 W until volitional exhaustion. Maximal power output (W_{max}) was calculated as the power of the last completed stage plus the fraction of time spent in the next stage multiplied by the intensity increment. W_{max} values determined 60% W_{max} used for the experimental trials. During the final minute of each stage and the final minute of the test, expired gases were collected into a Douglas bag and analysed for oxygen and carbon dioxide concentration (Servomex 1400 Oxygen and Carbon Dioxide Gas Analyser; Servomex, Crowborough, UK). Using a Harvard dry gas meter (Harvard Apparatus Ltd., Edenbridge, UK) and thermometer (Edale Digital Thermometer D515: Edale Instruments Ltd., Cambridge, UK), gas volumes and temperature were measured, respectively and corrected to STPD (standard temperature and pressure, dry). Following the VO_{2peak} test, subjects performed at least 50% of the time trial protocol used in the experimental trials to initially familiarise with the method. During the second visit, subjects performed a familiarisation of the exercise portion of the experimental trial. This involved a 10 minute bout at 60% W_{max}, 5 minute rest, and a cadence dependent linear-factor time trial (similar to that used by Hulston and Jeukendrup[15]), where subjects were asked to reach a target workload, based on cycling at 80% W_{max} for 20 minutes, as quickly as possible. The following formula was used to calculate work required:

$$Target\ kJ\ = \frac{(Wmax\ \times 0.8\ \times 1200s)}{1000}$$

Subjects were able to see work completed and received verbal notification upon completion of 25, 50 and 75% of the time trial. The time trial was completed in silence, in an enclosed area of the laboratory with no additional feedback provided. Time to complete each 25% segment and heart rate at every 25% were recorded. No food or fluid was ingested during either the steady-state exercise or TT.

In the 24 h prior to the first experimental trial, subjects recorded all food and fluid intake, and any low-intensity habitual physical activity, and repeated these patterns

before the two remaining trials. Subjects arrived overnight fasted between 0700 and 0900 h, with the specific time standardised for each individual.

On arrival, subjects provided a urine sample, and had nude body mass measured. A heart rate monitor (Polar Vantage; Kempele, Finland) was fitted before the subject sat for 5 minutes and resting heart rate recorded. At the end of the rest period a capillary fingertip blood sample (20 µl) was collected and later analysed for whole blood lactate and glucose concentrations. Subjects were also asked to rate their gastrointestinal (GI) comfort (1 = neutral; 12 = painful). Subjects were then asked to consume one of three breakfasts within 5 minutes: CON (7 ml·kg body mass(BM)$^{-1}$ water), PLA (6 ml·kg BM^{-1} water, 1 ml·kg BM^{-1} orange squash (Robinson's, Britvic, Hemel Hempstead, UK), 0.67 g·kg BM^{-1} xanthan gum (Doves Farm, Hungerford, UK) and 0.067 g·kg BM^{-1} artificial sweetener (Canderel, Merisant, High Wycombe, UK)) and CHO (6 ml·kg BM^{-1} water, 1 ml·kg BM^{-1} orange squash, 2 g·kg BM^{-1} maltodextrin (MyProtein, Northwich, UK), 0.67 g·kg BM^{-1} xanthan gum and 0.067 g·kg BM^{-1} artificial sweetener). PLA and CHO were matched for taste and texture. Xanthan gum was used to produce a semi-solid meal and increase the perception of 'energy intake'. When provided with either the PLA or CHO breakfast, subjects were told, "this is one of the two breakfast drinks". At 15, 30, 60 and 90 minutes post-ingestion, heart rate and GI comfort were measured and blood samples were collected.

Subjects then completed 10 minutes at 60% W_{max}. During the final minute of exercise, heart rate and rating of perceived exertion were measured, and a sample of expired gas was collected. On completion, a blood sample was collected and subjects rated GI comfort. Following a 5 minute period of rest, subjects began the time trial. Final measurements (blood and GI comfort) were collected at the end of the time trial. After the final trial, subjects were asked a series of questions: "Was there a difference between the drinks?", "If so, can you identify this difference?", "One of the drinks contained carbohydrate, which one was it?" and "Do you ever complete aspects of your training in the morning after an overnight fast?"

Sample analysis

Each 20 µl whole blood sample was collected in a capillary tube and placed in an Eppendorf containing 1 ml of haemolysing solution (EKF Diagnostics, Cardiff, UK). This was stored on ice until analysis for glucose and lactate concentrations (Biosen C-Line, EKF Diagnostics). Urine samples were analysed in duplicate for osmolality by freezing-point depression (Gonotec Osmomat auto Cryoscopic Osmometer; Gonotec, Berlin, Germany).

Statistical analysis

Data were checked for normality of distribution using Shapiro-Wilks tests. All data were normally distributed. A one-way repeated measures ANOVA was used to analyse data containing one factor (performance time, urine osmolality, expired air and substrate use). Data with two factors (pacing, blood lactate/ glucose concentrations, heart rate and scales) were analysed using a two-way repeated measures ANOVA. If a significant ANOVA was observed, paired samples t-test with Holm-Bonferroni correction were used to identify where the difference occurred. Statistical significance was accepted when $P < 0.05$. Data is expressed as mean ± standard deviation (SD). Statistical Package for the Social Sciences for Windows, version 22.0 (SPSS Inc., Chicago, IL, USA) was used to conduct the statistical analysis.

Results

Pre-trial urine osmolality was similar between trials (WAT: 670 ± 195 mOsmol·kg^{-1}, PLA: 801 ± 199 mOsmol·kg^{-1}, CHO: 754 ± 226 mOsmol·kg^{-1}; P = 0.158), suggesting subjects arrived in a similar state of hydration.

Performance measures

Time to complete the time trial was quicker in both the CHO (1120 ± 69 s; P = 0.005) and PLA (1112 ± 50 s; P = 0.030) trials compared to the WAT trial (1146 ± 74 s; figure 2), however, there was no difference in performance between the CHO and PLA trial (P = 0.544). No trial order effect was observed (P = 0.841).

Analysis of pacing strategy showed a time effect, with the first 25% TT section of all trials completed quicker than the 25-50% and 50-75% sections (P < 0.0001; figure 3) but similar to the final 25% (P = 0.141). The second 25% section was also completed faster than the third section (P = 0.004). There was a significant trial effect (P < 0.0001) but no interaction effect (P = 0.298).

Heart rate was similar between trials at baseline (61 ± 11 beat·min^{-1}; grouped mean and SD of trials; P = 0.780), during the rest period (58 ± 10 bpm; grouped mean and SD of trials; P = 0.316) and in the 10 minute steady state period of cycling (140 ± 19 bpm; grouped mean and SD of trials; P = 0.312). Mean heart rate was slightly lower during the TT in the WAT trial (174 ± 8 bpm) compared to the PLA (175 ± 6 bpm; P = 0.006) and CHO (177 ± 9 bpm; P = 0.003) trials.

Blood analysis

A significant time, trial and trial x time interaction effect was observed for blood glucose concentrations (P < 0.0001; figure 4a). Following breakfast in the CHO trial, blood glucose concentrations increased above baseline and remained elevated until 90 minutes, before dropping below baseline concentrations following the 10 minute steady state cycling. Blood glucose concentrations then increased above baseline following completion of the TT. This increase following the TT also occurred in the WAT and PLA trials. In the CHO trial, blood glucose concentrations were greater at 15, 30, 60 and 90 minutes and lower following steady state compared to the corresponding samples in both the WAT and PLA trials (P < 0.05).

Blood lactate concentrations were not influenced by trial (P = 0.088), however there was a time effect with concentrations peaking following the completion of the TT (P < 0.0001; figure 4b).

Substrate utilisation

Due to problems with expired gas analysis, respiratory exchange ratio (RER) and substrate utilisation during the period of steady state cycling were only available for 10 out of 13 subjects. RER was greater in the CHO trial (0.94 ± 0.03) compared to the PLA trial (0.89 ± 0.04; P <0.0001). RER during the WAT trial was not different to the other trials (0.92 ± 0.03; P = 0.112 v PLA; P = 0.117 v CHO). Carbohydrate oxidation was greater in the CHO trial (3.10 ± 0.17 g·min^{-1}) compared to the PLA trial (2.41 ± 0.53 g·min^{-1}; P <0.0001), however during the WAT trial (2.82 ± 0.48 g·min^{-1}), carbohydrate oxidation was similar to the two other trials (P = 0.088 v PLA; P = 0.148 v CHO). Fat oxidation was greater in the PLA trial (0.52 ± 0·23 g.min^{-1}) compared to the CHO trial

212 (0.26 ± 0.17 g·min^{-1}; P = 0.003), but similar in the WAT trial compared to the two other
213 trials (0.36 ± 0.16 g·min^{-1}; P = 0.108 v PLA; P = 0.121 v CHO).

214 There was no difference in GI comfort between trials (time x trial interaction, P = 0.446)
215 and no rise from baseline values of 1 ± 1 (WAT), 1 ± 1 (PLA) and 1 ± 1 (CHO, all P >
216 0.05) throughout the trials.

217 *Questionnaire data*

218 Out of thirteen subjects, five stated they felt there was a difference in the drinks, with all
219 of these subjects correctly identifying the CHO trial as either containing 'carbohydrate'
220 or 'energy'. Of these five subjects, two subjects performed better on the PLA trial (by
221 38 s and 83 s), one performed better on the CHO trial (by 50 s) and two had very similar
222 performance times (both 5 s faster on the CHO trial). Of the remaining eight subjects,
223 four correctly guessed the order of the PLA and CHO trials. Seven subjects completed
224 little to none of their training in a fasted state, with the remaining six subjects
225 performing a fraction (1-2 rides per week) of their training in a fasted state.

Discussion

The aim of the study was to examine the effect of a pre-exercise carbohydrate intake in the form of maltodextrin (i.e breakfast) on a short duration high intensity cycling time trial, compared to a placebo and water control. Performance was improved in both the CHO and PLA trials suggesting there was a placebo effect of ingesting breakfast. This would indicate that with the length and intensity of the exercise used in the current study, nutritional intake may be of psychological benefit, rather than physiological.

The main result of the study was the placebo effect observed on performance. The placebo effect has been observed in 60 minute performance trials[14] when perhaps the metabolic and psychological effects of carbohydrate ingestion may cross. However, when exercise is of longer duration and the metabolic benefits of carbohydrate intake are clearer, no placebo effect was observed[15]. The interesting aspect of this study was the short duration nature of the time trial in combination with a water control to maximise the perception of carbohydrate/ breakfast consumption. Pre-exercise carbohydrate studies tend to compare a carbohydrate drink with a taste-matched placebo[5,8], but have not increased the viscosity to create the perception of ingesting a meal. Few include a water control[15], preventing the investigation of knowingly ingesting nothing which may dampen any placebo effect. Palmer and colleagues[8] provided a 6.8% carbohydrate drink or a coloured and flavoured placebo 10 minutes prior to a cycle test of similar duration to the current study (20 km) but did not have a water control. Whilst no performance difference was observed between the trials, this does not discount the positive effect that both drinks may have had on performance. In the current study, it is possible the perception of nutritional intake resulted in an anticipatory effect encouraging increased self-selected intensity as evidenced by an increased HR in the PLA and CHO trials. Although more commonly practiced during exercise, this effect is not too dissimilar from the suggested mechanistic action of carbohydrate mouth rinsing, where oral sensing of carbohydrate has enhanced endurance performance[16,17]. It has been proposed that there is an increase in central motor drive rather than any metabolic effects[16]. In the present study the increased viscosity of the drink may have contributed to the sensing or perception of substrate and an increase in central motor drive.

The general trend of the time trials were to start quickly, slow in the second and third quarters before a tendency to speed up at the end. The lack of difference between segments in trials, particularly between the PLA and CHO trials suggests that substrate availability, or rather the increased availability from maltodextrin ingestion did not contribute to pacing. In addition, although non-significant, small differences in time to complete the first two WAT segments appeared to contribute to the overall slower time compared to the perception of breakfast.

Ingestion of maltodextrin increased carbohydrate oxidation during the steady state exercise in CHO compared to PLA and likely during the time trial. Maltodextrin ingestion would have stimulated insulin release and in combination with high blood glucose would decrease fatty acid oxidation[18], as well as increasing glucose uptake into the muscle[19]. In the current study, this did not appear to influence performance, either because the time trial was too short in duration for substrate utilisation to have a meaningful influence or the placebo effect of breakfast was greater than any metabolic effects and had greater regulation over pacing.

One of the main aims of a carbohydrate meal after an overnight fast is to replenish liver glycogen[13]. In the current study this did not appear to enhance performance as there was no difference between the PLA and CHO performance times. The absence of a difference is likely explained by the short duration of the time trial, where less glycogen availability is required compared to longer performance tests in which differences have been observed[5].

The pre-exercise feeding recommendation for exercise greater than 60 minutes is to ingest carbohydrate in the 1-4 hours before exercise[7]. The 90 minutes pre-exercise breakfast ingestion in the current study found similar results to Galloway and colleagues[20] when ingestion occurred 2 hours before a shorter exercise capacity test (~7.5-9.0 minutes). The amount of carbohydrate provided by Galloway et al.[20] used was 32 g (the present study used approximately 142 g) and there was no water control to determine if there was a placebo effect. In an interesting caveat, in the same study, a performance difference was observed when the 32 g of carbohydrate was ingested 30 minutes before exercise compared to a placebo. This was attributed to an increase in glucose uptake and oxidation in the early stages of exercise as well as possible non-metabolic effects such as positive alterations in mood and arousal. When carbohydrate is ingested close to exercise there is the possibility of rebound hypoglycaemia during the initial stages of exercise. Although the general results are mixed, the effect on performance has been largely refuted (reviewed by [21]). Whilst hypoglycaemia did not occur in the present study there was a small decrease in blood glucose concentrations following the 10 minute steady state. It therefore seems that for short duration exercise carbohydrate ingestion close to exercise may improve performance through a partial metabolic effect, however, when ingested around 90 minutes before exercise the improvement in performance is likely psychological hence the similar performance observed between the PLA and CHO trials.

The present research was conducted in well-trained cyclists, however experience of fasted training was limited to only 6 subjects and this largely comprised of low intensity or short duration rides. As the results appeared to be driven by psychological determinants it would be of interest to study a chronic effect of fasted high intensity training to determine if cyclists could become accustomed to the effort and alter their self-selected intensity without the perception of ingesting a CHO or PLA drink.

Practical Applications

Many athletes will complete some training sessions in a fasted state, however these are often limited to recovery and low intensity sessions. Typically, athletes will ingest a pre-exercise meal or source of carbohydrate prior to engaging in high quality and intense bouts of exercise, even if guidelines do not necessarily suggest consumption when exercise duration is less than 60 minutes[7]. The results of this study suggest that from a physiological perspective this is not necessary; however the act of ingesting a perceived breakfast improved performance regardless of energy content. Studies examining alternative methods of low carbohydrate availability (i.e. training after an overnight fast or in a depleted state – in both situations the athlete is not blinded to the condition) have repeatedly demonstrated a reduction in self-selected intensity[11,12], yet also beneficial cell signalling responses and the increasing of mitochondrial biogenesis[9,12,22]. This study poses the question of the possibility that the benefits of both

high (maintained self-selected intensity) and low (increased cellular adaptations) carbohydrate availability can be achieved through a placebo breakfast. The placebo effect is unlikely to last chronically so a carefully planned approach by the coaching team is required to maximise adaptations by selecting key sessions for acute implementation.

Conclusion

In conclusion, subjects in this study were able to complete a short duration (approximately 20 minutes) cycling time trial quicker when they consumed a PLA or CHO breakfast 90 minutes prior to the start of exercise compared to a water control. The improvement in performance was due to a psychological rather than physiological cause, with the subjects perceiving the ingestion of breakfast and nutrients as beneficial, resulting in an increased self-selected intensity.

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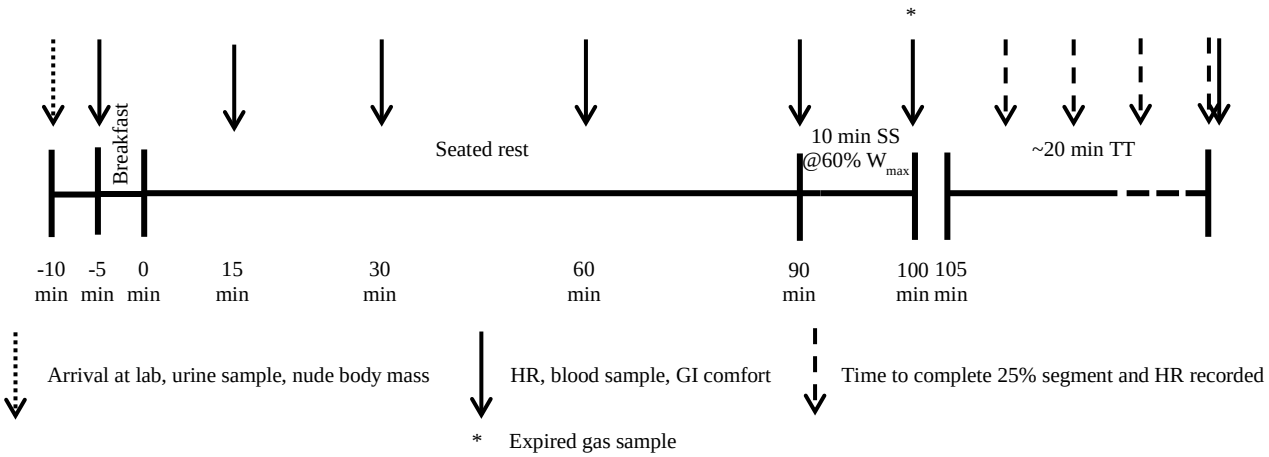
List of figures

405 Figure 1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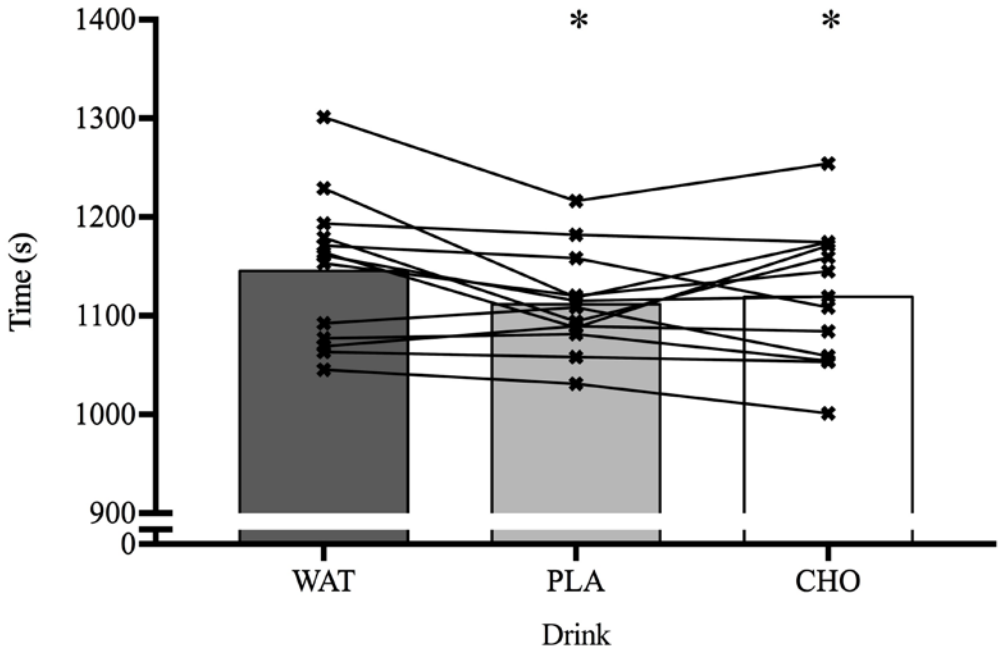
Breakfast
Seated rest
10 min SS
@60% W max
~20 min TT
-10 min
-5 min
0 min
15 min
30 min
60 min
90 min
100 min
105 min
Arrival at lab, urine sample, nude body mass
HR, blood sample, GI comfort
Time to complete 25% segment and HR recorded
* Expired gas sample

406 Figure 2



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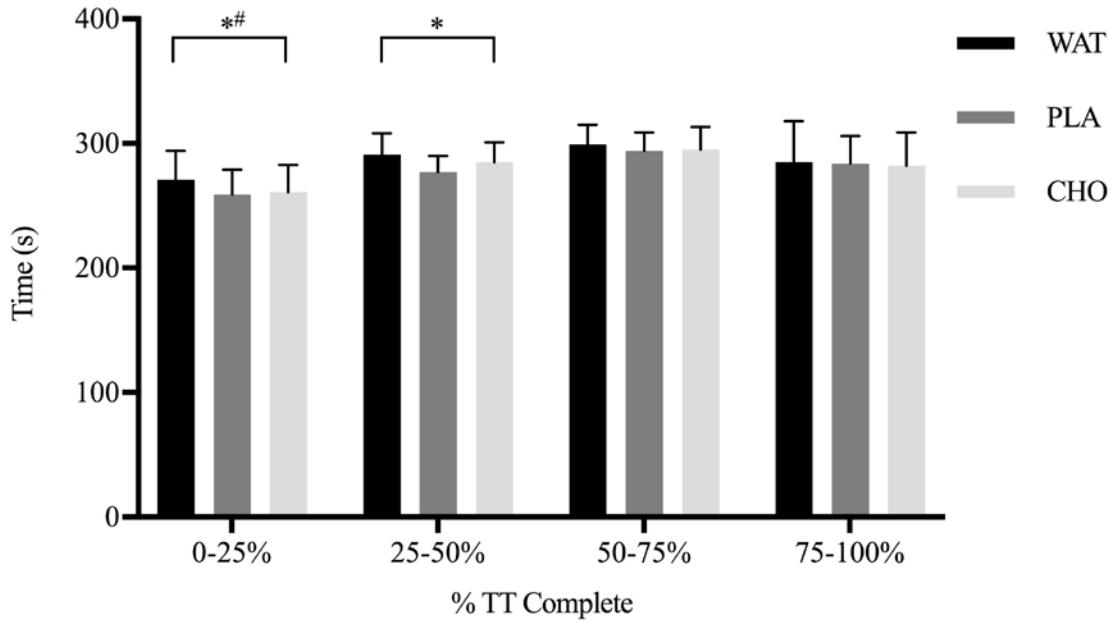

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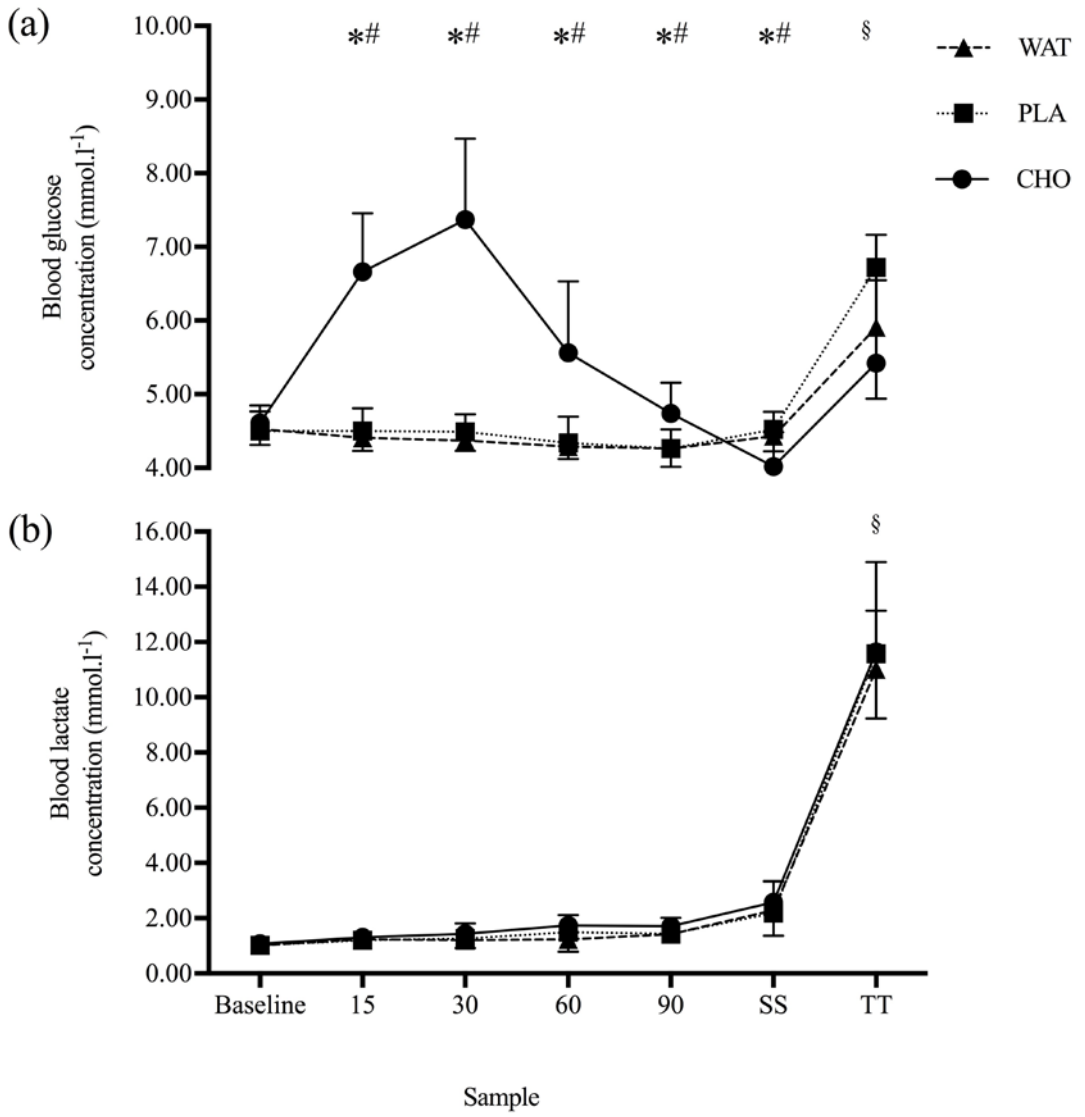

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