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The effect of a breakfast's glycaemic index and type of hydration on metabolism and cycling performance: a crossover, randomized, controlled clinical trial

El efecto del índice glucémico del desayuno y el tipo de hidratación en el metabolismo y el rendimiento del ciclismo: un ensayo clínico cruzado, aleatorizado y controlado

Mariana de Melo Cazal[1], Rita de Cássia Gonçalves Alfenas[1], Maria do Carmo Gouveia Peluzio[1], Paulo Roberto dos Santos Amorim[2], Priscila Alvez Tomaz[1] & João Bouzas Carlos Marins[2]

1. Departamento de Nutrição e Saúde. Viçosa Federal University. Brazil
2. Departamento de Educação Física. Viçosa Federal University. Brazil

Abstract

The purpose of this study was to compare the effect of the glycaemic index of breakfast on metabolic parameters and performance of cyclists with different types of hydration (water or isotonic beverage). Twelve male recreational cyclists participated in four experimental trials where they consumed either a high glycaemic index (HGI) or low glycaemic index (LGI) meal, 30 min before exercise on a cycle ergometer. Exercise was performed at 70% maximal oxygen uptake for 90 min followed by a 6 km performance. During each trial, 3 mL.kg-1 body mass of either water or isotonic beverage was provided. The postprandial glycaemic response and areas under the blood glucose curve 30 min after ingestion were higher after the consumption of the HGI meals than that after the consumption of the LGI meals. The glycaemic response and carbohydrate oxidation during the trials with isotonic beverage consumption were higher than that in trials with water consumption during exercise ($p<0.05$). There was no significant difference on exercise performance among all trials ($p=0.409$). This study demonstrated that, despite significant metabolic changes, neither LGI nor HGI meals consumed for breakfast, 30 min before exercise on a cycle ergometer, affect subsequent cycling performance.

Key Words: glycaemic response; isotonic solutions; breakfast; carbohydrate; exercise.

Resumen

El objetivo de este estudio fue comparar desayunos con diferentes índices glucémicos y efecto del tipo de hidratación (agua o bebida isotónica) sobre los parámetros metabólicos y el rendimiento de los ciclistas. Doce ciclistas recreativos de sexo masculino participaron en cuatro pruebas experimentales en las que consumieron un desayuno de alto índice glucémico (AGI) o de bajo índice glucémico (BGI), 30 minutos antes del ejercicio en un cicloergómetro. El ejercicio se realizó a un 70%VO2max durante 90 minutos, seguido de 6 km al menor tiempo posible. Durante cada prueba, se suministraron 3 mL.kg-1 de masa corporal de agua o de bebida isotónica. La respuesta glucémica postprandial y las áreas bajo la curva de glucosa en sangre 30 min después de la ingesta fueron mayores tras el desayuno de AGI que tras el desayuno con BGI. La respuesta glucémica y la oxidación de carbohidratos durante los ensayos con consumo de bebidas isotónicas fueron mayores que en los ensayos con consumo de agua durante el ejercicio ($p<0,05$). No hubo diferencias significativas en el rendimiento del ejercicio entre todos los ensayos ($p=0,409$). Este estudio demostró que, a pesar de los cambios metabólicos significativos, ni las comidas BGI ni AGI consumidas en el desayuno, 30 min antes del ejercicio en cicloergómetro afectan al rendimiento final del ciclismo.

Palabras clave: respuesta glucémica; soluciones isotónicas; desayuno; carbohidratos; ejercicio.

Correspondence/correspondencia: Mariana de Melo Cazal
Departamento de Nutrição e Saúde. Viçosa Federal University. Brazil
Email: marianademelocazal@yahoo.com.br

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Introduction

Although the importance of adequate dietary carbohydrate (CHO) for optimal physical performance has long been recognised, the type and amount of CHO might also impact on performance (Zajac, Poprzecki, Maszczyk, Czuba, Michalczyk, & Zydek, 2014). The glycaemic index (GI) of a CHO rich meal ingested before exercise can be used as an indication of glycaemic and insulinemic parameters, which subsequently affect metabolic responses during exercise (Wong, Chan, Chen, Hu, Lam, & Chung, 2009).

In practice, athletes usually consume supplements or food rich in CHO during the physical activity, in addition to pre-exercise meals. Additionally, international institutions recommend the intake of CHO (30-60 $g \cdot h^{-1}$) during exercises with duration of at least an hour, especially when the exercise is performed earlier in the morning (American College of Sports Medicine, 2016; Kerksick, Thomas, Campbell, Taylor, Wilborn, Marcello, Roberts, Pfau, Grimstvedt, Opusunju, Magrans-Courtney, Rasmussen, Wilson, & Kreider, 2009). Accordingly, the combination of nutritional strategies has been suggested to improve performance compared to the pre-exercise meal alone or the intake of CHO during exercise alone (Chen et al., 2009).

The intake of CHO during exercise enables the maintenance of glycaemia, thus increasing the availability of glucose for the working muscles. Thus, it decreases the usage of muscle glycogen and consequently extends the time for the onset of fatigue (Funnell, Dykes, Owen, Mears, Rollo, & James, 2017). This is mainly observed during endurance exercises. Currently, relatively few studies have proper investigated the interaction between the intake of pre-exercise meals with different GIs on performance when CHO supplementation is consumed during exercise (Burke et al., 1998; Chen et al., 2009; Wong et al., 2009).

Burke et al. (1998) analysed the impact of a pre-exercise GI meal and CHO-electrolyte solution during exercise on metabolism and performance during prolonged cycling. However, in this study, the meals were offered 2 h before exercise, which is too long for athletes who are training in the morning, because of the small time between the end of the meal and the beginning of the exercise. This period may therefore be sufficient to normalize the different metabolic effects that occur after the consumption of meals and, thus, participants may have initiated the exercises with normal glucose and insulin levels. Although the international recommendations (American College of Sports Medicine, 2016) indicate the consumption of the meal, at least 60 minutes before exercise, this is not always possible for those practitioners who start training between 5 and 7 o'clock in the morning, a reality very present in Brazil due to its tropical climate. In addition, to our knowledge, no study has compared the strategy of hydration with CHO drinks and water during exercise after the intake of pre-exercise meals with different GIs. This analysis would further enable us to investigate the effects of the meal's GI on performance and whether such effects are altered when CHO are consumed during exercise. Therefore, the mail goal of this study was to compare the effect of consuming a low (LGI) or high (HGI) breakfast, 30 min before exercise, on metabolic parameters and performance with different types of hydration (water or isotonic beverage) during exercise on a cycle ergometer.

Methods

Participants

Twelve male recreational cyclists volunteered to participate in the current study. All participants had a minimum of three years of cycling experience, training for 60 minutes at least 3 times per week. Table 1 presents the characteristics of the participants.

Table 1. Means ± standard deviation (SD), minimum and maximum of the characteristics of the participants

Characteristics	Mean ± SD	Minimum – Maximum
Age (years)	29.25 ± 6.54	21 − 40
Body mass (Kg)	69.25 ± 8.42	60.1 − 74.9
Height (m)	1.75 ± 0.05	1.68 – 1.82
Body mass index ($kg.m^{-2}$)	22.62 ± 2.31	20.31 − 24.82
Body fat (%)	9.97 ± 2.14	6.5 − 13.7
VO2max ($mL.kg^{-1}.min^{-1}$)	52.22 ± 7.63	45.11 − 64.36

After being informed of the procedures, all eligible participants signed informed consent document, in accordance with university guidelines for the protection of human subjects. The study was approved by the Ethics Committee in Research with Humans of the Universidade Federal de Viçosa (Opinion no. 057/2009), in accordance with the Declaration of Helsinki.

Experimental Design

The experimental design was a crossover and the trials were completely randomized. Participants completed four experimental trials, as follows:

(1) LGIHW trial: ingestion of LGI meal and hydration with water;

(2) LGIHI trial: ingestion of LGI meal and hydration with isotonic beverage;

(3) HGIHW trial: ingestion of HGI meal and hydration with water;

(4) HGIHI trial: ingestion of HGI meal and hydration with isotonic beverage;

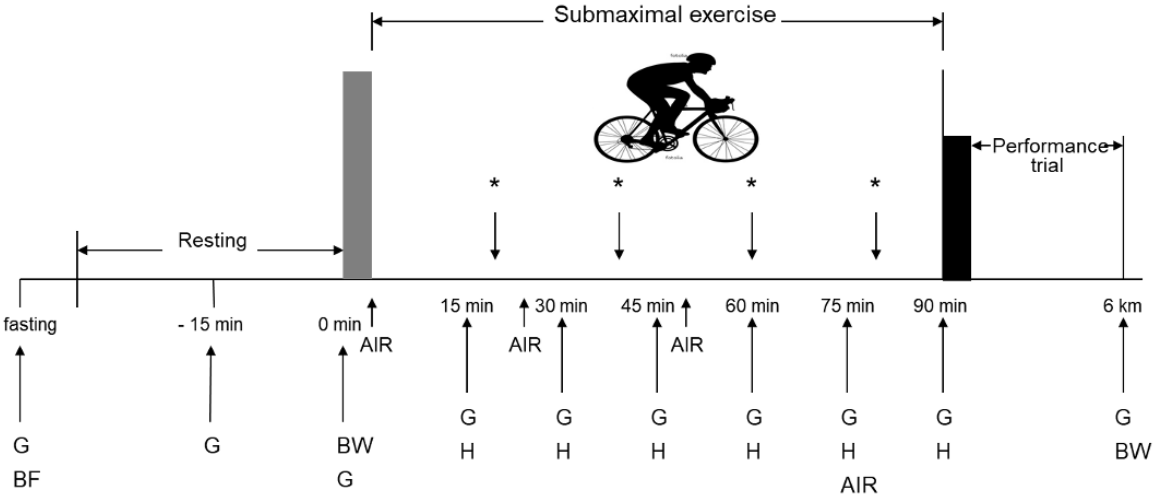
The trials were separated by at least seven days. The participants were required to record their diet during the day before the first trial, and were asked to repeat exactly the same diet for the day before each trial, which was verified by a food diary analysis. The energy intake and dietary composition of each food diary were subsequently analysed (DietPro® software, Brazil). They were also asked to abstain from alcohol, caffeine, tea, and tobacco consumption during the 24 h before each main trial, and had a 2 days rest period before each trial.

Baseline Maximal Oxygen Uptake (VO_2 max)

One week prior to their first trial, the participants performed a progressive exercise test to determine their maximal oxygen uptake (VO_{2max}). Expired air was measured breath-by-breath using an automated open-circuit gas analysis (Medial Graphics Corporation®, VO2000, Saint Paul, MN). The test began at 3-min warm-up at 35 W, and them after the work rate was increased to 50 W. Thereafter, the exercise intensity was increased by 20 $W \cdot min^{-1}$, while the participant continuously pedalled at 60 rpm (Storer et al., 1990). VO_{2max} was established according to the following criteria by Tanaka, Monahan and Seals (2001).

Experimental Protocol

Participants reported to the laboratory following a 12 h fast. After resting sited for 10 min, a baseline blood sample was collected. The participants then consumed either low or high isocaloric GI meal and rested for the next 30 min before they started the prescribed exercise protocol (Figure 1). Then, 30 min after meal consumption, participants completed a 5-min warm-up at 60% VO_{2max} on the cycle ergometer (Scifit®, ISO 1000, berkshire, UK). Immediately following the warm-up, the exercise intensity was increased to elicit 70% VO_{2max} and the exercise continued for 90 min, at a constant cadence of 60 rpm. Upon completion of the submaximal exercise, the participants rested for 3 min before they commenced the 6-km performance cycle. The participants were required to cover 6 km as fast as possible. The participants were not aware of their performance times but they receive a verbal reminder after every km completed and every 100 m completed in the last km. Notably, a similar exercise protocol was used in other studies (Febbraio et al., 2000; Sparks et al., 1998; Toone & Betts, 2010).



G Glycaemia	5-min warm-up	* Rating of Perceived Exertion
BF Breakfast	AIR Expired Air Collection	3-min rest period
BW Body Weight	H Hydration	

Figure 1. Schematic representation of the experimental procedures.

During the 90 min exercise, 3mL.kg^{-1} body mass of either water or isotonic beverage (6g CHO per 100mL) was given to the participants every 15 min in opaque bottles.

Expired air samples were collected during the first 5 min of exercise, during the last 5 min of every 20 min of submaximal exercise period and continuously throughout the performance trial.

The rating of perceived exertion (RPE) was evaluated every 20 min during the exercise using the Borg scale (1982).

Test Meals

Nine men completed testing to determine the GIs of the test meals. To accomplish this, participants reported to the laboratory following an overnight (12 h) fast. Glycaemic indexes of servings of the meals providing 25g of available CHO were assessed relative to 25g of glucose according to the methods of Wolever and Bolognesi (1996). Blood samples were collected during fasting and at 15, 30, 45, 60, 90, and 120 minutes after consumption of each meal (World Health Organization, 1998). The areas under the glycaemic response curves of the meals were expressed relative to the response to glucose (Wolever et al., 1991).

The test meals had the same energy, fibre content and macronutrient compositions (67.5% CHO; 8.5% protein; 24% fat) (Table 2). Each meal provided 1 g available CHO/kg body mass (CHO total [g] − fibre content [g]) (Febbraio et al., 2000; Moore et al., 2010; Sparks et al., 1998). The HGI meal was accompanied with a specific amount of water for each participant in order to have the same volume as the LGI meal and minimize differences in gastric volume.

Table 2. Means ± standard deviation of the macronutrient profile, energy and fibre content of test meals

Content	Meal	
	High glycaemic index	Low glycaemic index
Carbohydrate (g)	78.87 ± 8.81	77.87 ± 8.81
Protein (g)	8.40 ± 0.61	10.15 ± 1.50
Fat (g)	8.53 ± 0.10	8.91 ± 0.65
Fibre (g)	4.46 ± 0.51	4.46 ± 0.50
Energy (kcal)	425.83 ± 35.6	429.60 ± 46.0
Glycaemic index	76.60	45.45

The HGI meal consisted of corn flakes, soluble fibre, isotonic drink, plain yogurt, processed cheese and a banana. The LGI meal consisted of creamy yogurt, oatmeal and honey cookies, margarine, apple juice, and a fuji apple.

Analysis

Expired air samples were collected at 10s intervals using the open-circuit gas analysis described above. Analyser outputs were processed by Aerograph Breeze® software. The gas analysers were calibrated immediately before each test using ambient air. The CHO oxidation rate was calculated from VO_2 and VCO_2 values using a stoichiometric equation (Frayn, 1983).

Capillary blood samples (25 μL) were collected by fingertip perforation with sterile micro lancets coupled to the automatic Accu-check Softclix® lancing device (Accu-check Softclix®, Jaguaré, Brazil). The glucose was immediately determined using the Accu-check Go® portable glucometer. The precision of this method was previously approved (Thomas, Kane, Bakst, Busch, Hamilton, & Abelseth, 2008).

The HR was measured at 15 second intervals during the exercise using the Polar® S610 telemetry system and managed by Polar Precision Performance SW 3.0 software (Polar®, Rio de Janeiro, Brazil).

The body weight was obtained before and after exercise using the Welmy W200 digital balance (Welmy®, São Paulo, Brazil). Sweat was removed from the skin before weighing in order to measure body fluid balance. Participants were wearing minimal clothing.

Statistical Analyses

Data were subjected to Shapiro-Wilk's normality test and are presented as mean and standard deviation (M ± SD). Data that were normally distributed were analysed by parametric tests. Comparisons where at least one parameter failed to exhibit normal distribution, as well as RPE, were evaluated by non-parametric tests.

A two-way ANOVA with repeated measures was used to evaluate the variables among trials and over time. Significant mean differences were identified with a Tukey's *post-hoc* test.

In order to identify difference in specific time points (before × after), the Student's *t* test was used. All statistical analyses were performed using Sigma Plot v.11.0 software.

In addition, clinical significance was defined by calculating of the effect size (ES) through Cohen's d with values 0.2, 0.5, and 0.8 corresponding to small, medium, and large effect sizes (Cohen, 1988). Statistical significance was accepted at $p < 0.05$.

Results

Dietary Analysis

There were no significant differences in the total caloric consumption (p=0.215), carbohydrate (p=0.484), protein (p=0.928), fat (p=0.915) or fibre (p=0.757) composition from the diet consumed by participants during the day before each experimental trial.

Glycemic Response

There were no significant differences in fasting glycaemia among the trials. After 15 min of consuming each of the four meals, blood glucose concentration rose significantly. However, higher blood glucose concentration was observed at 15 and 30 min after ingestion of the HGI meals (HGIHW and HGIHI) compared to the LGI meals (LGIHW and LGIHI) ($p<0.05$; Figure 2).

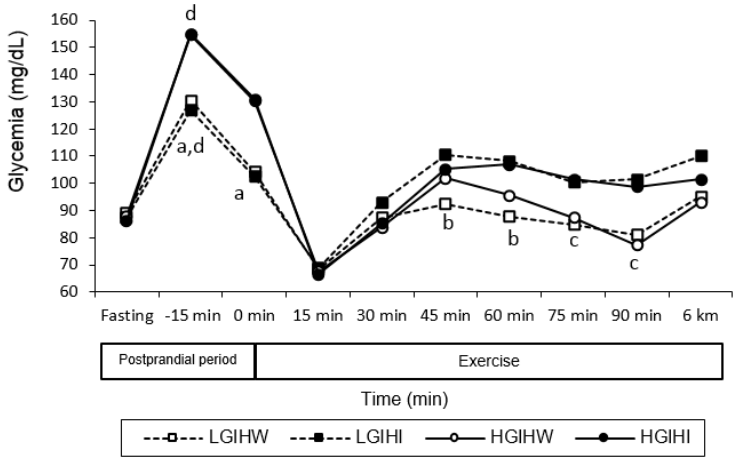


Figure 2. The mean values of glycaemic response during fasting, the postprandial period, and during the LGIHW, LGIHI, HGIHW, and HGIHI trials. The following significant differences ($p<0.05$) were observed: (a) lower blood glucose levels in the LGIHW and LGIHI trials vs the HGIHW and HGIHI trials; (b) lower blood glucose levels in the LGIHW trial vs the LGIHI and HGIHI trials; (c) lower blood glucose levels in the LGIHW and HGIHW trials vs the LGIHI and HGIHI trials; (d) value at −15 min was higher than that at any time point in the LGIHW, HGIHW, and HGIHI trials (Two-way ANOVA with repeated with a Tukey's *post-hoc* test).

After 45 min of exercise, the glycaemic response was higher in the trials with isotonic hydration (LGIHI and HGIHI) than in the trials with water hydration (LGIHW and HGIHW). During exercise, the blood glucose concentration at 45 and 60 min in the LGIHW trial and at 75 and 90 min in the LGIHW and HGIHW trials were significantly lower than in the LGIHI and HGIHI trials ($p< 0.05$; Figure 2).

Area under the curve

The incremental area under the curve (AUC) for blood glucose, over the postprandial period, was lower after ingestion of the LGI meals (LGIHW and LGIHI) compared to the HGI meals (HGIHW and HGIHI) ($p<0.05$; Figure 3).

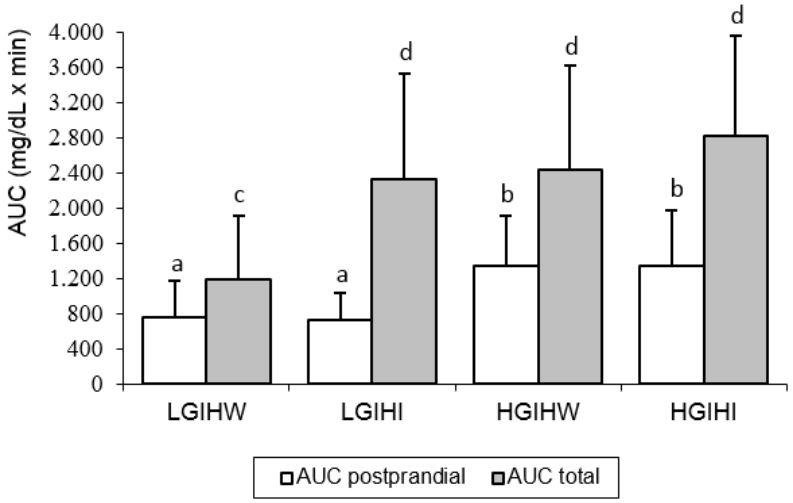


Figure 3. Mean ± standard deviation values of total and postprandial areas under the curves (AUC) for blood glucose during the LGIHW, LGIHI, HGIHW, and HGIHI trials. (a,b) Postprandial AUC was lower in the LGIHW and LGIHI trials vs the HGIHW and HGIHI trials ($p<0.05$); (c, d) Total AUC was lower in the LGIHW trial vs the LGIHI ($p=0.005$; ES=-1.15) , HGIHW ($p=0.002$; ES=-1.28) and HGIHI trial ($p=0.001$; ES=-1.69). Two-way ANOVA with repeated with a Tukey's *post-hoc* test; ES = Effect Size.

The total AUC (postprandial period AUC and AUC during exercise) in the LGIHW trial was lower than that in the LGIHI, HGIHW, and HGIHI trials ($p<0.05$).

Carbohydrate Oxidation

The CHO oxidation rate was significantly lower in the LGIHW and HGIHW trials at 75 min of exercise than that during the LGIHI and HGIHI trials. The CHO oxidation rate was higher in the LGIHI trial at the end of the performance cycle compared to the HGIHW trial ($p=0.027$; ES=0.76; Figure 4).

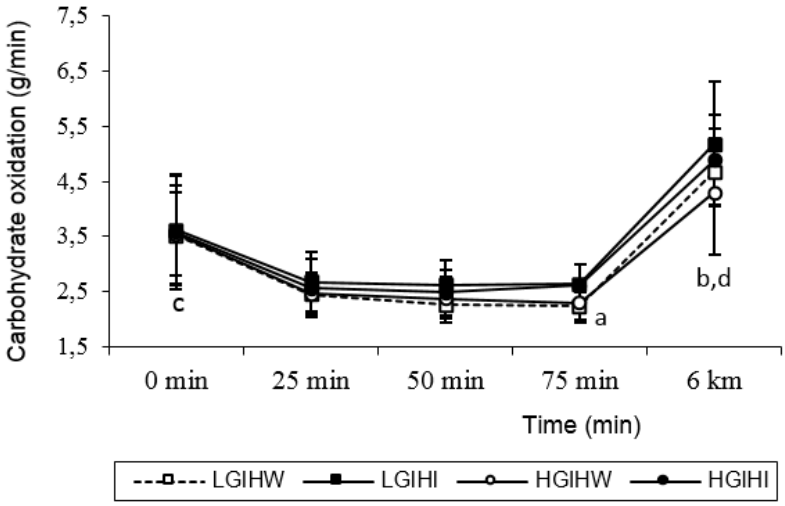


Figure 4. Mean ± standard deviation values of carbohydrate oxidation rates during the exercise in the LGIHW, LGIHI, HGIHW, and HGIHI trials. (a) Carbohydrate oxidation rates were lower in LGIHW and HGIHW vs LGIHI and HGIHI ($p<0.05$); (b) Carbohydrate oxidation rates were lower in HGIHW vs LGIHI ($p=0.027$; ES=0.76); (c) Value at 0 min higher than that at 25, 50 e 75 min during exercise in the LGIHW, LGIHI, HGIHW and HGIHI trials ($p<0.05$); (d) Value at 6 km was higher than that at all previous time points in the LGIHW, LGIHI, HGIHW and HGIHI ($p<0.05$). Two-way ANOVA with repeated with a Tukey's *post-hoc* test; ES = Effect Size.

During the first 5 min of submaximal exercise, the CHO oxidation rate was higher than at any other time point during exercise in all four experimental trials. The CHO oxidation rate during the performance test was higher compared to all time points during the submaximal exercise in all trials.

Heart rate

There were no significant differences in resting HR and during exercise among the four trials ($p=0.611$). The resting HR was lower than that at all other time points during exercise in the trials ($p<0.05$). During the performance cycle, the HR was higher compared with submaximal exercise and resting in all trials ($p<0.05$).

Body Weight

There were no significant differences in the body-weight change (before and after exercise) among the four trials ($p>0.05$).

RPE

The RPE value at 20 min was lower than that at 60 ($p=0.043$; SE=-0.43) and 80 min ($p=0.043$; SE=-0.43) during exercise in the LGIHI trial. There were no significant differences during exercise among the trials ($p>0.05$).

Performance

There were no significant differences with respect to completing the 6-km performance cycle among the four trials ($p = 0.409$).

Discussion

The aim of this study was to compare the effect of a meal's GI, consumed 30 min before exercise, on cyclists' metabolic parameters and performance while drinking different forms of fluids (water or isotonic beverage) during exercise. We found that the glycaemic response at 75 min of exercise was significantly higher in the trials with isotonic consumption (LGIHI and HGIHI) compared to trials with water consumption (LGIHW and HGIHW). The consumption of isotonic drinks during exercise minimizes the possibility of hypoglycaemia to a greater extent than when only water is provided. Additionally, at this time point, the CHO oxidation in the LGIHI and HGIHI trials was higher than that in the LGIHW and HGIHW trials. This suggests that the higher CHO oxidation observed during the trials with an isotonic beverage may be due to the availability and oxidation of exogenous glucose supplied as fuel during exercise. This additional CHO as a source of energy during exercise likely contributed to sparing limited muscle and liver glycogen stores (Luden et al., 2016). Considering the average body weight of the individuals (69.25 kg), the amount of liquid ingested ($3mL.kg^{-1}$) every 15 minutes and the concentration of carbohydrates in the drink (6%), the total carbohydrates they ingested on average were 49.86g/hour, ranging from 43.27-53.93g/hour of exercise. Therefore, the amounts of carbohydrate ingested are within the recommendations of 30-60g/hour (American College of Sports Medicine, 2016). According to Donaldson, Perry and Rose (2010), the CHO ingested during high-intensity exercise improves performance due to an increase in CHO oxidation in the latter stages of exercise when muscle glycogen stores are rather low. We further demonstrate that the CHO oxidation observed in the last 6 km in the LGIHI trial was higher than that in the HGIHW trial. It is important to note, however, that such metabolic changes were not sufficient to promote changes in the performance time between the four experimental trials.

The incremental area under the blood glucose curve after 30 min of HGI meal consumption was higher than after the ingestion of the LGI meal. Considering that the meals were both isocaloric and provided an average 78.37 g CHO, the 66.67% greater postprandial AUC after the HGI meal is, therefore, not the result of the differences in the energy or macronutrients content between the meals but was attributable to the GI difference. Such differences in postprandial AUC are due to the fact that LGI foods induce lower postprandial hyperglycaemia, thus improving the maintenance of blood glucose levels (Burdon et al., 2017). Accordingly, greater postprandial AUC in the HGI trial has also been observed previously (Chen et al., 2009; Wu & Williams, 2006).

Adequate fluid intake during exercise is crucial to minimize the fluid unbalance caused by losses through sweating and to prevent dehydration. A dehydrated state may cause physiological changes such as an increase in internal body temperature, heart rate, and perceived exertion (Carlton & Orr, 2015). However, no differences in HR or RPE during exercise among the trials were observed. Therefore, the results of the present study indicate that the exercise intensity was similar in the four experimental trials and that the GI of the pre-exercise meal and the type of hydration offered during exercise mostly did not affect the evaluated parameters. Similarly, Sparks et al. (1998) did not observe an effect of GI on body temperature, HR, and RPE during 50 min of exercise on a cycle ergometer.

Dehydration is also a limiting factor in exercise performance. Fluid replacement should balance sweat and urinary losses to maintain hydration at less than 2% reduction in body mass (Cotter et al., 2014). The change in body mass before and after exercise has been used in certain studies presenting itself as a precise evaluation parameter for the participant's state of hydration in shorter duration laboratory settings (Hew-Butler et al., 2015; Wu & Williams, 2006). In this

study, the body-weight change during the four trials ranged from −1.32% to +1.01%. This implies that the amount of fluid provided (3 $mL.kg^{-1}$ body mass every 15 min) during the 90 min of exercise sustained the hydration status of the participants and that their performance was clearly not impaired by fluid loss.

Our results are in good agreement that the studies of Jamurtas, Tofas, Fatouros, Nikolaidis, Paschalis, Yfanti and Raptis (2011) and Bennett, Chilibeck, Barss, Vatanparast, Vandenberg and Zello (2012) showing no significant difference in RPE among exercise trials. According to Garcin, Piton, Brésillion and Pérès (2001), the GI of the pre-exercise meal does not affect the RPE during high-intensity exercise, as other psychological and physiological factors can mediate perceived exertion responses. It is important to highlight that the RPE obtained during the four experimental trials shows the submaximal stimulus proposed for the development of the experiment, thus providing the internal validity for the study.

The main finding of the current study was that when an isotonic drink was ingested during 90 min of submaximal exercise on a cycle ergometer, performance time was highly similar to that observed when consuming water during the same exercise protocol, irrespective of consuming an LGI or HGI pre-exercise meal providing 1 g CHO/kg body mass. Although muscle glycogen was not measured, muscle glycogen at the onset of the performance cycle was likely to be of sufficient concentration in all trials, thereby not effect on performance. Considering that the glycaemic response was higher at the end of the isotonic beverage consumption trials, it seems reasonable to speculate that if the exercise period was extended, better performance times would be observed in these trials than in the trials that involved the consumption of water (LGIHW and HGIHW).

Our study has some limitations that must be considered. One of the study's limitations is related to the lack of evaluation of some parameters such as serum insulin levels, free fatty acids and muscle glycogen before and after exercise. These parameters must be evaluated in order to allow a more accurate analysis of the energy metabolism and the performance of cyclists. The number of our sample makes it difficult to generalize the results obtained. However, it is worth mentioning that this small number of participants is used in similar clinical trial studies. In addition, we used a low cadence (60 rpm) for the cycle ergometer, which may have resulted in fatigue and affected performance.

Future research in this area could indicate the type of CHO (glucose, fructose, maltodextrin) used before and during exercise is a suggestion in order to determine the specific effect of the type of carbohydrate, which was not the aim of the current study.

These results provide useful information for nutritionists and cyclists on dietary strategies that can be used before and during cycling exercise. To achieve good physical performance, it is necessary to assess the individual effects of each nutritional strategy so that to decide the best of each other.

Conclusion

The glycaemic response and CHO oxidation in the isotonic beverage trials were higher than that observed in trials with water consumption at the end of the submaximal exercise, regardless of whether a HGI or LGI pre-exercise breakfast was ingested. Despite these metabolic changes, our results clearly show that the CHO quality consumed 30 min before exercise on a cycle ergometer, as well as the type of hydration consumed during exercise, seems to not affect the subsequent performance for this group of participants.

References

American College of Sports Medicine. (2016). Nutrition and Athletic Performance. *Medicine and Science in Sports and Exercise*, *48*(3), 543–568. https://doi.org/10.1249/MSS.0000000000000852

Bennett, C. B.; Chilibeck, P. D.; Barss, T.; Vatanparast, H.; Vandenberg, A., & Zello, G. A. (2012). Metabolism and performance during extended high-intensity intermittent exercise after consumption of low-and high-glycaemic index pre-exercise meals. *British Journal of Nutrition*, *108*(SUPPL. 1), 81–90. https://doi.org/10.1017/S0007114512000840

Borg, G. (1982). Psychophysical bases of perceived exertion. *Medicine & Science in Sports & Exercise*, *14*(5), 377–381.

Burdon, C. A.; Spronk, I.; Cheng, H. L., & O'Connor, H. T. (2017). Effect of Glycemic Index of a Pre-exercise Meal on Endurance Exercise Performance: A Systematic Review and Meta-analysis. *Sports Medicine*, *47*(6), 1087–1101. https://doi.org/10.1007/s40279-016-0632-8

Burke, L. M.; Claassen, A.; Hawley, J. A., & Noakes, T. D. (1998). Carbohydrate intake during prolonged cycling minimizes effect of glycemic index of preexercise meal. *Journal of Applied Physiology*, *85*(6), 2220–2226. https://doi.org/10.1152/jappl.1998.85.6.2220

Carlton, A., & Orr, R. M. (2015). The effects of fluid loss on physical performance: A critical review. *Journal of Sport and Health Science*, *4*(4), 357–363. https://doi.org/https://doi.org/10.1016/j.jshs.2014.09.004

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). New York: Routledge. Retrieved from: https://www.taylorfrancis.com/books/9781134742707

Chen, Y. J.; Wong, S. H. S.; Chan, C. O. W.; Wong, C. K.; Lam, C. W., & Siu, P. M. F. (2009). Effects of glycemic index meal and CHO-electrolyte drink on cytokine response and run performance in endurance athletes. *Journal of Science and Medicine in Sport*, *12*(6), 697–703. https://doi.org/10.1016/j.jsams.2008.05.007

Cotter, J. D.; Thornton, S. N.; Lee, J. K. W., & Laursen, P. B. (2014). Are we being drowned in hydration advice? Thirsty for more? *Extreme Physiology and Medicine*, *3*(1), 1–16. https://doi.org/10.1186/2046-7648-3-18

Donaldson, C. M.; Perry, T. L., & Rose, M. C. (2010). Glycemic index and endurance performance. *International Journal of Sport Nutrition and Exercise Metabolism*, *20*(2), 154–165. https://doi.org/10.1123/ijsnem.20.2.154

Febbraio, M. A.; Keenan, J.; Angus, D. J.; Campbell, S. E., & Garnham, A. P. (2000). Preexercise carbohydrate ingestion, glucose kinetics, and muscle glycogen use: Effect of the glycemic index. *Journal of Applied Physiology*, *89*(5), 1845–1851. https://doi.org/10.1152/jappl.2000.89.5.1845

Frayn, K. (1983). Calculation of substrate oxidation rates in vivo from gaseous exchange. *Journal of Applied Physiology*, *55*(2), 628–634.

https://doi.org/0161-7567/83

Funnell, M. P.; Dykes, N. R.; Owen, E. J.; Mears, S. A.; Rollo, I., & James, L. J. (2017). Ecologically valid carbohydrate intake during soccer-specific exercise does not affect running performance in a fed state. *Nutrients*, *9*(1). https://doi.org/10.3390/nu9010039

Garcin, M.; Piton, A.; Brésillion, S., & Pérès, G. (2001). Does perceived exertion depend on glycemic index of foods ingested throughout three hours before a one-hour high-intensity exercise? *Perceptual and Motor Skills*, *93*(3 PART 1), 599–608. https://doi.org/10.2466/pms.2001.93.3.599

Hew-Butler, T.; Holexa, B. T.; Fogard, K.; Stuempfle, K. J., & Hoffman, M. D. (2015). Comparison of body composition techniques before and after a 161-Km ultramarathon using DXA, BIS and BIA. *International Journal of Sports Medicine*, *36*(2), 169–174. https://doi.org/10.1055/s-0034-1387777

Jamurtas, A. Z.; Tofas, T.; Fatouros, I.; Nikolaidis, M. G.; Paschalis, V.; Yfanti, C.; Raptis, S., & Koutedakis, Y. (2011). The effects of low and high glycemic index foods on exercise performance and beta-endorphin responses. *Journal of the International Society of Sports Nutrition*, *8*. https://doi.org/10.1186/1550-2783-8-15

Kerksick, C.; Thomas, A.; Campbell, B.; Taylor, L.; Wilborn, C.; Marcello, B.; Roberts, M.; Pfau, E.; Grimstvedt, M.; Opusunju, J.; Magrans-Courtney, T.; Rasmussen, C.; Wilson, R., & Kreider, R. B. (2009). Effects of a popular exercise and weight loss program on weight loss, body composition, energy expenditure and health in obese women. *Nutrition and Metabolism*, *6*, 1–17. https://doi.org/10.1186/1743-7075-6-23

Luden, N. D.; Saunders, M. J.; D'Lugos, A. C.; Pataky, M. W.; Baur, D. A.; Vining, C. B., & Schroer, A. B. (2016). Carbohydrate mouth rinsing enhances high intensity time trial performance following prolonged cycling. *Nutrients*, *8*(9). https://doi.org/10.3390/nu8090576

Moore, L. J. S.; Midgley, A. W.; Thurlow, S.; Thomas, G., & Naughton, L. R. M. (2010). Effect of the glycaemic index of a pre-exercise meal on metabolism and cycling time trial performance. *Journal of Science and Medicine in Sport*, *13*(1), 182–188. https://doi.org/10.1016/j.jsams.2008.11.006

Sparks, M. J.; Selig, S. S., & Febbraio, M. A. (1998). Pre exercise carbohydrate ingestion: Effect of the glycemic index on endurance exercise performance. *Medicine and Science in Sports and Exercise*, *30*(6), 844–849. https://doi.org/10.1097/00005768-199806000-00011

Storer, T. W.; Davis, J. A., & Caiozzo, V. J. (1990). Accurate prediction of VO2max in cycle ergometry. *Medicine and Science in Sports and Excercise*, *22*(5), 704–712.

Tanaka, H.; Monahan, K. D., & Seals, D. R. (2001). Age-predicted maximal heart rate revisited. *Journal of the American College of Cardiology*, *37*(1), 153–156. https://doi.org/10.1016/S0735-1097(00)01054-8

Thomas, L. E.; Kane, M. P.; Bakst, G.; Busch, R. S.; Hamilton, R. A., & Abelseth, J. M. (2008). A glucose meter accuracy and precision comparison: The freestyle flash versus the accu-chek advantage, accu-chek compact plus, ascensia contour, and the BD logic. *Diabetes Technology and Therapeutics*, *10*(2), 102–110. https://doi.org/10.1089/dia.2007.0244

Toone, R. J., & Betts, J. A. (2010). Isocaloric carbohydrate versus carbohydrate-protein ingestion and cycling time-trial performance. *International Journal of Sport Nutrition and Exercise Metabolism*, *20*(1), 34–43. https://doi.org/10.1123/ijsnem.20.1.34

Wolever, T. M. S., & Bolognesi, C. (1996). Source and amount of carbohydrate affect postprandial glucose and insulin in normal subjects. *Journal of Nutrition*, *126*(11), 2798–2806. https://doi.org/10.1093/jn/126.11.2798

Wolever, T. M. S.; Jenkins, D. J. A.; Jenkins, A. L., & Josse, R. G. (1991). The glycemic index: Methodology and clinical implications. In *American Journal of Clinical Nutrition* (Vol. 54, Issue 5, pp. 846–854). Am J Clin Nutr. https://doi.org/10.1093/ajcn/54.5.846

Wong, S. H. S.; Chan, O. W.; Chen, Y. J.; Hu, H. L.; Lam, C. W., & Chung, P. K. (2009). Effect of Preexercise Glycemic-Index Meal on Running When CHO-Electrolyte Solution Is Consumed during Exercise. *International Journal of Sport Nutrition and Exercise Metabolism*, *19*(3), 222–242. https://doi.org/10.1123/ijsnem.19.3.222

World Health Organization, F. and A. O. of the U. N. (1998). *Carbohydrates in human nutrition : report of a joint FAO/WHO expert consultation*. World Health Organization.

Wu, C. L., & Williams, C. (2006). A low glycemic index meal before exercise improves endurance running capacity in men. *International Journal of Sport Nutrition and Exercise Metabolism*, *16*(5), 510–527. https://doi.org/10.1123/ijsnem.16.5.510

Zajac, A.; Poprzecki, S.; Maszczyk, A.; Czuba, M.; Michalczyk, M., & Zydek, G. (2014). The effects of a ketogenic diet on exercise metabolism and physical performance in off-road cyclists. *Nutrients*, *6*(7), 2493–2508. https://doi.org/10.3390/nu6072493