Medicina Sportiva
Med Sport 17 (2): 60-66, 2013
DOI: 10.5604/17342260.1055257

BLOOD GLUCOSE RESPONSE BEFORE AND DURING EXERCISE: THE EFFECTS OF FASTING AND MEALS WITH HIGH AND LOW GLYCEMIC INDICES

Janaína Lubiana Altoé[1 (A-G)], Rafael Pires da Silva[2 (B-F)], Guilherme Giannini Artioli[2 (D,E)], Rita de Cássia Gonçalves Alfenas[3 (D,E)], Valéria Cristina de Faria[1 (B,D)], Lawrens Fabrício Cardozo Makkai[1 (B,D)], João Carlos Bouzas Marins[1 (A,C-G)]

[1]Laboratory of Human Performance, Department of Physical Education, Federal University of Viçosa, Viçosa, Minas Gerais, Brazil
[2]Laboratory of Applied Nutrition and Metabolism, School of Physical Education and Sport, University of Sao Paulo, Sao Paulo, Brazil
[3]Department of Nutrition and Health, Federal University of Viçosa, Viçosa, Minas Gerais, Brazil

Abstract

Objective: To investigate the effects of 60-minute running in a fasting state compared to ingesting low and high glycemic index (GI) breakfasts one hour prior to exercise on plasma glucose and physiologic parameters in physically active adults.

Methods: Fifteen men completed three trials in a randomized counterbalanced order. One hour before the run, following an overnight fast, each participant consumed a high GI (GI = 70) or a low GI (GI = 37) breakfast meal or performed the trial in a fasting state (FAST). Each trial consisted of a 60-minute run at 70% heart rate reserve on a motorized treadmill. Plasma glucose was measured at fast, at each 15-minute postprandial, and during the exercise period. Ratings of perceived exertion, stomach fullness, thirsty sensation and blood pressure were recorded.

Results: Following ingestion of high- and low-GI meals, plasma glucose concentrations increased in both trials and peaked at 15 minutes during the postprandial period (8.3 ± 1.2 mmol·L^{-1} and 7.6 ± 0.8 mmol·L^{-1}, respectively). At 15 minutes of exercise, plasma glucose decreased below fasting values in both breakfast trials and was significantly lower ($P < 0.05$) than in FAST. Plasma glucose was not different between trials after 15 minutes of exercise. There were no differences in physiologic and self-reported parameters during exercise among the trials.

Conclusions: We conclude that one-hour running in a fasting state or following a 60-minute rest after high or low GI meal ingestion does not cause hypoglycemia or anticipate fatigue in non-athletes.

Key words: *glycemia, pre-exercise meal, fatigue, fasting, carbohydrate*

Introduction

Individuals are advised to avoid prolonged fasting and to ingest carbohydrate meals in the hours prior to endurance exercise to provide a sustainable source of energy during exercise [1]. However, the access to meals in the hours prior to or during training and competition is not always easy or possible. In addition, most individuals observe an overnight fast (8-12h) on a daily basis, and tend to exercise in a state of fasting [2]. The human body copes well with such short duration of fasting and profound hypoglycemia might not occur, although there may be a modest decrease in blood glucose concentration [3,4]. On the other hand, it has been shown that consuming a high-carbohydrate meal right before exercise causes hyperinsulinemia that might lead to hypoglycemia at the onset of exercise [5,6]. The effect of fasting and carbohydrate meals on glycemic response to subsequent exercise remains an issue of debate, partially because of differences in study design, including the duration of fasting as well as the type and amount of carbohydrate ingested [7].

The study of the glycemic index (GI) of foods has increased [8-10], and specially emerged as an alternative tool for the preparation of pre-exercise meals [11-13]. Some authors have reported that consuming a low-GI meal before exercise might slow down the release of glucose, maintaining a favorable level of glucose that can be used continuously as an energy substrate during exercise [14,15]. In contrast, the sharp increase in insulin secretion after consumption of high-GI foods leads to a subsequent marked decrease in blood glucose at the onset of exercise [16,17]. Others, however, have not observed such pronounced reduction in blood glucose [18,19]. However, most studies used single foods or drinks, rather than using a mixture of foods to form commonly-available meals. Furthermore, even when mixed meals were provided, they were not always iso-energetic or were only matched for carbohydrate content and not for protein and fat. It is not a common practice to eat single foods at meal times in daily life and there is a need for studies that provide mixed meals that are matched both for energy and for macro-nutrient composition.

The aim of the present study, therefore, was to measure plasma glucose responses to 1-h running following an overnight fast, compared to low and high GI meals in physically active men.

Methods

Participants

Fifteen healthy recreational male runners (age: 23.1 ± 2.7 years; body mass: 70.9 ± 11.3 kg; height: 174.9 ± 8.1 cm; body fat: 6.4 ± 2.4%) volunteered to this study. All volunteers completed health questionnaires and were informed about the risks and benefits involved with participation before signing the informed consent form. This study was reviewed and approved by the University Research Ethics Committee in accordance to the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Preliminary testing

Participants visited the laboratory for preliminary tests and for a familiarization run on a motorized treadmill (EG700X, Ecafix, Sao Paulo, Brazil) before the main trials. A 20-minute incremental submaximal running test was performed to determine the treadmill velocity and gradient to be employed in the main trials that corresponded to 70% heart rate reserve [20]. The continuous intensity of 70% heart rate reserve assures that gastric emptying was not compromised by the exercise [21]. The initial speed of the treadmill was set between 3.0 and 4.0 $km \cdot h^{-1}$, depending on the participant's training status. Every 5 minutes, continuous adjustments in the speed (2 $km \cdot h^{-1}$) and gradient (1%) were applied, and the heart rate was controlled until a steady-state that corresponded to 70% heart rate reserve was reached. In case this test lasted more than 20 minutes, the initial treadmill velocity and gradient were adjusted, and volunteers performed the test again in another session.

Experimental design

The experimental testing protocol was completed over a 3-day period separated by at least 7 days. On days 1 and 2, participants were provided with a standard high GI or low GI breakfast. Participants remained at rest for one hour, followed by 60 minutes of running at 70% heart rate reserve on a motorized treadmill. On day 3, participants simply rested for one hour after arriving at the laboratory and performed a trial in a fating state (FAST). All trials were completed at the same time of the day (between 7:00 and 9:00 a.m.) and under the same environmental conditions: 21.3 ± 2.1°C and 65-75% relative humidity. The participants were asked to refrain from strenuous exercise and record their diet for 2 days before each main trial, which was replicated for the next trials. During this period they were instructed to avoid smoking, alcohol, and caffeine. They were also asked to ingest approximately 500 mL of water the night before and on the morning of each trial to ensure adequate hydration. The order of the experimental trials was randomized, and the study employed a counterbalanced crossover design.

Tests meals

The composition of the test meals is shown in Table 1. All the participants received the same standard pre-exercise meal, regardless the individual's body mass,

Table 1. *Nutritional composition of pre-exercise meals*

Food item	Weight (g)	GI of each food	CHO (g)	Protein (g)	Fat (g)	Energy (kcal)
High GI meal (70)						
Banana	80	52	18.2	1.04	0.24	79.2
Cereal bar	25	56	17	1.2	4.1	110
White bread	80	70	28.8	6.6	–	141.6
Butter	10	–	–	–	8	72
CHO-drink	300	78	18	–	–	72
Glucose	15	99	15	–	–	60
Low GI meal (37)						
Apple	130	38	19.7	0.39	0.39	84.5
All Bran	30	42	13.5	3.75	0.75	75.7
Milk	100	11	5	3	3.5	63.5
Brown bread	30	54	12	2.6	0.92	69
Grape juice	150	48	24	–	–	96
Butter	7.5	–	–	–	6	54
Fructose	23	19	23	–	–	92

Note. CHO = carbohydrate; GI = glycemic index. Calculated glycemic-index values were taken from Wolever et al. (1991).

this is similar to the methodology utilized by Febbraio et al. [22]. The high GI meal (GI = 70) consisted of white bread, butter, banana, cereal bar, a carbohydrate-rich drink (Gatorade Thirst Quencher; The Gatorade Co., Chicago, IL) and glucose solution. The low GI meal (GI = 37) consisted of All Bran (Kellogg's), brown bread, butter, milk, apples, grape juice, and fructose solution. Foods were carefully chosen so each diet was matched for energy content (534 kcal) and macronutrient composition (72% CHO, 7% protein and 21% fat). The nutritional content of each meal was calculated from information provided by the manufacturer. The Wolever et al. [23] method was used to calculate the GI of the mixed meals; the individual GI values for the foods were taken from the Foster-Powell et al. [24] GI table.

Procedures

The participants reported to the laboratory before each trial after an overnight fast of 10 h. On arrival, participants were asked to empty their bladders and bowel, if necessary. The nude body mass was recorded on a digital scale (Soehnle®, Spain) after they voided. A urine sample was collected for the pre-exercise hydration status assessment by urine specific gravity that was analysed using a clinical handheld refractometer (model A300; ATAGO Co, Tokyo, Japan). A finger-prick fasting blood sample was drawn and analyzed for plasma glucose (Accu-Check, Roche, Mannheim Germany). The participants then consumed the test meal within 15–20 minutes and remained at rest for one hour while the postprandial plasma glucose level was determined at every 15 minutes. They were not allowed to drink or ingest anything during this time and their activity level remained minimal. Thereafter, a heart rate transmitter (Polar S610, Kempele, Finland) was placed around the chest and pre-exercise plasma glucose, heart rate and blood pressure were measured, using a manual mercury sphygmomanometer (Wan Med, Sao Paulo, Brazil).

A 5-minute warm-up was completed and then followed by a 60-minute run at a fixed pre-determined speed and gradient equivalent to 70% heart rate reserve. On FAST trial, the participants initiated the test immediately after the 60-minute fasting blood collection. In all the trials the volunteers drank 3 $mL \cdot kg^{-1}$ body mass of water at every 15 minutes throughout the exercise. Blood collections for plasma glucose analysis were drawn at 15-minute intervals as well. Blood pressure was evaluated every 20 minutes while heart rate was measured every 10 minutes. At every 20 minutes during exercise, ratings of perceived exertion (RPE) were recorded, using a 6- to 20-point scale [25]. Stomach fullness and thirst sensation were evaluated at the same time, using a 5-point scale [26] ranging from "not full" to "very very full" and "not thirsty" to "very very thirsty" respectively. At the end of the trial, participants were asked to empty their bladders and to collect the entire urine volume so the post-exercise urine specific gravity and urine volume could be assessed. Any excess of sweat was toweled and volunteers were weighed, as they had been prior to the trial.

Statistical analyses

The data were tested for normality of distribution and are presented as the mean ± standard deviation (SD). A two-way analysis of variance (ANOVA) for repeated measures was used to analyze differences in the physiological and metabolic variables. When a significant difference was found, Scheffe's post-hoc test was used to locate the differences in mean values. Data analyses were conducted with SPSS (version 14.0; SPSS Inc, Chicago, IL). Differences were considered statistically significant when $P < 0.05$.

Results

Plasma glucose

Plasma glucose response among trials is shown in Fig. 1. With regard to the time effect of each trial,

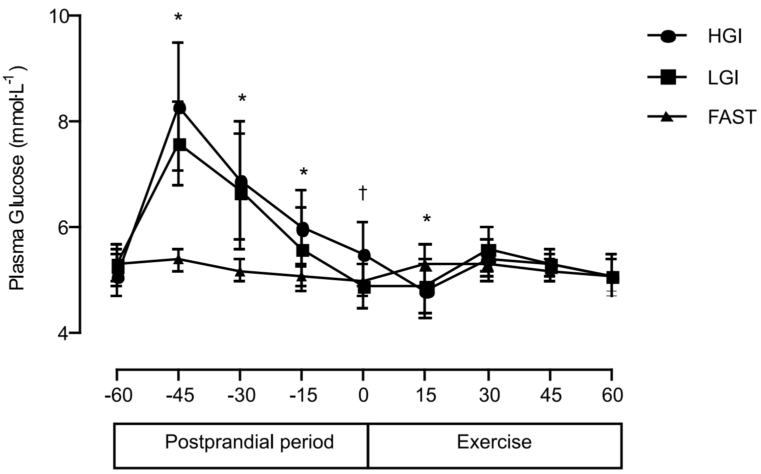

Fig. 1. *Plasma glucose changes ($mmol \cdot L^{-1}$) before and during exercise in the high-glycemic-index (HGI), low-glycemic-index (LGI) and FAST trials. *P < 0.05 HGI and LGI significantly different to FAST. †P < 0.05 HGI significantly different to LGI and FAST.*

following ingestion of the high and low GI meals, plasma glucose concentrations were increased in both trials and peaked at 15 minutes during the postprandial period (8.3 ± 1.2 mmol·L^{-1} and 7.6 ± 0.8 mmol·L^{-1}, respectively) and were significantly different ($P < 0.05$) across all time points. In the high GI trial, plasma glucose was higher ($P < 0.05$) at 30 minutes postprandial than at fast, 60 minutes postprandial and all time points during exercise. It was also higher ($P < 0.05$) at 45 minutes postprandial than at fast, 15, and 60 minutes during exercise. In low GI trial, plasma glucose was higher ($P < 0.05$) at 30 minutes postprandial than at fast, 40, 60 minutes postprandial and at all time points during exercise. In FAST trial plasma glucose was higher ($P < 0.05$) at the 15 minutes than at the 60-minute resting period. Plasma glucose levels gradually decreased after the 30-minute exercise on all 3 trials, but their values were not different between trials after the 15 minutes of each run (Fig. 1).

Physiological parameters and hydration status

There were no significant differences in blood pressure, heart rate, stomach fullness, thirst sensation, and RPE between the trials (Table 2). Blood pressure and heart rate increased significantly ($P < 0.05$) at the onset of exercise and remained elevated in all the trials. RPE was significantly higher ($P < 0.05$) at 60 minutes than at 20 minutes in all the trials; and also at 40 minutes than at 20 minutes in FAST trial ($P < 0.05$). There were no significant differences in urine specific gravity at the start of each trial (1.025 ± 0.004, 1.022 ± 0.008 and 1.024 ± 0.006 in the FAST, high GI, and low GI trials, respectively). Post-exercise urine specific gravity decreased significantly ($P < 0.05$) from the beginning in all the trials (1.020 ± 0.007 FAST; 1.018 ± 0.009 high GI; and 1.019 ± 0.010 low GI). The total volume of fluid ingest during exercise in each trial was of 0.85 ± 0.14 L and the changes in body mass (- 0.46 ± 0.17% FAST; - 0.64 ± 0.89% high GI; - 0.50 ± 0.49% low GI) were not different between trials ($P > 0.05$).

Discussion

The present study aimed to investigate plasma glucose response on 1-h running following an overnight fast, compared to ingestion of low and high GI pre-exercise meals. We observed that plasma glucose peaked at 15 minutes following the ingestion of both high and low GI meals but were not statistically different (Fig. 1). Thereafter, plasma glucose decreased and was significantly higher in the high GI trial than it was in the low GI and FAST trials at 60-minute postprandial period. In two other studies, plasma glucose was significantly higher after the consumption of high GI meal than it was after the low GI meal, peaking at 30 minutes [13] and 15 minutes [15] during the postprandial period and decreased gradually thereafter, followed by increases in insulin concentration. Although we did not assess any hormonal response, it is likely that insulin concentration increased as the plasma glucose increased and was responsible for plasma glucose declining after 15 minutes during the postprandial period [27].

Table 2. *Heart rate (HR), systolic blood pressure, ratings of perceived exertion (RPE), stomach fullness and perceived thirst during exercise in the high-glycemic-index (HGI), low-glycemic-index (LGI) and FAST trials*

Variables	Meal	Exercise period (min)					
		10	20	30	40	50	60
HR (beats/min)	HGI	152 ± 6.5	152 ± 6.8	157 ± 6.7	154 ± 6.5	153 ± 6.5	155 ± 6.8
	LGI	151 ± 7.9	153 ± 5.8	156 ± 8.2	153 ± 6.8	153 ± 7.4	155 ± 6.4
	FAST	151 ± 7.3	151 ± 4.6	156 ± 5.6	155 ± 7	154 ± 6.1	156 ± 6.5
Systolic blood pressure (mmHg)	HGI	–	136 ± 20.37	–	135 ± 17.26	–	134 ± 17.16
	LGI	–	130 ± 12.60	–	130 ± 16.52	–	127 ± 13.97
	FAST	–	128 ± 14.24	–	129 ± 16.41	–	129 ± 18.46
RPE	HGI	–	10.7 ± 1.1	–	11.7 ± 1.5	–	12.4 ± 1.7*
	LGI	–	10.7 ± 1.6	–	11.3 ± 1.5	–	11.8 ± 1.3*
	FAST	–	10.7 ± 1.5	–	12 ± 1.5*	–	12.5 ± 1.4*
Stomach fullness	HGI	–	1.4 ± 1	–	1.4 ± 1	–	1.5 ± 0.8
	LGI	–	1.8 ± 1.2	–	1.9 ± 1.4	–	1.6 ± 1
	FAST	–	1.0 ± 0.2	–	1.2 ± 0.5	–	1.2 ± 0.5
Perceived thirst	HGI	–	1.2 ± 0.5	–	1.3 ± 0.5	–	1.4 ± 0.7
	LGI	–	1.4 ± 0.6	–	1.3 ± 0.5	–	1.4 ± 0.8
	FAST	–	1.3 ± 0.5	–	1.3 ± 0.5	–	1.2 ± 0.5

*$P < 0.05$ Significantly different to 20 min within trial.

At 15 minutes of exercise, plasma glucose concentrations decreased below fasting values in both breakfast trials and were significantly lower than in the FAST trial. However, there were no signs of hypoglycemia at the onset of exercise, particularly after ingestion of the high GI meal. On the contrary, the reduction in plasma glucose concentration at 15 minutes of exercise was not observed when volunteers performed exercise following a 2-hour rest postprandial period [13] or when they consumed breakfast and lunch, both of which were followed by a 3-hour resting postprandial period [18]. These data might suggest that feeding time would be more relevant than GI regarding breakfast to plasma glucose declining at the beginning of the exercise. Indeed, in the present study, a possible risk of hypoglycemia at 15 minutes of exercise was more evidenced when individuals ingested both breakfasts than when they ran in the fasting state. Cycling-based studies that also have evaluated the ingestion of breakfast in shorter time (< 1 hour) prior to exercise observed a decrease in plasma glucose concentration at the 20- and 30-minute marks during exercise [19,28]. The lag between pre-exercise feeding time, GI of foods and hypoglycemia needs further investigation. In fact, it is not a normal pre-competition condition for athletes performing exercise in fasted state but, considering recreational exercise participants, this situation might occasionally happen. However, as it pertains to the volunteers in the present study, there was no evidence of any risk of hypoglycemia. We did not observe differences for plasma glucose concentration after 15 minutes of exercise between the trials. Our findings are consistent with observations from other studies that verified no differences in plasma glucose between high and low GI meals after 20 minutes of exercise performed at 70% $\dot{V}O_2max$ followed by a 2-hour postprandial period [29] or when volunteers ingested high or low GI gel immediately prior to a simulated 64-km cycling time trial [30]. Low GI diets theoretically release glucose from the gut at a slower rate and minimize postprandial insulin secretion, and therefore for an extended period [31], this may be accompanied by a reduced suppression of fat oxidation during subsequent exercise. Hence, this would allow maintenance of plasma glucose for a longer period of time, compared with high GI diets. It is likely that the time of exercise in the present study was not too long to highlight any differences on plasma glucose between the trials.

The training status of the participants, as well as the cessation of exercise at 60 minutes, may explain why plasma glucose concentrations were equally well maintained during the FAST trial. Although our volunteers were not athletes engaged in professional training routines, they do practice exercise periodically, which makes it plausible that they may have lower source of endogenous carbohydrate when compared to athletes, but a higher than that of sedentary individuals. It is important to consider that the participants in the current study did not have a restricted food access during the days preceding the10-hour fast period, as well as being asked to refrain from strenuous exercise the day before the tests. These recommendations would have assured an adequate store of participants' endogenous carbohydrate before trials. However, the more prolonged the exercise is, the more crucial plasma glucose becomes in offering energy. Therefore, it is likely that plasma glucose levels are not being sustained in activities performed in a fasting state and for a longer period of time than that of the present study.

The question of whether ingesting foods with different GI improves performance remains controversial with studies showing positives [12,31] and no effects [16,32]. To the participants in the current study, however, performance may not be as relevant as it is with trained athletes, but the issue of exercise tolerance is of importance for improving fitness and adhering to an exercise program. It should be considered that if any individual is not fed at the onset of exercise, the reliance on limited muscle glycogen reserve is increased, and therefore the exercise will feel more difficult and resulting in earlier fatigue during the exercise and poor adherence to the exercise program. We observed no effects in heart rate, RPE, and stomach fullness between the trials. RPE, however, was minimally higher at 60 minutes than it was with 20 minutes of exercise in all the trials ($P < 0.05$), and was significantly higher at 40 minutes than at 20 minutes ($P < 0.05$) in the FAST trial. Altoé et al. [3] found no substantial effect on RPE during a 1-h running activity following an overnight fast (12 h). Similarly, Cocate and Marins [33] did not find differences in heart rate, blood pressure, and RPE between two pre-exercise meals and the exercise performed at fast during 60 minutes on a treadmill. Likewise, in the current study the values of RPE were minimal and did not indicate the onset of fatigue.

Using a cut-off point of 1.020 [34] the mean values of urine specific gravity in the current study suggest that the participants were dehydrated before the trials (urine specific gravity > 1.020), in spite of the warning to ingest fluid before the trials began. Nevertheless, with constant fluid replacement (3 $mL \cdot kg^{-1}$ body mass of water every 15 minutes), changes in body mass of our volunteers were less than 1%, well below the 2% that is considered a threat to exercise and health [34]. This likely contributed to the low scores of RPE and thirst sensation in all the trials. However, it is unknown if these parameters would have been equal if reports on the participants had been completed if they were following their habitual physical and hydration regimes [35,36]. In the present study, the participants were also advised to refrain from exercise the days before testing but, in regular situations, the practice of exercise can be current and on consecutive days, even in a state of fasting. In addition, when hydrating *ad libitum*, the ingestion of fluid may not be enough to match changes in body mass and significant fluid deficit levels can contribute to fatigue [35,37]. Hence, future studies should examine the response of the fasting state compared with other GI meals on plasma glucose when habitual dietary and physical regimes have been maintained.

Pratical implications

The use of mixed high or low glycemic index meals by recreational exercisers before morning exercises is dictate according to their individual experiences and their habitual pre-exercise nutrition practices, as plasma glucose seems to respond similarly after consuming of each breakfast. Recreational exercisers are encouraged to follow standard recommendations in terms of the timing and amount of carbohydrate ingested before exercise and also, should avoid restricting food access before practicing exercise or exercise in state of fasting.

The chronic effects of practicing exercise in state of fasting remain unclear and the plasma glucose could not be maintained in the face of other aspects of exercise, such as the modality, intensity, and duration involved, or considering other population groups such as women, untrained individuals, or elderly people.

Conclusion

To summarize, the consumption of high or low GI meals 60 minutes prior to running exercise decreased plasma glucose at the onset of one hour of exercise, when compared with the exercise performed in a fasting state. However, there were no signs of hypoglycemia, particularly after ingestion of the high GI meal. Plasma glucose concentrations were equally well maintained after 15 minutes of exercise, as were physiological parameters. Since breakfast is conducted differently between individuals, new opportunities for future research involve the exploration of the possible effects of other types of exercise, meals, and feeding time on metabolic parameters.

Acknowledgements

We would like to thank CNPq for providing the necessary funding and all the volunteers and researchers involved, specially, Fabrícia Geralda Ferreira for sharing her technical expertise.

Declaration of interest

The authors report no conflicts of interest.

References

1. American Dietetic Association; Dietitians of Canada; American College of Sports Medicine, Rodriguez NR, Di Marco NM, Langley S. American College of Sports Medicine position stand. Nutrition and athletic performance. *Med Sci Sports Exerc* 2009; 41: 709-31.
2. Maughan RJ. Fasting and Sport: an introduction. *Br J Sports Med* 2005; 44: 473-5.
3. Altoé JL, Silva RP, Ferreira FG, et al. Blood glucose changes before and during exercise with three meal conditions. *Gazz Med Ital* 2011; 170: 177-84.
4. Warren RE, Frier BM. Hypoglycaemia and cognitive function. *Diabetes Obes Metab* 2005; 7: 493–503.
5. Angus DJ, Febbraio MA, Hargreaves M. Plasma glucose kinetics during prolonged exercise in trained humans when fed carbohydrate. *Am J Physiol Endocrinol Metab* 2002; 283: E573-7.
6. Coyle EF, Coggan AR, Hemmert MK, et al. Substrate usage during prolonged exercise following a pre-exercise meal. *J Appl Physiol* 1985; 59: 429-33.
7. Ingle L, Cooke C, King R. Effects of high and low concentration carbohydrate solutions on endurance performance consumed prior to and during intense, intermittent exercise. *Med Sport* 2011; 15: 62-7.
8. Bennett CB, Chilibeck PD, Barss T, et al. Metabolism and performance during extended high-intensity intermittent exercise after consumption of low- and high-glycaemic index pre-exercise meals. *Br J Nutr* 2012; 108 Suppl 1: S81-90.
9. Cocate PG, Pereira LG, Marins JC, et al. Metabolic responses to high glycemic index and low glycemic index meals: a controlled crossover clinical Trial. *Nutr J* 2011; 5: 1-10.
10. Moore L, Szpalek HM, McNaughton LR. Preexercise high and low glycemic index meals and cycling performance in untrained females: randomized, cross-over trial of efficacy. *Res Sports Med* 2013; 21: 24-36.
11. Brown LJ, Midgley AW, Vince RV, et al. High versus low glycemic index 3-h recovery diets following glycogen-depleting exercise has no effect on subsequent 5-km cycling time trial performance. *J Sci Med Sports* 2012; 12: S1440-2400.
12. Thomas DE, Brotherhood JR, Brand JC. Carbohydrate feeding before exercise: effect of glycemic index. *Int J Sports Med* 1991; 12: 180-6.
13. Wong SH, Chan OW, Chen YJ, et al. Effect of preexercise glycemic-index meal on running when CHO-electrolyte solution is consumed during exercise. *Int J Sport Nutr Exerc Metab* 2009; 19: 222-42.
14. Wee SL, Williams C, Gray S, et al. Influence of high and low glycemic index meals on endurance running capacity. *Med Sci Sport Exerc* 1999; 31: 393-9.
15. Wu CL, Williams C. A low glycemic index meal before exercise improves endurance running capacity in men. *Int J Sport Nutr Exerc Metab* 2006; 16: 510-27.
16. Stannard SR, Constantini NW, Miller JC. The effect of glycemic index on plasma glucose and lactate levels during incremental exercise. *Int J Sport Nutr Exerc Metab* 2000; 10: 51-61.
17. Wu CL, Nicholas C, Williams C, et al. The influence of high--carbohydrate meals with different glycaemic indices on substrate utilisation during subsequent exercise. *Br J Nutr* 2003; 90: 1049-56.
18. Stevenson E, Williams C, Nute M. The influence of the glycaemic index of breakfast and lunch on substrate utilisation during the postprandial periods and subsequent exercise. *Br J Nutr* 2005; 93: 885-93.
19. Moore LJ, Midgley AW, Thurlow S, et al. Effect of the glycaemic index of a pre-exercise meal on metabolism and cycling time trial performance. *J Sci Med Sport* 2010; 13: 182-8.
20. Karvonen MJ, Kentala E, Mustala O. The effects of training on heart rate; a longitudinal study. *Anns Med Ex Biol Fenn* 1957; 35: 307-15.
21. Silva RP, Altoé JL, Marins JCB. Relevance of temperature and gastric emptying of liquids consumed by individuals who practice physical activities. *Braz J Nutr* 2009; 22: 755-65. (In Portuguese: English abstract).
22. Febbraio MA, Chiu A, Angus DJ, et al. Effects of carbohydrate ingestion before and during exercise on glucose kinetics and performance. *J Appl Physiol* 2000; 89: 2220-6.
23. Wolever TM, Jenkins DJ, Jenkins AL, et al. The glycemic index: methodology and clinical implications. *Am J Clin Nutr* 1991; 54: 846-54.

24. Foster-Powell K, Holt SHA, Brand-Miller JC. International table of glycemic index and glycemic load values. *Am J Clin Nutr* 2002; 76: 5–56.
25. Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc* 1982; 14: 377-81.
26. Murray R, Seifert JG, Eddy DE, et al. Carbohydrate feeding and exercise: effect of beverage carbohydrate content. *Eur J Appl Physiol Occup Physiol* 1989; 59: 152-8.
27. Wee SL, Williams C, Tsintzas K, et al. Ingestion of a high--glycemic index meal increases muscle glycogen storage at rest but augments its utilization during subsequent exercise. *J Appl Physiol* 2005; 99: 707-14.
28. Kirwan JP, Cyr-Campbell D, Campbell WW, et al. Effects of moderate and high glycemic index meals on metabolism and exercise performance. *Metabolism* 2001; 50: 849-55.
29. Chen YJ, Wong SH, Wong CK, et al. Effect of preexercise meals with different glycemic indices and loads on metabolic responses and endurance running. *Int J Sport Nutr Exerc Metab* 2008; 18: 281-300.
30. Earnest CP, Lancaster SL, Rasmussen CJ, et al. Low vs. high glycemic index carbohydrate gel ingestion during simulated 64-km cycling time trial performance. *J Strength Cond Res* 2004; 18: 466-72.
31. DeMarco HM, Sucher KP, Cisar CJ, et al. Pre-exercise carbohydrate meals: Application of glycemic index. *Med Sci Sports Exerc* 1999; 31: 164–70.
32. Sparks MJ, Selig SS, Febbraio MA. Pre-exercise carbohydrate ingestion: Effect of the glycemic index on endurance exercise performance. *Med Sci Sports Exerc* 1998; 30: 844–9.
33. Cocate PG, Marins JCB. Effect of three breakfast interventions on blood glucose during low-intensity exercise performed on a treadmill. *Brazilian Journal of Kinanthropometry and Human Performance* 2007; 9: 67-75. (In Portuguese: English abstract).
34. Casa DJ, Armstrong LE, Hillman SK, et al. National Athletic Trainers' Association position statement: fluid replacement for athletes. *J Athl Train* 2000; 35: 212-24.
35. Silva RP, Mündel T, Altoé JL, et al. Preexercise urine specific gravity and fluid intake during one-hour running in a thermoneutral environment – a randomized cross-over study. *J Sports Sci Med* 2010, 9: 464-71.
36. Pickering AJ, Rehrer NJ, Hellemans IJ. Hydration status of male football players across a week of training and competition. *Med Sport* 2011; 15: 125-31.
37. Ferreira FG, Altoé JL, Silva RP, et al. Level of knowledge and hydration strategies of young soccer players. *Brazilian Journal of Kinanthropometry and Human Performance* 2009; 11: 204-11. (In Portuguese: English abstract).

Accepted: June 12, 2013
Published: June 28, 2013

Address for correspondence:
Rafael Pires da Silva
Laboratory of Applied Nutrition and Metabolism
School of Physical Education and Sport
University of Sao Paulo
Av Prof Mello Moraes, 65. Sao Paulo
Brazil
Post Code: 05508-030
Phone: +55 11 3091-3096
Email: rafaeldasilva@usp.br

Janaína Lubiana Altoé: janalub@yahoo.com.br
Guilherme Giannini Artioli: artioli@usp.br
Rita de Cássia Gonçalves Alfenas: ralfenas@ufv.br
Valéria Cristina de Faria: valeriaefiufv@yahoo.com.br
Lawrens Fabrício Cardozo Makkai: makkaiefi@yahoo.com.br
João Carlos Bouzas Marins: jcbouzas@ufv.br