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INGESTION OF MIXED MEALS OF LOW OR HIGH GLYCAEMIC INDEX DOES NOT AFFECT PERFORMANCE IN 3.000m RUNNING

Kleber dos Santos Almeida[1], Marcelo Magalhães Sales[1], Sérgio Rodrigues Moreira[2], José Fernando Vila Nova de Moraes[1, 2], Ricardo Yukio Asano[1, 3], Maysa Vieira de Sousa[4], Marcela Nôleto Mundim de Souza[1], Herbert Gustavo Simões[1] & Carmen Sílvia Grubert Campbell[1]

[1]Graduate program in Physical Education. Catholic University of Brasília. Brasília/DF, BRAZIL.
[2]College of Physical Education. Federal University of Vale do São Francisco. Petrolina/PE, BRAZIL.
[3]College of Physical Education. UNIRG University Centre. Gurupi/TO – BRAZIL.
[4]Medical Investigation Laboratory. School of Medicine. University of São Paulo. São Paulo/SP, BRAZIL.

Abstract The purpose of this study was to analyze the effects of meals with high (HGI) and low glycaemic index (LGI), and fasting (FAST) on performance, blood glucose (GLU), blood lactate concentration ([LAC]) and expired gases before, during, and after a test of running 3.000m. Eleven males underwent three experimental sessions (HGI, LGI and FAST). [LAC] and GLU were collected in the postprandial (PP) and post-exercise period. Expired gases were collected during all procedures. There were no differences ($p>0.05$) in performance (VO_{2peak} and mean velocity) during 3.000m running. GLU in the HGI session was lower immediately after the running test when compared to LGI and FAST ($p<0.05$). At the 15th and 30th min of PP, HGI GLUC values were higher when compared to the LGI and FAST sessions ($p<0.001$ HGI vs. FAST; $p<0.05$ HGI vs. LGI), while at the 5th and 15th min of post-exercise, HGI values were lower when compared to LGI and FAST ($p<0.001$ HGI vs. FAST; $p<0.05$ HGI vs. LGI). [LAC] was higher ($p<0.001$) in HGI and LGI when compared to FAST at the 15th and 30th min of the PP. Finally, LGI presented higher values ($p<0.05$) than HGI at the 5th min of post-exercise. We conclude that meals with different glycaemic indexes did not influence the performance in a 3.000m running test. However, there were increases in GLUC and [LAC] during the PP.

Key words: Meal, blood glucose, performance, nutrition, runners

INTRODUCTION

Nutrition has been considered one of the most important factors in sports performance. When well oriented, it can slow fatigue and, therefore, allow a higher training volume, maximize recovery between exercise sessions, and ultimately, improve performance [21, 25].

In a well-balanced diet, carbohydrates must account for the largest part of energy intake [16]. Even though glycogen stocks are reduced in the organism [16], they are important during fasting periods and throughout exercise bouts, especially the ones of long duration and high intensity, in which glucose and fatty acids are metabolized in order to produce energy and perform muscle contractions [21, 22].

Due to the fact that the human body does not absorb all carbohydrates at the same speed, Jenkins et al [12] developed a tool called glycaemic index (GI), which evaluates the effects of carbohydrates on glucose. The GI is a parameter of classification that groups food based on the glycaemic responses during the postprandial (PP) period when compared to the reference food [12, 18, 27].

The more intense or prolonged the exercise is, the more it will have to rely on carbohydrates as its fuel [16]. Therefore, beverages containing different amounts and types of carbohydrates, along with electrolytes, are used by athletes and physically active individuals in order to improve their physical performance. These beverages are consumed before, during, and after exercise. When ingested before, they aim to assure a normal plasmatic volume since the beginning of the exercise, by accumulating fluids in the gastrointestinal lumen. These fluids will be absorbed during exercise and will especially optimize the concentration of glucose in the blood [20, 21, 24].

However, there is no consensus in literature regarding the effects of the consumption of these beverages before exercise on metabolism and performance, since some studies show improvements [8, 14], while others do not [4, 5].

In addition, studies that relate GI to physical performance often use relatively long duration exercise protocols (30 min to 120 min) and moderate intensity (60% to 70% VO_{2max}) [1, 4, 5, 13, 14, 31]. Only one prior study involved the impact of previous intake of high glycaemic or low glycaemic index carbohydrates (HGI and LGI, respectively) on performance at time trial events [19]; however, these were long duration events (~90 min). Most studies on previous consumption of carbohydrate and performance include time of permanence in a specific exercise intensity, total work performed, and time until exhaustion in maximum incremental tests using cyclergometers [6, 28, 32].

Moreover, to our knowledge, there are no available studies in the literature that have investigated the influence of mixed meals containing all three macronutrients (carbohydrate, fat and protein) with distinct glycaemic indexes (HGI and LGI), and fasting (FAST) on physical performance in short duration exercise (3.000m run, ~13 min) and in the postprandial responses during exercise and throughout a recovery period.

In this scenario, the present study aimed to analyze the effects of mixed meals of HGI, LGI and FAST on physical performance and over glucose (GLU), blood lactate (LAC) and respiratory exchange ratio (RER) before, during, and after a maximum 3.000m running test in recreational runners.

MATERIALS AND METHODS

SUBJECTS AND PROCEDURES

The present study was performed at the Catholic University of Brasília during the year of 2009. After approval from the local ethics committee (CEP/UCB n. 157/2008) and informed consent granted from the volunteers, eleven male adults (31.4±3.6 years, 71.5±4.3 kg, 175.2±3.5 cm, 23.3±1.4 $kg \cdot m^{-2}$, 10.5±3.4 body fat percentage, 6.0±3.9 years of running practice) agreed to participate in the study.

The exclusion criteria for participating in the study were: any bone, muscle or joint impairments that could preclude performing the exercise sessions, having at less than two years of running practice, using or being treated with any kind of drug, smoking, and having any kind of allergy and/or intolerance to the components of the meals administered.

GENERAL PROCEDURES

Initially, the volunteers were submitted to a body composition and nutritional assessment and performed a 3.000m running test on a 400m athletics track for familiarization and determination of the individual energy expenditure.

After the individual energy expenditure was determined, all individuals underwent three experimental sessions performed in a randomized order, with a minimum interval of 48 hours, and in the same period of the morning (starting at 08:00 am), including: 1) the HGI session, which consisted of the 3.000m run after the ingestion of a HGI meal (GI > 70), followed by 60 min of post-exercise recovery; 2) the LGI session, with the 3.000m run after the ingestion of a LGI meal (GI <55), followed by 60 min of post-exercise recovery; and 3) the FAST session, where the volunteers underwent the same procedures as in the other sessions, but without previous consumption of food. All procedures were carried out under the same climatic conditions with temperatures between 20 and 24 degrees Celsius and relative humidity of approximately 60%. The GI characterization for the meals was based as suggested by Foster-Powell et al [7]. Caloric values of the HGI and LGI meals were calculated according to the data obtained during the nutritional assessment and in the preliminary 3.000m running test

ANTHROPOMETRIC MEASUREMENTS (BODY MASS INDEX AND BODY FAT)

The body mass index (BMI) was calculated through the quotient between body weight in kilograms (Toledo 2096 PP), and height in meters (SECA® 214, USA), raised to the second power ($kg \cdot m^{-2}$). The relative body fat (BF%) was calculated by skinfold thickness, in which the body density was estimated using the seven skinfold thickness measurements suggested by Jackson & Pollock [10], measured three times at each anatomical point, in a rotational sequence, on the right side of the body, with the mean value registered. The measurements were carried out by one experienced evaluator using a skinfold caliper (Lange, Cambridge Scientific Instruments, Cambridge, Maryland, USA). After the body density was calculated, it was converted into BF% using Siri's equation [26].

DESCRIPTION OF THE MEALS

The HGI and LGI meals were prepared and diluted in 300 ml of water and were composed of: skimmed powder milk (Molico®), albumin (DRY®), crushed Brazil nuts, sugar (for the HGI session) and fructose (for the LGI session), as shown in Table 1.

Table 1. Composition and glycaemic index of the meals. Data expressed in mean and (±) standard deviation (n=11)

Composition	HGI	LGI	FAST
CHO (%)	74.3±0.7	74.3±0.7	-
CHO (g)	41.9±2.7	41.9±2.7	-
PTN (%)	16.0±0.2	16.0±0.2	-
PTN (g)	10.2±1.9	10.2±1.9	-
Fat (%)	9.8±0.7	9.8±0.7	-
Fat (g)	2.3±0.3	2.3±0.3	-
Calories (Kcal)	229.2±15.2	229.2±15.2	-
Water (ml)	354.7±22.2	354.7±22.2	354.7±22.2
GI of the meal	81.7±1.8	33.8±0.2	-

CHO=carbohydrate; PTN=protein; GI=glycaemic index;
HGI=high glycaemic index; LGI=low glycaemic index; FAST=fasting

PRELIMINARY TEST

Before the experimental sessions, a 3.000m running test on the 400m athletics track was performed as a familiarization procedure and in order to calculate the energy expenditure and the meal to be provided to the volunteers during the experimental sessions (HGI and LGI).

HGI SESSION

After the administration of the HGI meal, the individuals remained seated for 30 min. During this period 25 µl of blood was collected from the ear lobe at the 15th and 30th min. Also, the same amount of blood was collected during the 5th, 15th, 30th, 45th and 60th min of the post-exercise recovery period. Blood samples were stored in microtubes (*Eppendorf*) containing 50 µl of Sodium Fluoride (NaF) at 1% for later analysis of LAC and GLU through the electro-enzymatic method (*Yellow Springs Instruments* 2700 STAT, Ohio, USA). In addition, expired gas was analyzed through a portable gas analyzer (Metamax 3B, Cortex, Biophysik, Germany) during the 30 min after the ingestion of the meal, during exercise, as well as during the 60 min of post-exercise recovery.

LGI SESSION

In this session, the procedures were the same as in the HGI session, except for the meal administered before the 3.000m running test.

FAST SESSION

Here, the procedures were the same as in the HGI and LGI sessions, but without the administration of any meals before the 3.000m running test.

3.000M RUNNING TEST

After the postprandial period (30 min), an 8-minute warm-up was performed at 60% of the heart rate (HR) reserve using the following equation: $HR_{warm\text{-}up} = (HR_{max} - HR_{rest}) \cdot 60\% + HR_{rest}$. After the warm-up, the subjects underwent the 3.000m running test and were advised to perform it as fast as possible. HR and RER were measured during the whole period of the session using a heart rate monitor (Polar® S810i, Polar Electo Oy, Kempele, Finland) and a portable gas analyzer (Metamax 3B, Cortex Biophysik, Germany), respectively.

BLOOD SAMPLES

Blood glucose (GLU) and lactate (LAC) were collected from the ear lobe during rest, before the ingestion of the meal, at the 15th and 30th min after feeding, immediately after the 3,000m run, and at the 5th, 15th, 30th, 45th and 60th min during the post-exercise recovery period. Blood samples were stored and analyzed through the electro-enzymatic method (*Yellow Springs Instruments* 2700 STAT, Ohio, USA).

VENTILATORY ANALYSIS

Expired gases were collected during every procedure taken after the administration of the distinct meals (HGI, LGI and FAST), as well as during the recovery period (1 min during every 15 min), through a portable gas analyzer (Metamax 3B, Cortex Biophysik, Germany) previously calibrated with a 3-L syringe (flux

calibration) and a mixed pattern containing 4.9% of CO_2 and 17% of O_2 (gas calibration). Ventilation values (VE), oxygen uptake (VO_2) and carbon dioxide production (VCO_2) were registered throughout the whole process and were collected breath-by-breath. The values analyzed were mean values of 20 sec intervals.

Statistical Analysis

Data shown are expressed in mean (±) standard deviation (SD) or standard error of the mean (SEM). After assessing normality of data through the test of Skewness and Kurotsis, Mixed Model ANOVA for repeated measures (between and within-subjects factors) with Bonferroni's *post-hoc* was applied to compare the values between and within sessions. In case any of the dependent variables did not show sphericity through the Mauchly's Test, the epsilon of Greenhouse-Geisser was used to analyze the F statistic. The level of significance adopted was 5% ($p<0.05$).

RESULTS

Physical Performance: peak VO_2, mean velocity and duration of the test

The results presented in Table 2 do not show statistical difference among the HGI, LGI and FAST sessions when comparing the values of peak VO_2, duration of the test, mean velocity in the 3.000m run and LAC. Only the glucose concentrations displayed statistically significant changes when HGI (116.8±17.6 mg·dL^{-1}) is compared with LGI (130.3±18.5 mg·dL^{-1}) and FAST (130.8±28.2 mg·dL^{-1}) immediately after the 3.000m run ($p<0.05$).

Table 2. Metabolic parameters and performance. Values expressed in mean and (±) standard deviation (n=11)

	FAST	HGI	LGI
PeakVO_2 (mL·kg^{-1}·min^{-1})	51.8±8.5	51.5±8.9	52.5±8.9
Time (sec)	805.1±159.6	773.5±128.0	787.5±136.5
MV 3.000 (km·h^{-1})	13.9±2.6	14.4±2.2	14.1±2.4
Glucose (mg·dL^{-1})	130.8±28.2	116.8±17.6†	130.3±18.5
Lactate (mmol·L^{-1})	11.8±3.8	11.3±4.1	12.6±3.3

PeakVO_2=peak of oxygen uptake; MV 3,000=mean velocity at the 3,000m run; FAST=fasting; HGI=high glycaemic index; LGI=low glycaemic index; † $p<0.05$ to FAST and LGI

Metabolic Variables: Glucose and Lactate

Fasting glucose, as expected, did not differ among the three distinct studied situations, being: 70.6±5.6 in the HGI session; 74.6±9.3 in the LGI session; and 74.1±5.1 mg·dL^{-1} in the FAST session (Figure 1).

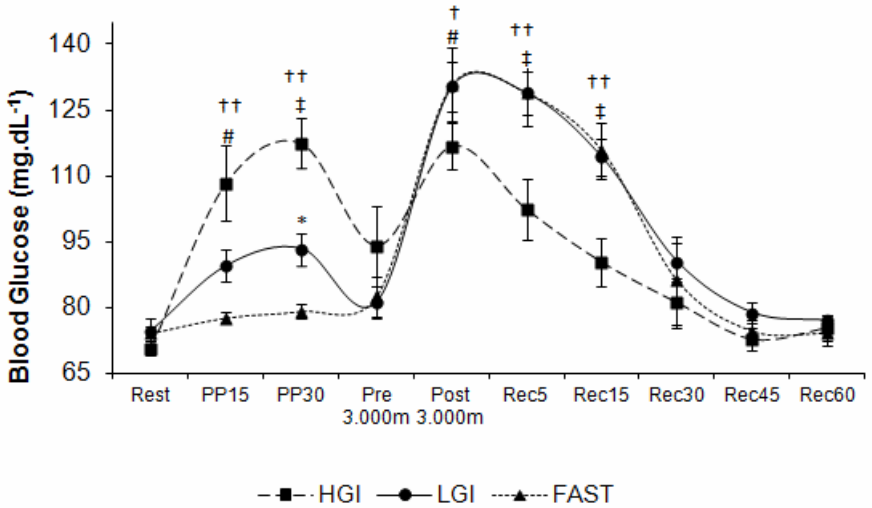

Figure 1. Glucose responses during all the three experimental sessions. HGI=high glycaemic index; LGI=low glycaemic index; FAST=fasting; PP15=15 min postprandial; PP30=30 min postprandial; Pre 3.000m=before the 3.000m running test; Post 3.000m=immediately after the 3,000m running test; Rec5, Rec15, Rec30, Rec45 and Rec60=corresponding moments of the post-exercise recovery period. †$p<0.05$ HGI vs. FAST; *$p<0.05$ LGI vs. FAST; #$p<0.05$ HGI vs. LGI; ††$p<0.001$ HGI vs. FAST; ‡$p<0.05$ HGI vs. LGI.

However, there was a significant increase in glucose 15 min after the ingestion of the HGI meal (108.4±18.1 mg·dL^{-1}) when compared to the LGI meal (89.5±12.0 mg·dL^{-1}) and FAST (77.6±4.5 mg·dL^{-1}) ($p<0.05$). Even higher values were found at the 30th min of the postprandial period (117.3±18.8; 93.4±12.1; 79.1±5.7 mg·dL^{-1}, for HGI, LGI and FAST, respectively) (Figure 1), where HGI was significantly different from LGI ($p<0.001$), while HGI and LGI were different from FAST ($p<0.05$).

Moreover, at the 5th and 15th min of the post-exercise recovery period there was a statistically significant difference in GLU when compared with HGI and LGI ($p<0.001$), as well as between HGI and FAST ($p<0.001$) with higher glucose values in the FAST and LGI sessions (Figure 1).

LAC concentrations at rest did not present statistically significant differences between the sessions performed. However, at the 30th min of the postprandial period, LAC values significantly increased in HGI and LGI (2.6±0.3 and 2.1±0.8 mmol·L^{-1}, respectively) when compared to FAST (1.1±0.4 mmol·L^{-1}) ($p<0.001$) (Figure 3). There was also a difference in LAC at the 15th and 30th min of the postprandial period when comparing the HGI and LGI sessions with FAST ($p<0.001$), as well as between the HGI and LGI sessions at the 5th min of the post-exercise recovery period ($p<0.05$) (Figure 2).

In all the other analyzed moments no differences were found in LAC concentrations during the three experimental sessions (Figure 2).

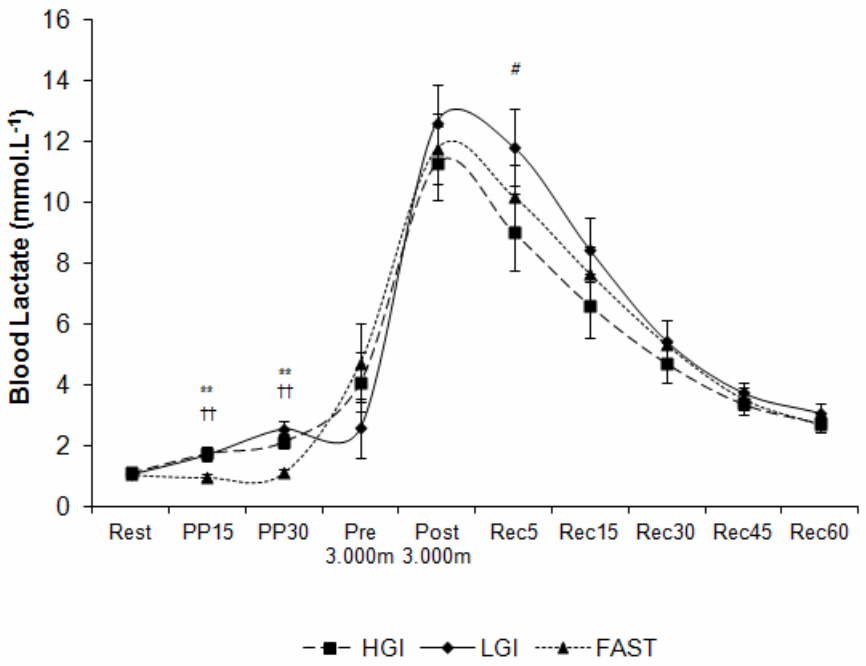

Figure 2. Blood lactate responses during all three experimental sessions. HGI=high glycaemic index; LGI=low glycaemic index; FAST=fasting; PP15=15 min postprandial; PP30=30 min postprandial; Pre 3.000m=before the 3.000m running test; Post 3.000m=immediately after the 3.000m running test; Rec5, Rec15, Rec30, Rec45 and Rec60=corresponding moments of the post-exercise recovery period. #p<0.05 HGI vs. LGI; ††p<0.001 HGI vs. FAST; **p<0.001 LGI vs. FAST

VENTILATORY ANALYSIS: OXYGEN UPTAKE (VO_2) AND RESPIRATORY EXCHANGE RATIO (RER)

No statistical differences were found among sessions when the oxygen uptake was analyzed during the postprandial period, the 3.000m run, and the 60 min of post-exercise recovery ($p>0.05$) (Table 3).

Table 3. Mean and (±) standard deviation oxygen uptake values in all three experimental sessions (n=11)

	PP15	PP30	3000m	Rec5	Rec15	Rec30	Rec45	Rec60
FAST	3.9±0.6	4.0±0.7	51.8±8.5*	6.9±1.3	6.2±1.1	5.5±0.9	5 .4±0.9	4.7±1.0
HGI	4.4±1.1	4.5±1.1	51.5±8.9*	7.4±1.2	5.9±1.5	5.5 ±1.6	4.7±1.3	4.9±1.4
LGI	4.1±0.9	4.2±0.8	52.5±8.9*	6.4±1.4	5.9 ±1.0	4.7±0.5	5.0±0.7	4.9±0.6

FAST=fasting; HGI=high glycaemic index; LGI=low glycaemic index; PP15=15 min postprandial; PP30=30 min postprandial; 3000m=3.000m run at maximal intensity; Rec5, Rec15, Rec30, Rec45 and Rec60=corresponding moments of the post-exercise recovery period. *p<0.001 to both postprandial moments and the whole post-exercise recovery period.

When comparing the LGI and FAST RER values, a statistically significant difference was found at the 15th min of the postprandial period, with higher values in the LGI session (0.86±0.1 *vs.* 0.81±0.1; p<0.05). In addition, RER values at the 30th min of the postprandial period were also different between HGI and FAST (0.92±0.1 *vs.* 0.80±0.1; p<0,001) and between LGI and FAST (0.93±0.1 *vs.* 0.80±0.1; p<0.001) (Table 4). No differences were found in the 3.000m run or during the post-exercise recovery period (Table 4).

Table 4. Respiratory Exchange ratio (RER) in all three experimental sessions (n=11). Data shown in mean and (±) standard deviation

	PP15	PP30	3000m	Rec5	Rec15	Rec30	Rec45	Rec60
FAST	0.81±0.1	0.80±0.1	1.00±0.1	0.98±0.1	0.83±0.1	0.77±0 .1	0.79±0.1	0.78±0.1
HGI	0.84±0.1	0.92±0.1†	1.04±0.1	0.96±0.1	0.81±0.1	0.74± 0.1	0.79±0.1	0.82±0.1
LGI	0.86±0.1*	0.93±0.1†	1.04±0.1	0.98±0.0	0.83±0.1	0.76 ±0.1	0.79±0.1	0.80±0.1

FAST=fasting; HGI=high glycaemic index; LGI=low glycaemic index; PP15=15 min postprandial; PP30=30 min postprandial; 3000m=3.000m run at maximal intensity; Rec5, Rec15, Rec30, Rec45 and Rec60=corresponding moments of the post-exercise recovery period. *p<0.05 to FAST; †p<0.001 to FAST

DISCUSSION

The main objective of the present study was to analyze the effects of mixed meals of HGI, LGI and FAST on physical performance, as well as on GLU, LAC and RER responses, before, during and after a 3.000m run in recreational runners. The present study demonstrated that the ingestion or not of mixed meals of different glycaemic indexes did not affect the results in a 3.000m run. On the other hand, the meals did promote changes in GLU and LAC, especially during the postprandial period.

Data referring to metabolic responses with the previous ingestion of only one kind of meal in sub-maximal exercise tests (65 to 70% of VO_{2max}) have been widely discussed in the literature [1, 2]. However, there are no available studies that approach the influence of mixed meals that include all three macronutrients (carbohydrate, protein and fat) on performance in the maximum of high intensity exercise.

The main finding of the present study was that there was no statistically significant difference in peak VO_2, mean velocity and time of duration in all three experimental sessions of the 3.000m run test (Table 2), suggesting that the ingestion or not of mixed meals with HGI and LGI before performing a 3.000m running test does not affect its final result (Table 2). In this scenario, the present study results disagree with Moore et al [19], who demonstrated that the time of duration in a 40 min time-trial cycling event was lower after the ingestion of a LGI meal (92.5 ± 5.2 min) when compared to the ingestion of a HGI meal (95.6 ± 6.0 min). In the present study, the shorter duration exercise (~13 min) was not affected.

On the other hand, several studies available in the literature also did not demonstrate an improvement in performance (time to exhaustion and total work performed) after the ingestion of meals with distinct glycaemic indexes (Table 2) [6, 28, 30, 32]. Donaldson et al [3], in a review paper, also reported several studies that did not present significant alterations in the performance of athletes after the previous ingestion of HGI and LGI carbohydrates. Nevertheless, when they referred specifically to ingestion of meals 60 min or less before exercise, the authors stated that LGI carbohydrates provided higher glucose concentrations during exercise although without altering total time to exhaustion. In the same way, Little et al [17], when investigating high intensity intermittent exercise (soccer), also did not find statistically significant differences between the distances ran after the ingestion of HGI or LGI carbohydrates.

In addition to the studies that analyze the acute responses of the ingestion of HGI and LGI carbohydrates, the available literature also provides information on the chronic effects of the issue at hand. Studying physically active healthy adults, Hamzah et al [9] did not find that a five day HGI and LGI diet ingestion caused any significant changes in the rate of fat and carbohydrate oxidation, nor in insulin, glucose, non-esterified fatty acids and glycerol levels, or in total time to exhaustion in a treadmill test at 65% of VO_{2max}.

In the present study, lower values of GLU immediately after exercise in the HGI session (116.8±17.6 $mg \cdot dL^{-1}$) were found when compared to the LGI (130.3±18.5 $mg \cdot dL^{-1}$) and FAST (130.8±28.2 $mg \cdot dL^{-1}$) sessions (p<0.05, Table 2). This could be explained by the abrupt increase in insulin induced by the HGI meal ingested before performing the exercise [15].

The significant increase of glucose in the HGI at the 15th min of the post-pandrial period (PP15), when compared to the same moment in the LGI and FAST sessions agree with the findings of Stevenson et al [31] and Wu & Williams [33]. The significant increase of glucose was also observed at the 30th min of the postprandial period (PP30) after the ingestion of HGI when compared to the other two sessions. This was also evidenced by Sapata et al [23].

In the present study, during the 5th and 15th min of the post-exercise recovery period (Rec5 and Rec15) the LGI and FAST sessions presented significantly higher glucose values ($p<0.05$) than at the same moments of the HGI session (Figure 1). Once more, this difference could be explained by the abrupt increase of insulin induced by the ingestion of the HGI meal before exercise, therefore promoting a higher glucose uptake by the muscles, resulting in lower glucose values observed in the recovery period (Rec5 and Rec15) [15].

Regarding the blood lactate concentrations, significantly higher values were found in the 15th and 30th min of the postprandial period (PP15 and PP30, respectively) in the LGI session when compared only to FAST ($p<0.05$). Other studies have reported that the previous ingestion of mixed meals with LGI resulted in significant increases in blood lactate levels during the postprandial period when compared to HGI meals [30, 31, 33]. However, Stannard et al [29], in agreement with the present study, also did not find statistically significant differences in blood lactate concentrations between the LGI and HGI until the 30th min of the postprandial period.

When the ventilatory variables (VO_2 and RER) were analyzed, VO_2 did not present differences among the distinct sessions in the postprandial and post-exercise recovery periods. However, oxygen uptake was significantly higher during the 3.000m run when compared to the postprandial and post-exercise recovery periods in all sessions (Table 3). On the other hand, RER values in the HGI and LGI sessions were significantly higher at the 30th min of the postprandial period when compared to FAST (0.92, 0.93 and 0.80, respectively) (Table 4). This suggests that at the 30th min of the postprandial period, there was a higher level of carbohydrate oxidation in the HGI and LGI sessions, whereas the main source of energy in the FAST session was fat. These findings are in agreement with Stannard et al [29].

One possible explanation for this finding can be attributed to the higher bioavailability of carbohydrate presented in the HGI and LGI sessions, due to the fact that the volunteers ingested a meal containing the referred macronutrient. On the contrary, this did not happen during the FAST session [15].

Since this was an experimental study, it also had some limitations. The development of the experiment with liquid meals can be one of them as most of our meals during the day are solid. However, Jamurtas et al [11] investigated the influence of solid meals of different glycaemic indexes (white bread with strawberry jam for the HGI and dried apricots for the LGI) on time to exhaustion in exercise performed at 90% of VO_{2max} on a cycle ergometer in subjects previously submitted to an exercise session performed at 65% of VO_{2max}, and showed no difference in time to exhaustion when comparing the three experimental sessions (FAST, HGI and LGI), which is in accordance with the present study.

CONCLUSION

The main finding of the present study indicates that there was no difference in performance in a 3.000m running test after ingestion or not (FAST) of a mixed meal with different glycaemic indexes (HGI and LGI). In addition, the ingestion of both mixed meals resulted in increases in blood glucose and lactate during the 30 min of the postprandial period. Moreover, also during the postprandial period, the respiratory exchange ratio was higher in the HGI and LGI sessions than when compared to FAST, suggesting a higher use of carbohydrate as energy source during these experimental sessions.

Lastly, it is important to highlight that these mechanisms are not fully elucidated by the literature. Therefore, additional studies that aim to explain the effect of administering mixed meals with different glycaemic indexes on performance in short duration and high intensity events are still necessary. As a suggestion, the effects of chronic administration of different glycaemic index meals on performance in exercises of short duration and high intensity may be investigated further. In addition, verifying the effects of training status on the metabolic ([LAC] and GLU) and ventilatory responses before, during, and after exercise in the face of previous ingestion of meals with different glycaemic indexes can be interesting.

PRACTICAL APPLICATION

Recreational runners who perform aerobic exercise of short duration and high intensity without prior carbohydrate intake do not seem to suffer any deleterious effects on the performance. On the other hand, previous consumption of foods or beverages with high glycaemic index seems to promote the hypoglycemia that may compromise the continued exercise beyond 3.000 m. We recommend that before performing exercises, recreational runners ingest food or beverages with a low glycaemic index in order to minimize the hypoglycemia that occurs at the beginning of the exercise, allowing higher quality in training.

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REFERENCES

1. 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 Physiol*ogy, 85(6), 2220-2226.
2. Cocate, P. G., & Marins, J. C. B. (2007). Efeito de três ações de "café da manhã" sobre a glicose sangüínea durante um exercício de baixa intensidade realizado em esteira rolante. *Revista Brasileira de Cineantropometria e Desempenho Humano*, 9(1), 67-75.
3. 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.
4. Febbraio, M. A., Chiu, A., Angus, D. J., Arkinstall, M. J., & Hawley, J. A. (2000). Effects of carbohydrate ingestion before and during exercise on glucose kinetics and performance. *Journal of Applied Physiology*, 89(6), 2220-2226.
5. 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.
6. Febbraio, M. A., & Stewart, K. L. (1996). CHO feeding before prolonged exercise: Effect of glycemic index on muscle glycogenolysis and exercise performance. *Journal of Applied Physiology*, 81(3), 1115-1120.
7. Foster-Powell, K., Holt, S. H. A., & Brand-Miller, J. C. (2002). International table of glycemic index and glycemic load values. *American Journal of Clinical Nutrition*, 76(1), 5-56.
8. Gleeson, M., Maughan, R. J., & Greenhaff, P. L. (1986). Comparison of the effects of pre-exercise feeding of glucose, glycerol and placebo on endurance and fuel homeostasis in man. *European Journal of Applied Physiology and Occupational Physiology*, 55(6), 645-653.
9. Hamzah, S., Higgins, S., Abraham, T., Taylor, P., Vizbaraite, D., & Malkova, D. (2009). The effect of glycaemic index of high carbohydrate diets consumed over 5 days on exercise energy metabolism and running capacity in males. *Journal of Sports Sciences*, 27(14), 1545-1554.
10. Jackson, A. S., & Pollock, M. L. (1978). Generalized equations for predicting body density of men. *The British Journal of Nutrition*, 40, 497-504.
11. 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 food on exercise performance and beta-endorphin responses. *Journal of the International Society of Sports Nutrition*, 8(15), 1-11.
12. Jenkins, D. J., Woleyer, T. M., Taylor, R. H., Barker, H., Fielden, H., Baldwin, J. M., Bowling, A. C., Newman, H. C., Jenkins, A. L., & Goff, D.V. (1981). Glycemic index of foods: a physiological basis for carbohydrate exchange. *American Journal of Clinical Nutrition*, 34(3), 362-366.
13. Kirwan, J. P., Cyr-Campbell, D., Campbell, W. W., Scheiber, J., & Evans, W. J. (2001). Effects of moderate and high glycemic index meals on metabolism and exercise performance. *Metabolism: Clinical and Experimental*, 50(7), 849-855.
14. Kirwan, J. P., O'Gorman, D., & Evans, W. J. (1998). A moderate glycemic meal before endurance exercise can enhance performance. *Journal of Applied Physiology*, 84(1), 53-59.
15. Kuipers, H., Fransen, E. J., & Keizer, H. A. (1999). Preexercise ingestion of carbohydrate and transient hypoglycemia during exercise. *International Journal of Sports Medicine*, 20(4), 227-231.
16. Lima-Silva, A. E., Fernandes, T. C., De-Oliveira, F. R., Nakamura, F. Y., & Gevaerd, M. S. (2007). Metabolismo do glicogênio muscular durante o exercício fisco: mecanismos de regulação. *Revista de Nutrição*, 20(4), 417-429.
17. Little, J. P., Chilibeck, P. D., Ciona, D., Forbes, S., Rees, H., Vandenberg, A., & Zello G. A. (2010). Effect of low- and high-glycemic-index meals on metabolism and performance during high-intensity, intermittent exercise. *International Journal of Sport Nutrition and Exercise Metabolism*, 20(6), 447-456.
18. Liona, A. (2006). El índice glicémico. Una controversia actual. *Nutrición Hospitalaria*, 21(2), 55-60.
19. Moore, L. J., Midgley, A. W., Thomas, G., Thurlow, S., & McNaughton, L. R. (2009). The effects of low- and high-glycemic index meals on time trial performance. *The British Journal of Nutrition*, 4(3), 331-344.
20. Palmer, M. S., & Spriet, L. (2008). Sweat rate, salt loss, and fluid intake during an intense on-ice practice in elite Canadian male junior hockey players. *Applied Physiology Nutrition and Metabolism*, 33(2), 263-271.
21. Rodriguez, N. R., DiMarco, N. M., & Langley, S. (2009). Position of the American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and athletic performance. *Journal of the American Dietetic Association*, 109(3), 509-527.
22. Romijn, J. A., Coyle, E. F., Sidossis, L. S., Gastaldelli, A., Horowitz, J. F., Endert, E., & Wolffe, R. R. (1993). Regulation of endogenous fat and carbohydrate metabolism in relation to exercise intensity and duration. *The American Journal of Physiology*, 265(3 Pt 1), E380-391.
23. Sapata, K. B., Fayh, A. P. T., & Oliveira, A. R. (2006). Efeitos do consumo prévio de carboidratos sobre a resposta glicêmica e desempenho. *Revista Brasileira de Medicina do Esporte*, 12(4), 189-194.
24. Sawka, M. N., Burke, L. M., Eichner, E. R., Maughan, R. J., Montain, S. J., & Stachenfeld, N. S. (2007). American College of Sports Medicine position stand. Exercise and fluid replacement. *Medicine and Science in Sports and Exercise*, 39(2), 377-390.
25. Schabort, E. J., Bosch, A. N., Weltan, S. M., & Noakes, T. D. (1999). The effect of a preexercise meal on time to fatigue during prolonged cycling exercise. *Medicine and Science in Sports and Exercise*, 31(3), 464-471.
26. Siri, W. E., (1961). *Body composition from fluid spaces and density. Analysis of methods. In: Techniques for Measuring Body Composition* (1th edition). Washington, DC: National Academy of Sciences, National Research Council. p. 223-44.
27. Siu, P. M., & Wong, S. H. S. (2004). Use of Glycemic Index: Effects on feeding patterns and exercise performance. *Journal of Physiological Anthropology and Applied Human Science,* 23(1), 1-6.
28. 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.
29. Stannard, S. R., Constantini, N. W., & Miller, J. C. (2000). The effect of glycemic index on plasma glucose and lactate levels during incremental exercise. *International Journal of Sport Nutrition and Exercise Metabolism*, 10(1), 51-61.

30. Stevenson, E., Williams, C., Mash, L. E., Phillips, B., & Nute, M.L. (2006). Influence of high-carbohydrate mixed meals with different glycemic indexes on substrate utilization during subsequent exercise in women. *American Society for Nutrition*, 84(2), 354-360.
31. Stevenson, E., Williams, C., & Nute, M. (2005). The influence of the glycemic index of breakfast and lunch on substrate utilization during the posprandial periods and subsequent exercise. *The British Journal of Nutrition*, 93(6), 885-893.
32. Thomas, D. E., Brotherhood, J. R., & Miller, J. B. (1994). Plasma glucose levels after prolonged strenuous exercise correlate inversely with glycemic response to food consumed before exercise. *International Journal of Sport Nutrition*, 4(4), 361-373.
33. 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.

Address for correspondence:

Marcelo Magalhães Sales
Graduate program in Physical Education. Catholic University of Brasília.
QS 07 Lote 1, EPCT, Room 116.
Taguatinga – DF, BRAZIL.
ZIP CODE: 72.022-900
Tel.: +55 61 3356-9350
E-mail: marcelomagalhaessales@gmail.com