

Impact of meal's glycemic index pre-exercise in the performance

Abstract

This study reviewed the effects of pre-exercise ingestion of high, moderate and low glycemic index (GI) meals on physical performance. Some studies have indicated the use of GI as a nutritional strategy to provide adequate metabolic state in the exercise, which constitutes an additional tool to optimize the availability of carbohydrate for exercise. The consumption of low glycemic index (LGI) meal has been recommended in the pre-exercise, so as result in lower glycemic response, in addition to spare glycogen stores during the exercise, increasing the performance. However, the results of the studies that examined the effect of GI of the meals ingested pre-exercise on physical performance are contradictory. Some studies revealed a positive association between ingestion of LGI or moderate GI meal and the improvement on performance, others observed no significant differences after consumption of meals differing in GI. However, it is worth mentioning that was not reported cases of performance decrease with the consumption of low or moderate GI diets before the exercise.

Keywords: glycemic index, exercise, carbohydrate, performance

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Abbreviations: HO, carbohydrates; GI, glycemic index; HGI, high glycemic index; LGI, low glycemic index; MGI, moderate glycemic index

Introduction

The ingestion of carbohydrates (CHO) by athletes and practitioners of physical activity is important before, during and after the exercise. The carbohydrate consumption before exercise may stabilize glycemia, minimizing the reduction of glycogen stores during exercise.¹ When used during the exercise, the carbohydrates can prevent hypoglycemia and spare the glycogen by providing exogenous substrate as a source of energy.² The consumption of carbohydrates after exercise is recommended to encourage muscle and hepatic glycogenesis.³

Due to the fact that the body does not digest or absorb all carbohydrates at the same speed, a parameter called glycemic index (GI) was proposed by Jenkins et al.⁴ to classify carbohydrates according to the digestion and absorption rate of foods.^{3,5} It is defined as the area formed under the glycemic response curve, after the consumption of 50g of available carbohydrate from a test food, expressed as a percentage of the glycemic response to the same amount of carbohydrate of a standard meal (glucose or white bread) ingested by the same individual.⁶⁻⁸

This index was created from the observation that the glycemic response obtained after carbohydrate ingestion was not only proportional to the amount of carbohydrate consumed, but to a set

of factors that affect their digestion and absorption.⁹ Thus, the GI is a qualitative indicator of the ability of ingested carbohydrate, to raise glycemia levels.⁶ The high glycemic index (HGI) meals are digested and absorbed faster than low glycemic index (LGI) meals.⁵

In sports nutrition, the GI has been used as a nutritional strategy to provide appropriate metabolic state in the exercise, which makes it an additional tool to optimize the availability of carbohydrates for the exercise.⁵ The consumption of LGI meal has been recommended in pre-exercise, for inducing lower and constant glycemic response, besides it spares the glycogen stores during the exercise, increasing the physical performance.^{5,9}

Thomas et al.,¹⁰ were among the first to demonstrate that the time to exhaustion was improved over 20 min when LGI meal was consumed before exercise compared with HGI meal. After their study, several others were performed in order to evaluate the effect of meal's GI consumed before exercise in the metabolic response and performance. However, the results of these studies are contradictory. While some studies found the occurrence of positive effects,^{7,11-14} other¹⁵⁻²⁰ observed no improvement on physical performance. Table 1 presents several studies in which the effect of the GI of pre-exercise meal on the physical performance was evaluated. In this sense, the aim of this study was to analyze the published studies in which was evaluated the effect of pre-exercise ingestion of high, moderate and low glycemic index meals on physical performance.

Table I Studies of the effect of GI pre-exercise meals on physical performance

Estudy, year	N	Participants Characteristics	Exercise Protocol	Meals composition	Timing of feeding	Performance response
Thomas et al. ¹⁰ (1991)	8	Men trained cyclists	Cycled to exhaustion at 65–70% VO_{2max}	4 protocols: 1) Meal HGI: Potato 2) Meal LGI: Lentils 3) Glucose 4) Water The CHO-containing meals provided 1g CHO/kg body mass.	60 min	The time exhaustion was 20 min longer after LGI than after HGI
Kirwan et al. ¹¹ (1998)	6	Active women but, no athletes	Cycled to exhaustion at 60% VO_{2max}	3 protocols: 1) Meal MGI: sweetened whole-grain rolled oats. 2) Meal MGI: sweetened whole-oat flour. 3) Control: water The meals contained 75g of available carbohydrate, 4.7g of fat, 9.4g of protein and had GI between 60 and 70.	45 min	Exercise time to exhaustion was 16% longer during the sweetened whole-grain rolled oats than during the control trial
Sparks et al. ¹⁷ (1998)	8	Men trained triathletes	Cycled at 67% VO_{2peak} for 50 min, followed by 15 min at maximum work output	3 protocols: 1) Meal HGI: instant mashed potato. GI=80. 2) Meal LGI: Lentils. GI=29. 3) Control: noncarbonated diet soft drink The CHO-containing meals provided 1g CHO/kg body mass.	45 min	No difference in total work performed in 15-min performance Trial
Burke et al. ¹⁶ (1998)	6	Men trained cyclists	Cycled at 70% VO_{2max} for 2 hr followed by performance ride of 300kj	3 protocols: 1) Meal HGI: instant mashed potato. GI=87. 2) Meal LGI: pasta. GI=37. 3) Control: low-energy jelly The CHO-containing meals provided 2g CHO/kg body mass, \pm 1.8g of fat and \pm 23g of protein.	2 hours	There was no difference in time to complete the performance ride
DeMarco et al. ¹² (1999)	10	Men trained cyclists	Cycled at 70% VO_{2max} for 2 hr followed by performance-trial cycling at 100% VO_{2max} to exhaustion	3 protocols: 1) Meal HGI: Cornflakes, milk and banana. GI=69.3. 2) Meal LGI: All-Bran, apple and yogurt. GI=36. 3) Control: Water The CHO-containing meals provided 1.5g CHO/kg body mass. The meals differed in fiber, fat and protein.	30 min	Time to exhaustion in performance trial longer with LGI
Wee et al. ¹⁸ (1999)	8	5 male and 3 woman recreational runners	Run at 70% VO_{2max} until exhaustion	2 protocols: 1) Meal HGI: Refeição AIG: Baked potato, tuna, sweet corn, toast and honey. 2) Meal LGI: Lentils. The meals provided 2g CHO/kg body mass and were similar in energy, protein and fat content	3 hours	No difference in time to exhaustion

Table Continued..

Estudy, year	N	Participants Characteristics	Exercise Protocol	Meals composition	Timing of feeding	Performance response
Stannard et al. ¹⁹ (2000)	10	Men trained cyclists	Cycling ride at 50 rpm to exhaustion (load was increased by 50 watt every 3-min with an initial loading of 50 watt)	3 protocols: 1) Meal HGI: Glucose GI =100. 2) Meal LGI: Pasta. GI=41. 3) Control The CHO-containing meals provided 1g CHO/kg body mass.	65 min	No difference in time to exhaustion
Febbraio et al. (2000)	8	Men trained cyclists	Cycled at 70% VO_{2peak} for 120 min, followed by 30 min at maximum work output	3 protocols: 1) Meal HGI: instant mashed potato 2) Meal LGI: Muesli. GI=52. 3) Control: diet jelly The CHO-containing meals provided 1g CHO/kg body mass.	30 min	No difference in total work performed in 30-min performance trial
Kirwan et al. ⁹ (2001)	6	Active men but, no athletes	Cycled to exhaustion at 60% VO_{2max}	3 protocols: 1) Meal MGI: sweetened whole-grain rolled oats. GI=61 2) Meal HGI: puffed rice. GI=82 3) Control: water The meals contained 75g of available carbohydrate. The meals differed in fiber, fat and protein.	45 min	Time to exhaustion ~23% longer in MGI trial than control
Wu et al. ¹³ (2006)	8	Men recreational runners	Run at 70% VO_{2max} until exhaustion	2 protocols: 1) Meal HGI: Corn flakes, skim milk, white bread, jam, a glucose drink and water. GI=77. 2) Meal LGI: All Bran, skim milk, peaches, apples, and apple juice. GI=37. The meals provided 2g CHO/kg body mass, \pm 4% of fat, 12% of protein and 84% of carbohydrate.	3 hours	Time to exhaustion 6.8% longer in LGI trial than HGI
Chen et al. ²⁹ (2009)	8	Men trained runners	21 km performance run. The first 5 km, the participants ran at a fixed speed of 70% and the remainder (16 km) they then could change their running speed ad libitum.	3 protocols: 1) Meal HGI: jasmine rice, parsnips, orange soda, canned lychees, ham, fish sticks, egg and water. GI=82.9. 2) Meal LGI: clear chicken broth, soymilk, hard boiled egg, 38 g fish sticks, green peas, mung bean thread noodles and water. GI=35.9. 3) Placebo The meals provided 1.5g CHO/kg body mass and were similar in energy, protein and fat content.	2 hours	There were no differences in time to complete the 21km run

Methods

A bibliographic revision was made evaluating the national and international journals indexed in the scientific data bases Medline, Pubmed, Science Direct and Scielo. The descriptors used were: glycemic index, carbohydrate, performance, glycemia, pre-exercise meal, exercise, metabolism and their correspondent in Portuguese. The terms of the research were built combining two or more descriptors or using them isolated. Articles published between the years 1981 and 2010 were used, approaching the influence of consuming high, moderate and low glycemic index meals in the performance. Relevant articles referenced in the selected studies were also used. The bibliographic research included original and review articles, excluding the studies that evaluated the effects of other interventions, besides glycemic index of meal, in the metabolism and performance. A critical analysis was made of the selected studies to verify the validity of the results obtained.

Studies in which a positive effect of glycemic index on physical performance was observed

The ingestion of carbohydrates before the exercise has been associated with glycogen sparing effect.¹¹ This effect can be attributed to the availability of exogenous glucose, glucose uptake by tissue and its subsequent oxidation.²¹ However, the food consumption of the HGI before exercise may induce acute elevation of postprandial glycemia, followed by a marked increase in insulin secretion. Hyperinsulinemia reduces gluconeogenesis and hepatic glycogenolysis, decreasing the release of glucose by the liver and increasing circulating glucose uptake by muscle, which increases the possibility of hypoglycemic state.^{19,22} Furthermore, hyperinsulinemia, triggered by the significant increase of glycemia, limits the release of free fatty acids by adipose tissue, reducing its use as an oxidative substrate and accelerating the muscle glycogen use as energy substrate during exercise.^{23,24}

In turn, the food consumption of LGI pre-exercise has been associated with increase of glycemia slowly and steadily, leading to lower insulin release, which favors the use of free fatty acids as energy substrate and, reduces the oxidation of muscle glycogen during exercise.^{25,26} Therefore, the GI of food consumed before exercise may alter the substrate oxidation during the exercise, interfering thus, in the distance, at work or at the time of physical performance test.^{16,24}

The effect of diet consumption differing in GI in metabolic response and performance was evaluated in 10 athletes during exercise on a cycle ergometer lasting 120 minutes at 70% of maximal volume of oxygen ($\text{VO}_{2\text{max}}$), followed by maximal exercise at 100 % of $\text{VO}_{2\text{max}}$ until exhaustion. Participants consumed HGI meals ($\text{GI}=69.3$), LGI ($\text{GI}=36$) or placebo (water) 30 minutes before exercise. Each meal provided 1.5g CHO.kg⁻¹ body weight. The glycemia observed at the end of submaximal exercise after meal consumption of LGI was higher compared to that obtained with the ingestion of the HGI meal. However, it was found that insulinemia and respiratory exchange ratio during the exercise were higher after meal consumption of HGI, which suggests reduced availability of free fatty acids as an energy source for muscle and, possibly, lower lipid oxidation. In addition, time to exhaustion in the LGI test was 59% higher compared to the HGI test. The results of this study indicate that LGI meal consumption pre-exercise can positively affect the maximum performance after sustained exercise.¹²

Kirwan et al.,¹¹ conducted a study to verify the effects of the consumption of two meals of moderate glycemic index (MGI) with different amounts of dietary fiber in metabolic response and physical performance. In this study, six active women performed exercise on a cycle ergometer at 60% of $\text{VO}_{2\text{max}}$ to exhaustion. Each participant completed three experimental sessions which were provided two different meals of MGI composed of thick oat flakes in sweetened grain and sweetened oats flour, and placebo 45 minutes before exercise. Meals tested presented levels of lipids and proteins similar and were consisted of 75g of available carbohydrate. The meal of sweetened oat flakes provided 6.8g total fiber and 2.3g soluble fiber, the meal of sweetened oats flour presented 3.1g of total fiber and 1.6g of soluble fiber. There was no significant difference or hypoglycemia in glycemia during exercise performance between the three experimental sessions. Serum level of free fatty acids (FFA) tended to be higher in the exercise in response to the consumption of sweetened oat flakes regarding testing of sweetened oats flour. Although the time to exhaustion had to be extended in 16% in the test of sweetened oat flakes, compared to the placebo trial, there was no difference on the performance between the two meals or between the sweetened oats flour and the placebo. In addition to that, we found no difference on muscle glycogen use, in the rate of oxidation of carbohydrate and in total oxidation of carbohydrate between the tests. The authors of this study concluded that consumption of MGI meal 45 minutes before aerobic exercise may prolong the time of execution of physical activity.

However, it should be noted that the oat flakes meal presented higher fiber content and viscosity compared to the oats flour meal, in addition, the carbohydrate presented in the first meal was in the form of grain, while the second was presented more processed (flour). According to Kirwan et al.,¹¹ these factors may have contributed to the difference obtained between the two meals and the placebo. Thus, despite two meals present MGI, the combination of the factors above in the sweetened oat flakes test may have provided the best performance compared with the placebo trial for unknown reasons. A possible explanation is the lower insulin response observed after ingestion the whole grain compared to processed grain.²⁷ This insulin response may lead to the increased use of glycogen stores and reduction in exercise time.

In a subsequent study, using similar methodology, Kirwan et al.,⁹ also observed better performance after ingestion of the MGI meal. However, in this study were contrasted the effects of the MGI meal and the HGI. On that occasion, six men consumed a HGI meal ($\text{GI}=82$), MGI ($\text{GI}=61$) or placebo. Each meal provided 75g available carbohydrate, and differed considerably in lipids, proteins and fiber (total and soluble). FFA levels were higher in the placebo trial at 30, 60 and 120 minutes of exercise, compared to other tests. It was found that total carbohydrate oxidation in the MGI test was higher compared to the placebo trial. It was also observed a positive association of this parameter with the performance, but the use of muscle glycogen, was not different between tests. The exhaustion time in the MGI test was 23% higher than in the placebo trial. These results show that the additional carbohydrate oxidized during the test MGI was provided by ingested meal. This source of additional carbohydrates is important, since the glycogen stores are limited and the availability of carbohydrates is one of the major determinants of the duration of exercise of endurance, providing better performance in this type of physical activity.

The results of Kirwan et al.,^{9,11} are especially important for practitioners to morning physical activity, because they suggest that consumption of MGI foods 45 minutes before exercise provides enough energy to avoid rebound hypoglycemia during two hours of exercise at 60% $\text{VO}_{2\text{max}}$, ensuring their implementation safely. Wu and Williams¹³ found that the consumption of LGI meal three hours before exercise increased *endurance* capacity compared with the ingestion of the HGI meal. This study has involved the participation of eight recreational runners, which carried out an exercise on a treadmill at 70% $\text{VO}_{2\text{max}}$ to exhaustion after three hours of ingestion of HGI meal (GI=77) or LGI (GI=37). The meals provided 2.0g CHO.kg^{-1} body weight, 12% protein and 4% lipids. It was observed lower glycemic response and insulinemia during the postprandial period after ingestion of the LGI meal. In addition, carbohydrate oxidation was lower and fat oxidation was higher in the LGI test. The highest rate of fat oxidation was accompanied by increased plasma concentrations of FFA and glycerol during this test. It was observed that the LGI meal ingestion before exercise, prolonged the running time for 8 minutes compared to ingestion of the HGI meal. Taking into account that one of the limiting factors for the continuation of the exercise performance is appearance of fatigue, and that this in turn is initiated mainly by the lack of carbohydrates, the increase in performance promoted by the LGI meal, can be attributed to greater release of the HGI, which served as energy substrate for muscle and provided the reduction of muscle glycogen use as an energy source for exercise.

Studies in which was observed lack of effect of glycemic index on physical performance

Although some studies have shown a positive association between the ingestion of the LGH or MGI meal before exercise and improvement on physical performance, others have not observed significant differences in the distance, at work or at the time of performance testing conducted after the consumption of meals differing in the GI.^{16–19,21}

Sparks et al.,¹⁷ evaluating the effect of the GI of meals consumed 45 minutes before exercise on the metabolism and performance, found no differences in the total work done between tests. In this study, eight cyclists performed exercise on a cycle ergometer at 67% $\text{VO}_{2\text{max}}$ lasting 50 minutes, followed by 15 minutes of performance testing, in which the total work (kilojoule-KJ) was measured. The participants consumed the HGI meal (mashed potatoes), LGI (lentils) or placebo (*diet drink*) 45 minutes before exercise. Each meal provided 1.0g CHO.kg^{-1} of body weight. After consumption of the HGI meal, hyperglycemia and hyperinsulinemia was observed in the postprandial period, thus, it was verified hypoglycemia at the start of the exercise, unleashed by the action of insulin. In addition, it was observed that after ingestion of HGI meal, the serum level of HGI was lower at 20, 50 minutes, and carbohydrate oxidation was higher throughout the exercise compared to consumption of the LGI meal. However, although the LGI diet promotes more stable glycemic response and low carbohydrate oxidation, these changes were not sufficient to promote changes in performance.

According to Sparks et al.,¹⁷ the performance similarity between tests can be attributed to ingestion of a standardized meal (containing 100g of CHO) provided approximately five hours before of the meals consumption with different GI. This standard meal may have reduced the effects of GI of meal consumed 45 minutes before exercise, due to the significant increase in glycogen content produced by

the first. The initial glycogen content (before exercise) allowed the performance testing in all treatments, without differences. Despite the higher carbohydrate oxidation observed in the HGI test, the time and intensity of exercise were not enough to deplete glycogen stores and reduce the total work performed in this test. According to Mcardle et al.,²⁸ it takes two hours of high-intensity aerobic exercise (strenuous exercise) to almost deplete the hepatic and muscle glycogen. This situation probably did not occur, since the total exercise time was 65 minutes, long enough to deplete the glycogen stores.

Wee et al.,¹⁸ examined the effect of the HGI and LGI meals consumed three hours before exercise on metabolism and *endurance* exercise capacity. This study involved the participation of five men and three women, who consumed the HGI or LGI meal three hours before exercise performed on a treadmill at 70% $\text{VO}_{2\text{max}}$ to exhaustion. The meals were isocaloric, presented similar composition in protein and lipids, and provided 2.0g CHO.kg^{-1} body weight. After 15 minutes of ingestion of the HGI meal, glycemia increased significantly compared to the values of fasting and declined sharply to 20 minutes of exercise. The insulin response after the consumption of HGI meal was greater than after ingestion of the LGI meal during the postprandial period. It was found that carbohydrate oxidation during the first 80 minutes of exercise was 12% lower and the lipids oxidation was 118% higher in the LGI test compared to the HGI, but the time to exhaustion was similar between the treatments. These results suggest that LGI meal ingested before exercise increases the lipids oxidation to the detriment to carbohydrate oxidation during exercise; however, this effect does not promote the ability to improve *endurance* running.

Stannard et al.,¹⁹ conducted a study to evaluate the effect of foods ingestion differing in GI on performance of physical exercise. Ten trained cyclists have carried out an exercise on a cycle ergometer with increasing workload to exhaustion (the load was increased 50 watts every 3 minutes, starting with a load of 50 watts) 65 minutes after ingestion of the HGI meal (glucose), of LGI (macaroni) or placebo (artificially sweetened water). The postprandial glycemic response after ingestion of the HGI meal was significantly higher compared to that obtained in other tests. However, the level of glycemia observed in LGI test to 200 watts of exercise to exhaustion was higher than the HGI test. It was observed that the concentration of serum lactate in the HGI test from 30 minutes postprandial up to 200 watts of exercise was greater than in the placebo trial, and 45 minutes postprandial to 100 watts was higher compared to the LGI test.

The main finding of this study was that the time of the decrease of glycemia at the beginning of the exercise in the HGI test, coincided with the concentration peak of plasma lactate in this test, also coinciding with the period in which the respiratory exchange ratio was higher compared to the placebo trial. Therefore, the decrease of glycemia observed during exercise in the HGI test was due to higher uptake and oxidation of glucose by muscle and its lower hepatic release in response to hyperinsulinemia. However, these metabolic responses were not sufficient to reduce exercise performance. Thus, the strategy of the LGI meal employed by Stannard et al.,¹⁹ is sufficient to impose metabolic changes, but does not change the capacity of maximum yield.

Febbraio et al.,²¹ conducted another study to evaluate the effect of meals consumption differing in GI on muscle glycogen use and physical performance. Eight athletes have consumed the HGI meal (GI=80), LGI (GI=52) or placebo 30 minutes before exercise on a

cycle ergometer for 120 minutes at 70% $\text{VO}_{2\text{max}}$ followed by 30 minutes of maximal exercise for performance evaluation. The total amount of carbohydrate in the meals was 1.0g CHO.kg⁻¹ body weight. It was observed that carbohydrate oxidation after consumption of the HGI meal was higher and lipid oxidation, tended to be lower compared to ingestion of the LGI meal. In addition, muscle glycogen tended to be lower at the end of submaximal exercise in the HGI test. However, there was no difference in performance between the three tests. It should be noted that, although the authors have not shown the content of lipid, protein and fibers offered in the LGI meal, this was composed of muesli (oat-based cereal, fruits and nuts). This kind of cereal certainly contains higher fiber content than the mashed potatoes (HGI meal) and the amount of carbohydrates available was the same at both meals, indicating that the amount of carbohydrates available differed. Taking into account that GI of meals was not determined in experimental test, the metabolic and physiological differences obtained in this study comparing the two meals tested, cannot be attributed only to differences in GI between them.

The type of hydration used during exercise after consumption of meals differing in GI can also influence the glycemic response and subsequent performance. In studies of Kirwan, Demarco et al.^{11,12}, Wu & Williams¹³, Sparks et al.¹⁷, Wee et al.¹⁸, Febbraio et al.²¹, hydration was performed with water. In studies of Kirwan et al.⁹ and Stannard et al.¹⁹ there was no hydration or it was not described, and had no other type of carbohydrate ingestion during exercise. On the other hand, Burke et al.¹⁶ evaluated the effects of GI of pre-exercise meals on metabolism and physical performance when carbohydrate solution was ingested throughout the exercise. In this study, six trained athletes consumed the HGI meal consisting of mashed potatoes (GI=87), LGI consists of macaroni (GI=37) or placebo (low-calorie jelly) two hours before exercise on a cycle ergometer at 70% $\text{VO}_{2\text{max}}$ for two hours, followed by a performance test of 300 KJ. Each meal provided 2.0g CHO.kg⁻¹ of body weight. In addition to meals and placebo, the individuals consumed 4 and 3.3ml/kg body weight of a glucose solution (concentration 10g/100ml) 15 minutes before and every 20 minutes of exercise, respectively.

Serum levels of insulin after ingestion of the HGI meal were higher at times 30, 60 and 90 minutes postprandial compared with consumption of the LGI meal. The glycemic response and insulinemia during exercise was similar between the HGI and LGI meals. It was observed that after consumption of two meals, HGI concentration was suppressed until the beginning of the exercise and whereby 20 minutes of this, was greater on the control test compared to the HGI test. The time to complete the performance exercise (300KJ) was similar among the three tests. There was no significant difference in respiratory exchange ratio, total carbohydrate oxidation and glucose oxidation ingested in carbohydrate drink between tests. Burke et al.,¹⁶ concluded that consumption of expressive quantities of carbohydrates during exercise, reduces the effect of GI of meal ingested before exercise. Under such conditions, athletes can choose the pre-exercise meal according to your habits and preferences.

Corroborating the study of Burke, Chen et al.,^{16,29} also did not observe improved performance after the LGI meal ingestion and consumption of carbohydrate drink during exercise. In this study, eight trained individuals have consumed the HGI meal (GI=82.9), LGI (GI=35.9) or placebo (low-calorie jelly) two hours before running 21km on a treadmill in the shortest time possible. Each meal had 1.5g CHO.kg⁻¹ body weight and had similar levels of

proteins, lipids and calories. It was consumed 2ml kg⁻¹ body weight of carbohydrate drink with 6.6% carbohydrate immediately before and every 2.5km of running. The area under the glycemic curve response after ingestion of the HGI meal was four times higher when compared with consumption of LGI meal. There was no significant difference in the rate of oxidation of carbohydrates and lipids and total carbohydrates and oxidized lipids between tests. There was also no significant difference in time to complete 21km of running between the two meals. According to these authors, the GI of pre-exercise meal is not as relevant to 21km race of performance when large amount of carbohydrate drink is consumed during exercise.

These results suggest that the GI of pre-exercise meal is more important for exercise lasting less than an hour, because after this period is recommended to consume sports drinks that contain carbohydrates in their formulation. In this condition, the pre-exercise meal could possibly be both the HGI as the LGI, without significant differences in metabolic response during the execution of physical activity.

Points of discussion

Although some studies had not observed improvements on performance, it was found a best outcome of metabolic and physiological parameters after the meal consumption of LGI^{17-19,21}. In addition, few studies found no significant differences in these parameters in response to ingestion of meals differing in GI.¹⁶

These divergent results between studies can be attributed to their methodological differences, such as characteristics of participants (gender, age, nutritional status, anthropometric profile and level of training), environmental factors, diet control and exercise in the days preceding the survey, exercise protocol (type, duration and intensity), type, shape and amount of carbohydrate offered, composition of the meal, time of ingestion of the meal before exercise, specific metabolic responses to meals, type of hydration offered during exercise (water or drink sports) and the method for evaluating performance. All these factors make it difficult to compare the results of these studies.

It is noteworthy that despite the results of some studies showed no benefits of ingestion of the LGI meals before exercise in the performance or in metabolic responses during exercise, in this bibliographic review was not observed study in which have found decreased performance in response to consumption of the LGI or MGI meals compared with the ingestion of the HGI meal.

It is also interesting to note that all the studies analyzed in this study were conducted under laboratory conditions. However, the execution of experimental models in field conditions, or even in competition, may also provide important information. The achievement of research in laboratory has the advantage of controlling the entire chronology of the research since the beginning, the temperature and humidity conditions of the environment. The control of possible variables that may interfere with the experiment is the main advantage of the study in laboratory, since it provides the study of the relation of cause and effect of a particular phenomenon, in a stringent and objective manner. However, it is necessary to verify the effect of the GI in practical situation, such as conditions of competition, can observe the variability of environmental conditions of temperature, humidity and pressure, the psychological state of the participant, the situation of the route, and other factors that interfere with athlete performance. The achievement of the study in training environment or competition

also allows analysis of the effects of carbohydrate quality in the performance of other modalities, as well as cycling and running. Another suggestion of research, evaluating the effect of the GI on physical performance is to conduct tests involving athletes over the age of 40 or individuals with any pathology that interferes with the glycemic response, for example, diabetes.

Conclusion

The effects of pre-exercise ingestion of meals of high, moderate and low GI on physical performance are still controversial. However, different metabolic responses in relation to the behavior of glycemia and FFA mobilization throughout the exercise resulting from consumption of the HGI or LGI meal were observed consistently. It is important to emphasize that were not reported cases of reducing performance with the consumption of diets of low or moderate GI before exercise. Furthermore, methodological differences applied in the studies make the comparison between them difficult. It is necessary to perform better-controlled studies to evaluate the effect of the GI on physical performance.

Author s' contributions

MMC and JCBM designed the study and assisted the manuscript preparation. MMC was responsible for conducting the study. RCGA and MCGP assisted the design of the study and manuscript preparation. All authors read and approved the final manuscript.

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Conflict of interest

None of the authors has any competing interests to disclose.

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