Effect of prior consumption of carbohydrate on the glycaemia and performance

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ABSTRACT

Bases and Objective: Nutrition is an important tool for the sport practice. Among the nutrients, the carbohydrates are one of the most important. In that way the aim of this study was analyze the influence of glycaemic response on performance of healthy subjects, after intake of different carbohydrate solutions. **Methods:** Ten healthy male subjects, 23 ± 2.1 years old, were asked to answer a three days nutritional and physical activity recordatory. Anthropometric data were collected and a progressive test in cycle ergometer was performed to measure the maximal oxygen uptake and ventilatory thresholds. Each subject performed three submaximal tests at the intensity of second ventilatory threshold. Thirty minutes before each submaximal test, 250 ml of each drink: maltodextrin (Malto), glucose (Glicose) plus sport drink or dietetic juice (Placebo) was ingested. Venous blood was collected to determine the glycaemic index and lactate. **Results and Conclusion:** There was a significant increase after 30 minutes when the subjects ingested maltodextrin solution (87.4 ± 11.2 to 116.9 ± 19.6 $ml.dl^{-1}$). After 15 minutes of exercise, there was a decrease in the glycaemia after the consumption of Malto (116.9 ± 19.6 to 77.6 ± 14.5 $ml.dl^{-1}$) and Glicose (113.2 ± 23.5 to 81.8 ± 13.1 $ml.dl^{-1}$) plus sport drink solutions when compared with Placebo solution. The glucose plus sport drink solution induced a significant increase in the heart rate during exercise (167.7 ± 14.2 and 177.1 ± 10.4 bpm). The consumption of different carbohydrate solutions with high glycaemic index before exercise was not capable to change the performance of the volunteers. However it induced changes in the glycaemia and heart rate during exercise. Thus the oscillations on glycaemia during exercise may affect negatively the long distance performance, this fact was not verified in our study.

Keywords: Carbohydrate drinks. Glycaemia. Exercise.

INTRODUCTION

Nutrition is an important tool within the sports practice, once when well oriented it may reduce fatigue, which allows the athlete to train longer or better recover between training sessions[1]. Since many food nutrients provide energy and regulate the physiological processes related to exercise, it would be tempting to associate the dietetic changes with improvement of the athletic performance[2].

According to the Subcommittee of the Dietetic Ingestion Recommendations (DIR) from 1989[3], in a balanced diet the carbohydrates should represent the biggest part of the energetic ingestion. Although being small, the body's glycogen supplies[4], are important during the fasting period, as well as during extended exercise situations, in which the glucose and the fatty acids are oxidized in order to provide energy to the muscular contraction[5].

The carbohydrates are divided in three main categories: monosaccharides, disaccharides and polysaccharides. As examples of monosaccharides we have the glucose and the fructose, as disaccharides we have the saccharose, maltose and lactose and in the polysaccharides group we find the complex carbohydrates which include the glucose polymers (as the maltodextrin)[6].

Due to the fact that the body does not digest and absorb the carbohydrates with the same velocity, a mechanism called glycemic index was developed in order to evaluate the effect of the carbohydrates on the blood glucose[7]. The glycemic index is a qualitative indicator of the ability of an ingested carbohydrate to increase blood glucose levels[8], providing effective information for a suitable nutritional plan in relation to the strategic supplementation of carbohydrates for the exercise[9]. Such fact suggests that besides the kind of carbohydrate (simple or complex), the glycemic index can be used as a reference guide for the selection of the ideal carbohydrates nutritional support for athletes.

The more intense the exercise, the bigger its dependence in relation to the carbohydrate as fuel[4]. Thus, the measurement of some functional limitation indexes during physical activity becomes important in order to have a suitable follow-up of the individual's physical performance. Among these variables, we find the heart rate (HR), the oxygen maximal consumption ($\dot{V}O_{2max}$) and the blood lactate[10], which help in the training control and physical performance of athletes and physical activities practitioners.

The drinks containing different quantities and kinds of electrolytes and/or nutrients such as carbohydrates are used by athletes and physical activities practitioners, with the objective to improve the physical performance. The sport drinks can be taken before, during or after exercise. When taken before exercise, they have as objective to prevent or delay the homeostatic disturbs which may follow the physical activity, granting a suitable plasmatic volume from the beginning of the exercise. It also promotes a small fluids reserve in the gastrointestinal lumen, which will be absorbed during the activity. Moreover, the consumption in the pre-exercise can optimize the glucose concentrations in the flowing blood, through the supply of carbohydrates[11]. When used during exercise, the carbohydrates can improve the performance as shown in the study by Carter *et al.*[12]. The intake of solutions containing carbohydrates after exercise is recommended by the Brazilian Society of Sports Medicine[13], with the aim to favor a maximal resynthesis of muscular and hepatic glycogen.

The effect of the intake of drinks containing carbohydrates in the pre-exercise in relation to metabolism and performance is questioned yet. Some studies presented performance improvement[14-16], while others did not obtain effects[17-20] or even demonstrated performance decrease[21-22]. Therefore, this work aims to clarify the effects of the prior consumption of drinks with different kinds of carbohydrates before an exercise in cycle ergometer with stable intensity in the second ventilatory threshold.

METHODS

Sample: 10 healthy male, non-smoker and non-athlete volunteers, who did not use supplements, were evaluated and invited

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to participate in the study after reading and signing the informed consent term. This study was approved by the Ethics in Research Committee from the Methodist Educational Group – IPA (# 1100 from 06/08/2004).

Dietetic intervention: After completion of three days diet query, physical activity recording and anthropometrical evaluation[23], individualized diets containing 60% of carbohydrates, 12% of proteins and 28% of lipids were calculated, with the aid of the nutrition software DIETWIN, Professional version 2.0, which should be followed during three days prior each submaximal test.

Preliminary test: Initially, a progressive load cycle ergometer test was performed with the aim to verify the $\dot{V}O_{2max}$ and the ventilatory thresholds (VT) of each volunteer, according to the protocol proposed by Lucía *et al.*[24]. The $\dot{V}O_{2max}$ was determined through an ergospirometer (Medical Graphics Corporation, CPX-D, USA) and through cycle ergometer (Cybex, The Byke, USA). The HR was obtained through frequency meter (Polar S610, Finland). The VTs were determined from the results obtained. The oxygen consumption ($\dot{V}O_2$) of the first ventilatory threshold (VT1) was determined from the first disproportional increase of ventilation (VE) in relation to $\dot{V}O_2$, proportional to the increase in the carbon dioxide increase (CO_2). The second ventilatory threshold (VT2), was determined through simultaneous increase in the equivalent ventilatory of oxygen ($VE.\dot{V}O_2^{-1}$) and of the equivalent ventilatory of CO_2 ($VE.VCO_2^{-1}$) while the expired pressure of CO_2 ($P_{ET}CO_2$) started to increase. The $\dot{V}O_{2max}$ was determined as the highest value obtained in periods of 30 s during the test.

Drinks: Thirty minutes before the exercise beginning, the volunteers ingested 250 ml of one of the three different drinks chosen through a previous draw. The drinks were named and constituted as follows: Placebo drink – consisted of flavored juice and unsweetened from the brandname *Clight*® (composition: 0 g of CHO); Malto drink – consisted of 1 g of maltodextrin/kg of body weight, reconstituted in water, with the same flavor from the Placebo drink; Glicose drink – consisted of 250 ml of *Gatorade*® (composition: 18 g of CHO) added to the necessary glucose amount to complete 1 g of glucose/kg of the body weight in the same flavor of the other drinks. *Gatorade*® was used only in the drink glucose-based in order to flavor the preparation, once the placebo solution (consisted of dietetic juice) and the maltodextrin-based drink had the same flavor. All drinks were prepared by the same researcher, and the volunteers did not have knowledge of the content of the drink he was ingesting.

Experimental tests: each volunteer performed three submaximal tests in the second ventilatory therhold, with the aim to verify the variation in the glycemia and performance after prior ingestion of the three different drinks. A glucometer (*Accu Check Active*, Roche, Germany) was used to verify glycemia, and to evaluate performance, the HR variables and respiratory exchange rate (RER) were analyzed during the exercise, as well as the blood lactate concentration (lacto meter *AccuSport,* Roche, Germany) and weight loss in the end of the exercise. Before the drinks intake, a blood sample was collected in order to determine the glycemia in rest. Thirty minutes after the drink intake, the volunteer was weighted and the capillary glycemia was measured again. Immediately after such procedure, the exercise began. Its protocol consisted of a load increase period until the stabilization of the target load, which could last up to 10 minutes. After this adaptation period, the glycemia was measured at each 15 minutes of the exercise, which was performed up to exhaustion or up to 60 minutes completion. At the end of the test, besides the glycemia measurement, the blood lactate was also checked, and the individual was weighted in order to verify the weight loss through sudoresis. The same protocol was repeated in the two following tests, with the prior ingestion of the other drinks.

Statistical analysis: The data were structured and analyzed using the SPSS statistical package (*Statistical Package for Social Sciences*) version 12.0 for Windows. The Shapiro-Wilk and Levene tests were used to verify the pre-concepts of normality and homogeneity of variances, respectively. ANOVA Two Way for repeated measures and *post hoc* by Tukey were used for the glycemia results in the different moments, when significant alterations were verified. ANOVA One Way and *post hoc* test by Tukey were used for the lactate results in the end of the exercise, weight loss, HR, RER and exercise time. The results were expressed in average ± standard deviation and the accepted significance level were of p < 0,05.

RESULTS

The studied population, as described in table 1, was characterized as eutrophic[25], presenting HR_{max} values within the expected values. The values found for the $\dot{V}O_{2max}$ and the VT indicated, according to the American College of Sports Medicine[26], a healthy sedentary population, and none of the volunteers presented alterations in the fasting glycemia.

TABLE 1
Sample characterization

	Average ± dp
Age (years)	23 ± 2,10
Weight (kg)	72,71 ± 6,69
Height (cm)	177,1 ± 5,15
IMC (kg/m²)	23,16 ± 1,32
Fat (%)	16,63 ± 5,63
$\dot{V}O_{2\,max}$ (ml.kg^{-1}.min^{-1})	44,97 ± 7,68
HR_{max} (bpm)	180,1 ± 15,84
LV (ml.kg^{-1}.min^{-1})	33,71 ± 5,15
Glicemia fasting (mg/dl)	91,06 ± 7,47

Values expressed in average ± dp of the ten participants of the study.

The caloric ingestion of the volunteers was within the recommended standards for healthy individuals when carbohydrates (56,69% ± 6,45) and lipids (25,95% ± 4,20) were analyzed. However, they presented a protein consumption above the recommendation (17,34% ± 3,13) for non-athlete individuals[3].

No significant differences were observed between groups in weight loss caused by the exercise (p = 0,190), in the final lactate values (p = 0,077), in the HR_{max} (p = 0,211) in the submaximal tests and in the total exercise time (p = 0,683) (table 2).

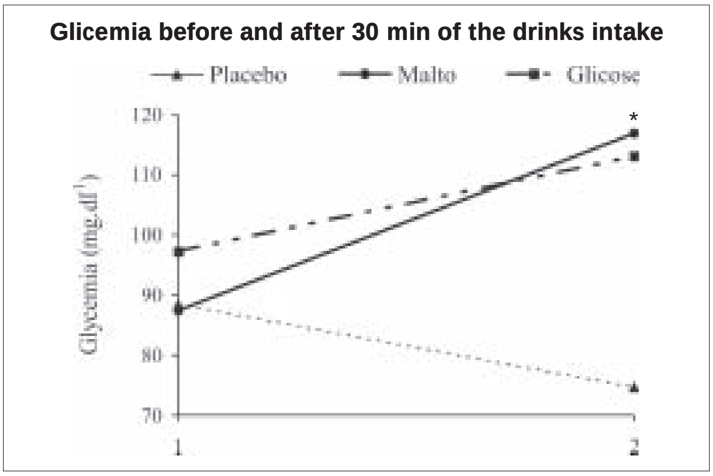
TABLE 2
Weight loss, final lactate, exercise time and HR_{max} in the exercise after different drinks intake

	Weight loss	Final lactate	Exercise time	HR_{max}
Placebo drink	0,59 ± 0,36	9,26 ± 3,9	37,9 ± 17,8	175,1 ± 11,6
Malto drink	0,54 ± 0,25	6,45 ± 2,5	34,9 ± 15,1	177,4 ± 8,7
Glicose drink	0,55 ± 0,24	9,15 ± 3,7	39 ± 14,7	178,1 ± 11,7

Values expressed in average ± dp of the weight loss (kg), final lactatein the end of the exercise (mg/dl), test time (min), and HR maximal in the exercise of the ten volunteers during each submaximal test after drinks intake: Placebo, Malto (drink maltodextrin-based) and Glicose (drink glucose-based).

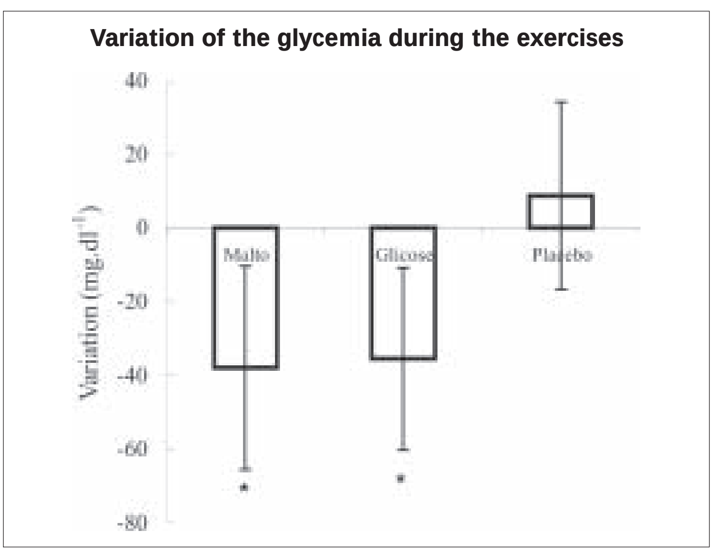
After intake of the Placebo and Glicose drinks, the volunteers did no present alterations in the glycemia in the prior and post 30 minutes of ingestion (88,5 ± 14,9 for 74,7 ± 25,6 ml.dl^{-1}, p = 0,240 and 97,3 ± 14,5 for 113,2 ± 23,5 ml.dl^{-1}, p = 0,091, respectively), differently from the glycemic response after the Malto drink intake, which significantly increased glycemia (87,4 ± 11,2 for 116,9 ± 19,6 ml.dl^{-1}, p = 0,001) in the same period (graph 1).

After 15 minutes of exercise, the glycemia was stable after the Placebo drink intake, significantly decreasing in the groups that



Graph 1 – *Glicemia of the 10 volunteers before* ***(1)*** *and after* ***(2)*** *30 minutes of the drinks intake. Malto (drink maltodextrin-based), Glicose (drink glucose-based) and Placebo, without exercise intervention. * Significant difference after the Malto drink intake (p = 0,001). Data expressed in average ± dp.*

ingested the Malto and Glicose drinks (116,9 ± 19,6 for 77,6 ± 14,5 $ml.dl^{-1}$, p = 0,000 and 113,2 ± 23,5 for 81,8 ± 13,1 $ml.dl^{-1}$, p = 0,002, respectively). Between the 15 and 30 minutes of exercise, no statistically significant differences were observed in the three groups, however, a tendency to decrease the glycemic levels was observed in the individuals who ingested the Glicose drink. Between the 30 and 45 minutes of exercise, no statistically significant differences were found. After the Malto and Glicose drinks intake, a significant decrease in glycemia occurred (116,9 ± 19,6 for 78,8 ± 17,8 $ml.dl^{-1}$, p = 0,002 and 113,2 ± 23,5 for 77,6 ± 10,4 $ml.dl^{-1}$, p = 0,001, respectively) when the groups were compared before and after exercise, while the Placebo drink did not significantly change glycemia (74,7 ± 25,7 for 83,4 ± 21,05, p = 0,309) (graph 2).



Graph 2 – *Variation of the glycemia between the beginning nad the end of the tests after intake of the drinks Malto (drink Maltodextrin-based), Glicose (drink glucose-based) and Placebo. * Significant differences after the intake of the drinks: Malto (p = 0,002) and Glicose (p = 0,001). Data expressed in average ± dp.*

No significant changes were found throughout the submaximal tests in the RER data.

When analyzed the heart rate at the beginning of the exercise, no significant alterations were found after the Placebo drink intake (166,1 ± 15,7 and 169,6 ± 19,6 bpm, p = 0,984) and the Malto drink intake (173,1 ± 13,4 and 175,2 ± 7,64, p = 0,193), however, after the Glicose drink intake, a highly significant increase was observed (167,7 ± 14,2 and 177,1 ± 10,4 bpm, p = 0,004).

DISCUSSION AND CONCLUSION

Divergences are found in literature about the intake of drinks composed of different kinds of carbohydrates and its relation with performance in exercises done in cycle ergometer. Some studies report that the ingestion of carbohydrates with high glycemic content before exercise would negatively affect endurance performance due to the fast increase of the blood glycemia, which would generate a reactive hypoglycemia or rebound hypoglycemia, due to the induction of an increase of insulin liberation by the pancreas[(15)]. A resulting backfire hypoglycemia, the catabolism of fats deprived and a possible early depletion of the glycogen supplies, may negatively impact the endurance performance[(27)]. Foster and collaborators[(21)] demonstrated that the ingestion of 75 g of glucose 45 minutes before an exercise relatively intense (84% $\dot{V}O_{2peak}$) was associated with a decrease in the time up to exhaustion compared to a mixed meal or control.

The data of present study suggest that intake of carbohydrate drinks 30 minutes before the exercise, composed of simple or complex carbohydrates (glucose and maltodextrin, respectively) and both solutions of high glycemic level[(1)], did not alter the performance in the exercise when compared to the intake of drinks with no carbohydrates (placebo). Our results corroborate with the findings by Febbraio and Stewart[(17)] and Febbraio *et al.*[(18)]. In the study by Hargreaves *et al.*[(15)], the intake of carbohydrates with high glycemic level, 45 minutes before exercise, did not generate effects in performance, independently of the glycemic response. Other studies, in which solutions with low and high glycemic indexes were compared to placebo, demonstrated that when carbohydrates with high glycemic index were ingested, an increase in the CHO use during exercise was observed. However, they did not obtain effects on the performance either[(19,28)].

In the results analysis of the glycemic levels of this study, after the glucose-based drink intake, no changes in glycemia up to the beginning of exercise was observed (30 minutes period). Such stability in glycemic levels, according to McArdle *et al.*[(27)], may have been caused by rebound hypoglycemia, that is, the intake of the solution composed of a simple carbohydrate and of high glycemic index would generate an increase in the blood glucose concentrations between the 5th and 10th minute after ingestion. Such increase in glycemia, would lead to an increase of insulin by the pancreas, which due to a rapid transportation of plasmatic glucose to the cells through the type 4 glucose transporters (GLUT-4)[(29)], would cause a decrease in the plasmatic glucose, returning to basal glycemic levels close to the beginning of the exercise. In the study by Marmy-Conus *et al.*[(30)] the decrease in the glycemic levels occurred after 20 minutes of the glucose-based drink intake, later returning to values close to the initial ones.

The glycemia significantly decreased with the beginning of the exercise after the glucose-based drink intake (p = 0,002) up to 15 minutes of test compared to placebo drink intake. Our results corroborate with the findings by Febbraio *et al.*[(17)] in a study in which the increase in the glycemic levels occurred after approximately 15 minutes of intake of the solution with high glycemic level, followed by the constant decrease up to the beginning of the exercise (45 minutes after ingestion). However, in studies conducted by Kirwan *et al.*[(31)], the ingestion of a meal with high glycemic index caused an increase in glycemic levels after 30 minutes of ingestion, followed by a constant decrease up to the end of the exercise. In the study by Febbraio *et al.*[(19)], such decrease after the beginning of exercise approximately continued up to 40 minutes, followed by an increase in glycemia up to the 90 minutes of exercise, with a new decrease after this period. This fact may have happened due to the increase of the carbohydrates oxidation and decrease of fatty acids oxidation during the exercise.

In the results of the glycemic levels after the maltodextrin-based drink intake, significant differences were observed when compared to the results obtained after ingestion of the glucose-based and the placebo drinks. The maltodextrin being classified as of a high glycemic index and also a complex carbohydrate causes glucose to pass to the blood stream more slowly. Thus, the increase of glycemic curve is stable for a longer time. In the study by Kirwan *et al.*[31], when a meal with complex carbohydrate and of high glycemic index was offered 45 minutes before exercise, an increase in glycemia after 30 minutes of ingestion was observed. After this period, it generated a decrease in glycemia up to the end of the test. In our study, when the solution with similar classification was provided, such decrease occurred up to 15 minutes after stabilization was experienced.

When the volunteers ingested Placebo drink, no oscillations in glycemia were found, neither caused by the drink intervention nor by the exercise influence. This behavior of the glycemic curve was expected and corroborates with results found in many studies[31-33]. During a 30 minutes or longer exercise, insulin concentrations tend to decrease, although glucose concentration may be relatively constant[34]. Such fact is probably due to a gradual increase in the plasmatic concentrations of glucagon, which will stimulate hepatic glycogenolysis. Therefore, an increase of availability of glucose for the cells occurs, being suitable to the plasmatic concentrations of glucose in order to satisfy metabolic demands increased by exercise.

The heart rate did not present significant differences during exercise after the placebo drink intake and the maltodextrin-based one. However, when individuals ingested the glucose-based drink, a significant increase was observed (167,7 ± 14,28 for 177,1 ± 10,43; p = 0,004) of HR during the exercise (after adaptation period up to the end of the test). Yet, such alteration was not observed in studies conducted by Fielding *et al.*[35], Kirwan *et al.*[31] and Sparks *et al.*[33]. The HR increase could be related to the insulin increase[36-37]. The insulin generates an adrenergic effect which induces to a positive chronotropic effect on the heart[38]. The insulin effect is evident even when hypoglycemia is avoided by glucose infusion or when β-adrenergic receptors are blocked[39]. Thus, it is suggested that whenever a higher availability of glucose is present, it would lead to a higher insulin production[39], causing an increase of the activity of the sympatic nervous system and hence increasing the HR[36]. However, since seric insulin has not been measured during our study, new studies would be necessary in order to test such hypothesis.

The blood lactate, which may be used as a diagnosis, prescription and control of exercise intensity index[40], did not present differences after the tests with the three different drinks. Our data corroborate with results obtained in the study by Gleeson *et al.*[16]. In the study by Febbraio *et al.*[17], the blood lactate levels increased after 120 minutes of exercise comparing to rest. When compared to the groups that ingested meals with high glycemic index, low glycemic index and placebo, no significant alterations were observed, though. The found values in our study suggest that the three submaximal tests were performed in the same intensity. The blood lactate measurement is widely used in order to predict the exercise performance[41-42], as well as the exhaustion time. The exercise time was not altered by the drinks intake, being reasonable then, that the lactate concentration at the end of the exercise is not different either.

No significant differences in the values of the RER were found during the tests conducted after the Placebo, Malto and Glicose drinks intake. However, DeMarco *et al.*[43] when comparing the intake of solutions with high glycemic index, low glycemic index (1,5 g of CHO/kg of weight) and placebo found an increase in the RER in the group that ingested the solution of high glycemic index compared to the other two groups in the first 100 minutes of exercise, followed by a decrease up to 120 minutes. The increase in the values of RER were also demonstrated in the study by Sparks *et al.*[33], where the ingestion of a solution of high glycemic index increased the RER, concomitantly with the increase in the carbohydrates oxidation. Probably, if the test time was not limited, significant differences in the RER of the volunteers after the different drinks ingestion could have been found.

This study demonstrated that the intake of drinks with different kinds of carbohydrates (simple and complex) and of high glycemic index, 30 minutes before a submaximal exercise in the second ventilatory threshold was not able to alter the volunteers' performance. However, alterations in the glycemia after intake of the glucose and maltodextrin-based solutions in the adaptation period to the exercise were verified. Besides that, increase in the HR after intake of the glucose-based solution was observed as well. Although it is speculated that oscillations in the glycemia during the exercise may harm performance in long run exercises, such fact was not verified in our study. Additional studies measuring seric concentrations of pancreatic and adrenergic hormones are needed in order to better elucidate these findings.

All the authors declared there is not any potential conflict of interests regarding this article.

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