Effect of hydration with carbohydrates on the glycemic response in type I diabetics during exercise

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ABSTRACT

It is not clear whether the carbohydrate (CHO) ingestion through sports drinks can maintain blood glucose concentrations in type I diabetics. The objective of this study was to examine blood glucose concentrations in adolescents with type I diabetics who ingest a sport drink with 6% CHO during and after exercise. Ten (5 males and 5 females) adolescents (15.3 ± 2.4 years) with a well-controlled type 1 diabetics (HbA_{1C} < 12%), and without complications of the disease, cycled at 55-60% of their peak $\dot{V}O_2$ during 60 minutes in two separate days. In a randomized order and double-blinded design, subjects ingested (5 ml· kg^{-1} prior to exercise, and 2 ml· kg^{-1} every 15 minutes of exercise) a sport drink with 6% CHO (CHO-6%) or a flavored water without CHO (placebo) with similar color and taste as the sport drink. After one hour of exercise, blood glucose concentrations in the CHO-6% situation did not decrease significantly (221.0 ± 78 to 200.5 ± 111mg· dL^{-1}, p > 0.05) as it did in the placebo situation (282.9 ± 85.1 to 160.2 ± 77.0 mg· dL^{-1}, p < 0,05) (9 vs 43.2%). After 30 min of recovery, blood glucose concentrations were 177.2 ± 107 mg·dL^{-1} with CHO-6% and 149.1 ± 69.6 mg·dL^{-1} in the placebo situation, representing 20.1% and 47.3% of pre-exercise levels. No significant differences between situations were found in heart rate, rate of perceived exertion or in blood insulin and electrolytes levels. No changes in hematocrit and hemoglobin were found during exercise, indicating that subjects remained euhydrated. In conclusion, the use of drinks containing 6% of CHO was shown to attenuate the exercise-induced reduction of blood glucose concentration in adolescents with type I diabetes.

Key words: Diabetes. Sports drinks. Hypoglycemia.

INTRODUCTION

One of the objective of controlling *diabetes mellitus* (DM) is to allow individuals to have a better quality of life with the inclusion of the practice of regular physical activities and participation in many sports, especially those individuals with type I diabetes (insulin-dependent *diabetes mellitus*), whose disease usually manifests during childhood and adolescence. Physical exercises are recommended for individuals with diabetes because DM is associated with the increase on the lipoproteins circulation (LDL cholesterol and triglycerides), vascular impairments, high blood pressure and hence cardiovascular problems[1].

The risk of hypoglycemia caused by exercise in individuals with type I diabetes is a concern both for professionals and for their families. Studies have been conducted to identify factors to decrease the risk of hypoglycemia during exercise. The main factors are: the maintenance of the blood glucose concentration, diet control and local insulin application[2], application time in relation to exercise[3] and the absorption rate according to room temperature[4]. Once these aspects have been controlled, an important way for hypoglycemia prevention during exercise is the adequate CHO ingestion.

The specific recommendations considering the amount of CHO supplementation during exercise change among researchers[5-8]. It has been suggested in recent review[9] that the reposition may be calculated based on the relative use of CHO in the energetic supply of each physical activity. For example, in moderate intensity exercises, about 50% of the energetic expenditure occur through carbohydrate oxidation. Thus, for an energetic expenditure of 12 Kcal/min^{-1}, 1.5 g of carbohydrates per minute are required. This would be necessary to replace 45 g of carbohydrates each 30 minutes.

Young[8] suggests the ingestion of a snack containing 40-69 g of CHO before a moderate-intensity exercise, while Horton[5] proposes the ingestion of 35-40 g of CHO each 30 minutes. Wallberg-Henriksson[7] suggests the decrease of the insulin dose and the supplementary CHO ingestion for 30-minutes moderate-intensity exercise for two hours of cycling. Kemmer[6] proposes an adjustment on the insulin dose and ingestion of 15-30 g of CHO each 30 minutes for extended exercises. However, adjustments on the insulin dose may not be convenient for children and adolescents who present spontaneous physical activity pattern.

In order to avoid hypoglycemia, the ingestion of CHO must match the amount of CHO used. This was studied by Riddell *et al.*[10] in 20 adolescents with type I diabetes who exercised in cycle ergometer during one hour ingesting water or sport drink with 6-8% CHO. In the session containing sport drink with CHO, the blood glucose concentration did not drop significantly and in the session using only water in nine subjects, the test was interrupted due to the risk of hypoglycemia. The individualized CHO quantification requires indirect calorimetry; this resource is quite sophisticated and may not be accessible for routine use.

As the euhydration maintenance is vital not only for thermal regulation, performance and blood glucose control[1], the CHO reposition during exercise may be obtained and well monitored when done under the form of liquids.

The objective of this study was to examine the glycemic response in adolescents with type I diabetics after 60 minutes of exercise in cycle ergometer (55-60% of the $\dot{V}O_{2peak}$) and after 30 minutes of recovery in two situations: 1) with replacement of sport drink containing 6% of CHO, and 2) with replacement of flavored water with similar color and taste of the sport drink, however, free of CHO and electrolytes (placebo).

METHODS

Sample – Ten voluntary individuals (five boys and five girls) participated in this study after being informed about the procedures. Individuals above 18 years of age signed the consent form and the underaged were authorized by their parents. The projects was ap-

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proved by the Ethics Committee of the Porto Alegre General Hospital. The individuals were recruited from the Nursing sector – Porto Alegre General Hospital at the Rio Grande do Sul Federal University (UFRGS) through note published in local newspaper.

The subjects aged from 12 to 19 years with diagnosis of type I diabetes between one and ten years (average = 4.9 ± 3.21 years). The physical characteristics, disease duration and the glycosylated hemoglobin values (HbA_{1C}) are shown in table 1. Subjects with diabetes complications such as nephropathy, retinopathy, autonomic neuropathy, ischemic cardiopathy and uncontrolled diabetes were excluded from the study.

TABLE 1
Physical characteristics, duration of disease and glycosylated hemoglobin values (HbA_{1c}) of each subject (average ± standard deviation)

Subject	Gender (M/F)	Age (years)	Weight (kg)	Stature (cm)	*∑ Folds (mm)	Duration of diabetes (years)	HbA_{1C} (%)
1	M	15	73.7	180.5	89	4	8.0
2	M	16	61.9	185.5	55	3	6.3
3	M	19	61.0	173.0	53	1	4.9
4	M	16	71.3	178.0	86	4	7.6
5	M	15	70.6	174.0	113	10	5.6
6	F	15	71.8	161.5	260	9	11.2
7	F	19	60.4	172.0	64	2	5.5
8	F	12	44.3	157.2	145	4	8.2
9	F	14	50.0	157.1	191	9	10.5
10	F	12	39.6	154.0	103	3	7.8
Average ± SD		15.3 ± 2.4	60.4 ± 12.7	169.2 ± 11.0	115.9 ± 66.1	4,9 ± 3,21	7.56 ± 2.0

* ∑ Folds = summation of the skinfolds: biceps, triceps, subscapular, abdominal, suprailliac, thigh, calf, thorax and medial-axillary; M/F: male/female.

Drinks – The sports drinks with 6% CHO presented isotonic composition containing 4% sucrose and 2% fructose, Na^+ 18,5 mEq· L^{-1}, Cl^- 15,5 mEq· L^{-1} and osmolarity of 292 mOsm· L^{-1} (*Gatorade*, Quaker Oats). The drink placebo (CHO-free and electrolytes) was elaborated by the Quaker laboratories (São Paulo), that simulated flavor and color of the commercial drink. Both drinks presented tangerine flavor and color in order to assure double-blinded design of the study. A flavor-perception questionnaire[11] was applied for both drinks (placebo and CHO-6%) in all individuals in order to verify their similarity. The same questionnaire was applied in 35 non-diabetic volunteers. No significant difference in the flavor perception for both drinks in the non-diabetic group (p = 0.0678) and in the study group (p = 0.512) was observed.

Procedures – All individuals were firstly evaluated for the selection and participated in the flavor test and later submitted to two experimental sessions. The evaluation session comprised verification of the health and physical activity status, weight (Filizola scale), stature (wall mounted stadiometer) and nine skinfolds (biceps, triceps, subscapular, suprailliac, thigh, calf, thorax and medial-axillary) were measured using a *Lange* skinfolds caliper.

In order to standardize the exercise intensity in the experimental sessions, the oxygen intake peak ($\dot{V}O_{2peak}$) was determined using indirect calorimetry (KBIC – Metabolic Analysis System Aeroport – USA). A continuous and progressive protocol was used[12] in *Cybex* cycle ergometer (USA), the same equipment used in experimental sessions.

For the $\dot{V}O_{2peak}$ test, the subjects were told to apply the insulin in the abdominal region in order to avoid the fast absorption as in the case of application in the leg[8]. The blood glucose concentration was monitored using *Accutrend* (Boehringer Mannheim GmbH – Germany) before the test, each 5 minutes of test and after 30 minutes of test. The criterion adopted for the test interruption was: if blood glucose concentration reached 60 mg.dL^{-1} or reduction rate higher than 10 mg·dL^{-1} at each stage in case of absolute value lower than 90 mg·dL^{-1}[13]. In this session and in the experimental ones, the individuals were told to inform their blood glucose perception (GP) before each blood glucose monitoring. Studies have demonstrated good correlation between GP and blood glucose[14-16].

Both experimental sessions took place in the Exercise Research laboratory (Lapex) with controlled room temperature between 20 and 22°C. Except for the drink ingested, both sessions were identical with interval of four to seven days between sessions. The sessions were performed in the morning, about three hours after the abdomen insulin application. The individuals were told to maintain their food habits during the period of the procedures. These recommendations were strengthened at the arrival of individuals at the laboratory.

Before exercise, the blood glucose concentration was monitored with *Accutrend* (Boehring Mannheim GmbH – Germany) according to the same criteria of the $\dot{V}O_{2peak}$ test. In three sessions the test was interrupted; in two of them, the subjects presented hypoglycemia (54 mg· dL^{-1} and 34 mg· dL^{-1}, respectively); and in the other, one subject presented hyperglycemia (blood glucose > 400 mg· dL^{-1}).

The blood glucose concentration was monitored 5 minutes before exercise and during exercise at 15, 30, 45 and 60 minutes, during recovery at 10, 20 and 30 minutes. The individuals reported their GP before the blood glucose monitoring, values not informed to subjects. The criterion to interrupt test was the same used during the $\dot{V}O_{2peak}$ test.

In both sessions the subjects exercised in cycle ergometer during 60 minutes at 55-60% of their $\dot{V}O_{2peak}$. The heart rate (HR) was continuously monitored through frequencimeter (*Polar Electro*, Finland), and the individuals indicated the rate of perceived exertion (RPE) through the Borg scale[17].

The volume of drink ingested was the same for both sessions and calculated according to the sweating rate for the maturation degree[18]. This was 5 ml· kg^{-1} before the beginning of the test and 2 ml· kg^{-1} each 15 minutes of test (15, 30 and 45 minutes). The drink temperature was 8-10°C.

Blood collecting and biochemical analyses – Venous blood was collected from forearm 15 minutes before and 5 minutes after exercise sessions. The blood from one subject could not be collected in one of the two sessions; the blood from a second subject could not be collected after exercise in the second session.

The blood was maintained in vacutainers tubes with EDTA. Hemoglobin (Hb) and hematocrit (Hct) were analyzed at the same collecting day. For insulin and electrolytes (Na^+, Cl^-, K^+), the blood was centrifuged for plasma separation. These samples were frozen at –70°C and all of them were analyzed after the end of the experiments.

The plasma insulin levels were analyzed through radioimmunoassay technique (*Gamma Irradiation Counter*, Gamma Count-DPC) and glucose pre and post-exercise using enzymatic method through glucose hexokinase (*Glucose Merck Mega* 107116) and electrolytes Na^+, Cl^- and K^+ through the indirect potentiometry method (*Mega Merck*, Merck).

Htc and Hb were analyzed according to the impedance variation method (*Cobas Argos 5 Diff*, Roche) and the glycosylated hemoglobin (HbA_{1c}) analyzed through high-pressure liquid chromatography (*HPLC – L9100*, Merck-Hitachi).

Statistical analysis – Data are presented as average and standard deviation (SD). The results were analyzed using the independent and paired Student's *t* test, according to the situation. Simple linear correlation (Pearson) was used for GP and blood glucose concentration. The significance level adopted was $p < 0.05$. The data were processed in *Excel* 97 and *Statistical Package for Social Science*, SPSS V6.0.

RESULTS

Figure 1 shows the HR results during experimental session in both situations (CHO-6% and placebo). The HR response during exercise presented no significant difference between situations in none of the stages. The average difference of HR was of 7 bpm ($p = 0.61$) in time 0 (rest) and the average values were of 3 and 6 bpm ($p = 0.93$ and 0.5) during exercise. After 10 minutes recovery, the HR remained similar ($p = 0.85$).

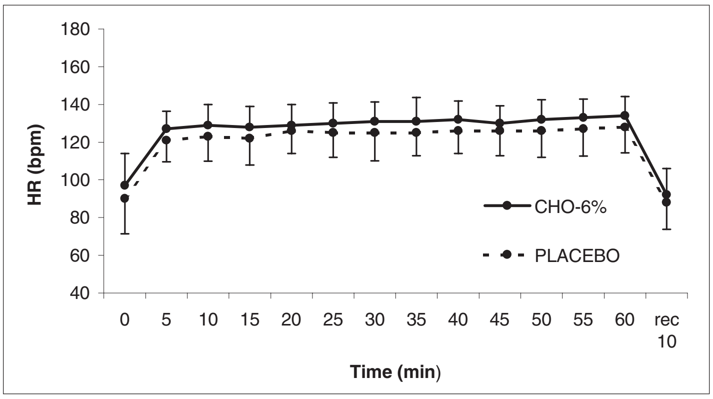

***Fig. 1** – Heart rate (HR) in CHO-6% and placebo situations (average ± standard deviation)*

The exertion similarity between both situations may also be observed in the RPE (figure 2). The RPE values were similar in both situations, regardless the time of exercise, showing values of 12-13 (a little high), according to the Borg scale.

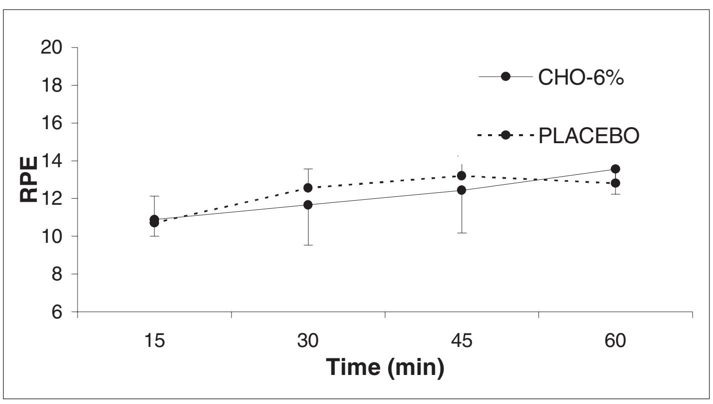

***Fig. 2** – Rate of perceived exertion (RPE) in CHO-6% and placebo situations (average ± standard deviation)*

GP presented average values below those found in blood glucose concentration. In some intervals, the agreement was higher in the placebo situation than in the CHO-6% situation. This similarity may be related with the blood glucose levels, once the GP showed to be more precise at low blood glucose concentrations. The blood glucose concentration in placebo situation for 30 minutes of exercise in the experimental session was lower than the CHO-6% situation.

Blood glucose concentration and GP presented low correlation in all intervals ($p = 0.248$). However, some individuals presented good capacity to perceive blood glucose. The agreement showed to be higher with blood glucose values lower than 150 mg· dL^{-1}.

After one hour of exercise, the blood glucose concentration measured through the enzymatic method (hexokinase glucose) in CHO-6% situation did not decrease significantly (221.0 ± 78 for 200.5 ± 111 mg· dL^{-1}, $p > 0.05$); in placebo situation, the blood glucose concentration decreased significantly (282.9 ± 85 for 160.2 ± 77 mg· dL^{-1}, $p < 0.05$) (9 vs 43.2%).

The blood glucose concentration results measured through *Accutrend* before, during and at the 30 minutes of recovery from exercise are shown in figure 3. In placebo situation, a significant drop ($p < 0.05$) in the blood glucose concentration was observed in comparison with CHO-6% situation. Although the average pre-exercise blood glucose concentration in placebo situation had been high (~20%), this difference was not statistically significant. Furthermore, there was a increase tendency of 13 mg· dL^{-1} in CHO-6% situation at the first 15 minutes of exercise, while in placebo situation, a drop of 37 mg· dL^{-1} was observed. The reduction on the blood glucose curve was more remarkable in placebo situation, especially during exercise. The reduction on the blood glucose at the beginning of the exercise, at the end of the 60 minutes and at the recovery period was significant only in placebo situation. Between situations, the drop on the blood glucose concentration at the end of the 60 minutes was of 101.4 mg· dL^{-1} ($p = 0.02$), and at the 30 minutes of recovery was of 89.2 mg· dL^{-1} ($p = 0.05$).

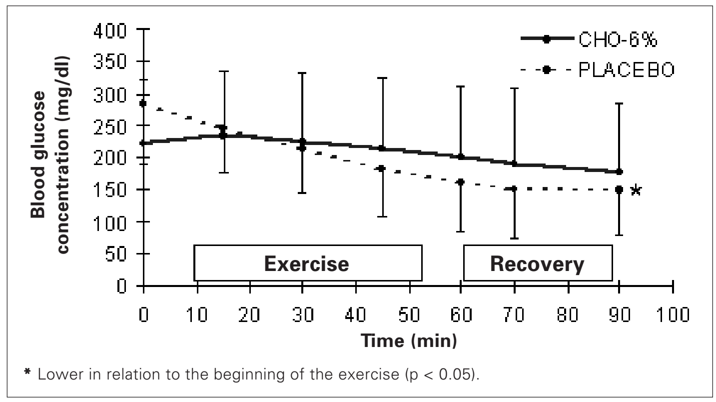

***Fig. 3** – Blood glucose concentration in CHO-6% and placebo situations during exercise and at recovery period (average ± standard deviation)*

Table 2 shows the results of the blood analyses before and after exercise. No significant alterations were observed for insulin concentrations, Hct, Hb and electrolytes in both situations.

TABLE 2
Plasma insulin, hematocrit, hemoglobin and electrolytes (average ± standard deviation) before and after exercise in CHO-6% and placebo situations

	CHO-6%		Placebo	
	Before	After	Before	After
Insulin (µUI ·ml^{-1})	86 ± 58	82 ± 49	94 ± 48	94 ± 47
Hematocrit (%)	41 ± 2.8	41 ± 2.6	41 ± 2.9	43 ± 3.8
Hemoglobin (g·dl^{-1})	13.75 ± 1.3	13.61 ± 1.2	13.57 ± 1.1	14 ± 1.3
Na^+ (mmol·l^{-1})	138 ± 2.2	138 ± 2.2	137 ± 1.8	138 ± 1.5
K^+ (mmol·l^{-1})	4.4 ± 0.3	4.7 ± 0.3	4.5 ± 0.3	4.8 ± 0.4
Cl^- (mmol·l^{-1})	90 ± 2.6	90 ± 2.3	91 ± 1.7	91 ± 1.3

DISCUSSION

Not many studies have investigated with controlled and double-blinded characteristics the use of liquid CHO in individualized amounts according to body weight in individuals with type I diabetes during exercise. This study indicated that when well-controlled children and adolescents with type I diabetes (control based on HbA_{1c} levels) presenting no disease complications, ingest liquids containing 6% of CHO, the reduction on the blood glucose concentration is significantly lower if compared to those who ingest CHO-free liquids.

The average amount of CHO ingested was 39.56 ± 8.08 g during the first 45 minutes of exercise. This amount does not necessarily maintain the blood glucose concentration during a period of 60 minutes of a moderate-intensity exercise. Many subjects presented some degree of reduction on the initial blood glucose concentration at the end of the exercise and recovery, maybe indicating that individuals with type I diabetes may need a higher amount of CHO. The study by Riddell *et al.*[10], where the glucose ingestion was combined with total-CHO using drinks containing 6-8% of glucose, showed that these drinks attenuated the blood glucose drop in adolescents with type I diabetes. In another study[19], it was verified that the exogenous glucose oxidation rate was reduced during moderate-intensity exercise in boys with type I diabetes when compared with non-diabetic individuals, even with high plasma insulin levels, reason why drinks with high CHO concentration may be necessary for some individuals with type I diabetes, who may not use a large amount of the exogenous glucose ingested.

In the present study, it was observed that the reduction on the blood glucose concentration during exercise in CHO-6% situation may be clinically insignificant. The average decrease on the blood glucose concentration was of 21 mg· dL^{-1} (9.5%). In 3 out of the 10 individuals, however, a slight increase on the blood glucose concentration was observed without the significant characterization of hyperglycemia effect. In placebo situation, all subjects presented decrease on the blood glucose concentration during exercise with an average of 122 mg· dL^{-1} (43.2%), being statistically and potentially important for the development of the hypoglycemia clinical picture. These findings corroborate previous studies that have demonstrated the effect of exercise on the hypoglycemia of controlled individuals with type I diabetes who did not make use of CHO supplementation[10,20-22], and emphasized the necessity of CHO supplementation during extended exercises for type I diabetics.

In the present study, it was observed that diabetic individuals present higher pre-exercise blood glucose concentration and higher blood glucose reduction as response to exercise when compared to those who initiated exercises with lower values. This finding was also observed by Stratton *et al.*[21] and should be elucidated.

Exercises practiced before or after insulin application affect the glycemic response. Soo *et al.*[23] tested the effect of simple or complex CHO supplementation on the glycemic response of type I diabetics during morning exercises, before insulin application. Nathan *et al.*[24] used 13 g of orange juice and 13 g of milk as supplementation during exercise (45 minutes, 50% of the $\dot{V}O_{2peak}$) in five individuals with type I diabetes. These two studies[23,24] reported excessive increase on the blood glucose concentration, showing the relevant effect of the CHO supplementation than that observed in our research. This is probably due to the low plasma insulin levels of individuals, situation that is common in the morning before insulin application. In our study, the insulin application occurred three hours before the beginning of exercises.

When GP was compared with the blood glucose concentration, it was observed that the subjects showed a tendency to underestimate GP. This was also observed by McNiven-Temple *et al.*[25] and Nurick and Johnson[26]. Another observation in our study is that the subjects presented inter-individual variation on the capacity of perceiving blood glucose. Some individuals demonstrated precision between blood glucose concentration and perception of this.

Cox *et al.*[14], tested the blood glucose concentration of diabetic subjects in two situations: in the hospital, with the artificial manipulation of the blood glucose concentration and at home. In their findings, the subjects also presented variation on the capacity of perceiving blood glucose; the accuracy was higher at home than in the hospital. Further studies may elucidate the individual capacity of perceiving blood glucose in association with the blood glucose concentration measured.

During exercise, the RPE values (figure 2) were similar in both situations, even with the blood glucose concentration difference. This result corroborates the study by Riddell *et al.*[27], who found that the CHO ingestion did not affect RPE in adolescents with type I diabetes. In relation to the end of a 30-minute exercise session at 60% of the $\dot{V}O_{2peak}$, the RPE values (14-15) showed in this study were little higher than in the present study (12-13). Despite the similarity of the exercise protocols, in the study by Riddell *et al.*, the subjects ingested much less liquid per hour (213 ± 23 ml) when compared with subjects from our study (659.4 ± 134.8 ml). Thus, the hydration state may have influenced the high RPE results. We believe that in the present study, the total amount of liquid ingested during the exercise session was adequate in order to maintain hydration in both situations with room temperature kept between 20 and 22°C. This has reflected in the electrolytes, Htc and Hb blood concentration, once these concentrations presented no alterations in both situations (table 2). One advantage of the supplementation is that it maintains hydration.

In short, this study showed that the ingestion of drinks containing CHO-6% has attenuated the drop on the blood glucose concentration induced by one hour of moderate-intensity exercise in adolescents with type I diabetes.

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