The Effect of Oral Carbohydrate Solutions on the Performance of Swimmers

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ABSTRACT
It is well established that carbohydrate solutions can improve the performance in prolonged exercise. The aim of this study was to compare the impact of sugar and glucose solutions on exercise performance of swimmers. Twelve male teenager elite Iranian swimmers aged 12-17 years from Waterpolo Team of Ahvaz Oil Industry participated in a double-blind cross-over trial. They consumed three oral 6% purified carbohydrate solutions as glucose, sugar or placebo (aspartame) formulas in three non-consecutive days. In each day the swimmers undertook a 2×200-meter incremental swimming by 15 minutes time interval. Before starting the second course, subjects consumed their solutions. Blood glucose levels and time elapsed in two phases were recorded. Longer Swimming time significantly caused by sugar solution in the second course. Blood glucose level was increased by sugar and glucose solutions higher than the placebo before starting the second swim (p<0.05). However, after swimming, blood glucose concentrations were significantly elevated in all groups. After drinking a sugar solution and before starting the second 200-m swimming, the blood glucose level was higher than two other groups at this phase. Oral 6% sugar solution increased the time of swimming compared with oral glucose and placebo solutions in a 200-m swim. It can be explained by differences in Glycemic index in which sucrose has a lower GI than glucose.

Key Words: Glucose Solution, Swimming Time, Blood Glucose.

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INTRODUCTION

Sports drinks consist of components which provide energy, essential nutrients and the balance of body fluids (1). It is a common practice for athletes from different sports to ingest carbohydrate-electrolyte solutions for performance purposes. The ergogenic effects of carbohydrate intake during prolonged exercise have been well explained (2).

Glucose availability and an increase in peripheral glucose requirements during prolonged exercise has been highlighted (3). In order to maximize prolonged endurance performance, it is suggested that athletes should have CHO intake during endurance activities (2). Carbohydrates are one of the two main fuels for optimal sport performances (4). Ingestion of carbohydrate is a general contributor and ergogenic agents to fulfill daily energy needs of athletes during a sports event or during the days preceding it (1, 4, 5).

The main determinants of substrate utilization during exercise are the strength and the length of the exercise as well as the pre-exercise carbohydrate stores and the training status of the athlete (6). Ingestion of CHO from 15 to 20 min prior to the exercise results in an increase in plasma glucose (7), the time of performance (8), CHO oxidation during exercise (9), and reduces endogenous glucose production (10).

The CHO can be in the forms of maltodextrins, glucose, sucrose, or some high glycemic starches. Fructose should be limited for the reason of the likelihood of gastrointestinal distress. The rate of CHO ingestion can be along with drinking 600–1200 ml/h of a solution containing 4–8% CHO (4–8 g/100 ml) (11). CHO solutions containing 6–8% will increase time trial performance (~2%) and time to exhaustion (~15%). More than 8–10% solutions can enhance endurance exercise in events which are longer 1 hour (4, 12). The rate of glycogen resynthesis depends on the amount of CHO ingested (13). Sport drinks which contain 6% (w/v) glucose solution are effective for exercise performances (14). Carbohydrate ingestion during long-duration exercise, lasting 2 hours or more, almost always delays the onset of fatigue and improves the performance. However, ingesting too much carbohydrate can have detrimental effects (15). Sports beverages containing CHOs and electrolytes may be consumed before, during and after the exercises to help maintain blood glucose concentration, provide fuel for muscles, and decrease the risk of dehydration and hyponatremia.

The Glycemic Index (GI) categorizes CHO-rich foods based on their postprandial blood glucose response compared with a reference food. Sugar (Sucrose), as a disaccharide, consists of 50% glucose and 50% fructose, while it has a glycemic index in a similar amount lower than glucose. Sucrose is absorbed quickly, but it has a low glycemic index because of containing of fructose which has a slight influence on blood glucose (16). Basically, the GI aimed to point out the total rate of digestion and absorption of the CHO in a food. If the GI of CHO causes the rate of blood glucose to response to CHO, it seems reasonable that ingestion of CHO with different GI before, during and after exercise will impact sport performance. However, there is still much uncertainty and an insufficiency of data about the profits of ingestion of high GI and low GI CHO to enhance performance (17).

Endurance sports are rising in popularity, and athletes are seeking ways to enhance their performance at all levels by training and nutrition. For endurance exercises with duration of 30 min or more, the most likely causes of fatigue are dehydration and carbohydrate reduction. Recently, the role of carbohydrate intake has been established to improve performance during shorter lengths and of higher intensity exercise (2). It is thought that during higher intensity exercise,
plasma glucose concentrations do not decrease, as there is sufficient glycogen to sustain the short duration of exercise (~60 min) (6). To our knowledge, no studies have proven that consuming large amounts of CHO will cause higher exogenous CHO oxidation rates and improvement of performance. Until recently, the positive effects of carbohydrate feeding were only demonstrated with exercises lasting over two hours in duration (15). Hence, the present investigation aimed to determine the effects of glucose formula on short duration exercise and sport performance of swimmers in comparison to sugar and aspartame solutions.

**MATERIALS AND METHODS**

**Participants.** Twelve healthy male elite swimmers in the age range of 12-17 years from waterpolo team of Ahvaz oil industry participated in this double-blind cross-over trial. The study was approved by the ethical committee of Ahvaz Jondishapur University of Medical Sciences. The volunteers were briefed on the purpose of the study, experimental protocol and their written consents were obtained.

**Liquid Supplements.** The carbohydrate solution used in the present study was prepared by researchers. In order to prepare 6% glucose, 6% sugar and aspartame solutions, 6gm of them was dissolved in 100 ml of water separately. The placebo solution was matched in formulation to the carbohydrate solution except that it did not contain CHO and contained artificial sweeteners (aspartame).

**Procedure.** Twelve male teenage elite swimmers consumed three oral 6% purified carbohydrate solutions (6g/100ml) as glucose, sugar or a placebo (aspartame) formula in three non-consecutive days. During each day, the swimmers tried two 200 meters course separated by 15 minutes between each course. Immediately after finishing the first course, subjects consumed their solutions. Blood glucose levels and time elapsed in two phases were recorded. The reason for deferral carbohydrate feeding until 5–15 min before starting an activity is to minimize the glycemic and insulinaemic responses during exercise (18).

In the three separate ingestion trials, all swimmers ingested the equivalent of 200 ml of a 6% of sugar (19, 20), glucose and matched placebo solution in 15-min intervals before the second swim in three non-consecutive days separately. The solutions were served in two plastic volumetric syringes (Kendall Monoject, Mansfield, MA). The solutions were weighed using an electronic balance (Mettler, Toledo AB54-s, Greifensee, Switzerland) to ensure the correct volume was ingested 15 min before the exercise. A container contains the solution which was placed on the same electronic balance to ensure that the correct volume of the solution was taken up into the plastic syringe. The feeding schedule was designed to provide the swim with approximately 6 g CHO.

**Statistical Analysis.** Statistical Package for Social Sciences (SPSS) version 20 was used for the analysis. The mean was applied for all the variables. Paired t-test was used to compare the performance time and blood sugar level between the first and the second swim among three groups. Repeated measures ANOVA analysis was applied to study the difference before and after trial. Differences were considered significant at P<0.05.

**RESULTS**

The mean blood sugar and performance time of the subjects showed no significant difference between the trials using repeated-measures ANOVA. The ANOVA results for blood sugar and performance time were [F(2, 33) = 0.053; P>0.05] and [F(2, 33) = 0.02; P>0.05] respectively. The subjects were not aware of the drinks consumed during trials. Oral 6% sugar solution increased the time of swimming compared with oral glucose and
placebo solutions in 200 m course (Figure 2). The mean total exercise time showed significant difference between two swims in the sugar group (Table 1).

During exercise the blood glucose levels showed a significant increase ($P<0.05$) with an increase after the first swim and before the second swim in sugar and glucose group ($P<0.05$) (Table 1). The result of paired t-test for post exercise blood glucose levels of the subjects in all the three trials showed a significant increase after the second swim ($P<0.05$) (Table 1). The trials with glucose and sugar recorded no significantly higher blood glucose levels when compared with aspartame. The trend of blood glucose in subjects before and after the first and the second swims is shown in the Figure 1. However, in each time interval no significant difference was observed in the blood glucose levels between the trials.

Table 1. comparison of the time of performance and blood sugar between first and second swim among three groups

| Trials                        | Sugar (n=12) | Glucose (n=12) | Placebo(Aspartam) (n=12) |
|-------------------------------|--------------|----------------|--------------------------|
| Mean blood sugar before first swim (mg/dl) | 87.6         | 89.3           | 89.6                     |
| P-Value                       | 0.002*       | 0.006*         | 0.110 NS                 |
| Mean blood sugar before second swim (mg/dl) | 99.5         | 96.5           | 96.6                     |
| P-Value                       | 0.008*       | 0.025*         | 0.005*                   |
| Mean blood sugar after second swim (mg/dl) | 108.3        | 105.8          | 105.1                    |
| P-Value                       | 0.017*       | 0.323 NS       | 0.496 NS                 |
| Mean of time for first swim (min: s: ss) | 2:57:81      | 2:57:62        | 2:58:60                  |
| P-Value                       |               |                |                          |
| Mean of time for second swim (min:s:ss) | 3:1:76        | 2:58:87        | 2:59:61                  |
| P-Value                       | 0.017*       | 0.323 NS       | 0.496 NS                 |

* Significant at $P<0.05$; NS: Not significant

Fig. 1. Repeated measures ANOVA. Blood sugar level of the subjects before and after first and second swims among three groups (Sugar;Glucose; Placebo) (n=12)
**DISCUSSION**

The aim of this study was to compare the effect of sugar and glucose solutions on exercise performance of swimmers. The main finding of the study was that ingestion of sugar solution significantly increased the time of swimming performance in comparison with the same volume glucose or placebo solutions. Furthermore, relative sucrose has a lower GI than glucose and glucose consumption might be predictable to stimulate greater muscle glycogen resynthesis than sucrose. However, due to its fructose content, sucrose may favorably renovate liver, rather than muscle glycogen stores post exercise (21).

Even though it has been reported in a study in the UK (21) that there was not any significant differences in mean exercise time among subjects through ingestion of sugar and glucose solutions. The researchers demonstrated that highly-trained subjects by administration of glucose were capable to do exercise for longer while fasting without any further decrease in muscle glycogen. They suggested that after the end of exercise, oxidation of CHO was retained as a result of glucose ingestion, which was adequate to equalize the reduction in muscle glycogen oxidation that happened as a consequence of glycogen depletion, allowing exercise to continue. The reduction of blood glucose, and subsequent decrease in muscle glucose uptake and oxidation during the final stages of exercise without CHO ingestion, was believed to be a main source of fatigue (21).

It has to be mentioned that carbohydrate ingestion before exercise can cause hyperglycemia and hyperinsulinaemia following by a rapid reduction in blood glucose 15–30 min after exercise, changed to reactive hypoglycemia (14). The decline in blood glucose is most likely the consequence of an increased muscle glucose uptake and reduced liver glucose output. Furthermore, hyperinsulinaemia following by carbohydrate ingestion inhibits lipolysis and fat oxidation and this may result in quick muscle glycogen depletion. Therefore, pre-exercise carbohydrate ingestion may have the potential to impair performance. However, only two studies (22, 23) have reported reduced performance.
ability, whereas the majority of studies have stated no changes or an enhancement in performance following pre-exercise carbohydrate ingestion (24).

Ingestion of CHO during endurance exercise will lead to keep the blood glucose levels, related increase in the rate of CHO oxidation and release glycogen of muscle during the last stages of the exercise (25). During first and second swim, the blood sugar values increased in sugar, glucose and placebo trials and no significant differences were found between the trials. This increase in glucose concentrations with CHO solutions in this study was also similar to the responses found in study conducted by de Salles Painelli, Nicastro, and Lancha (26) which showed that solution with 6.4% glucose or maltodextrin improved around 2-3% of the time trial and average power in comparison with placebo. No differences have been found among the solutions with different type of CHO.

Of course, the performance properties and metabolism of carbohydrate ingestion just before exercise (5-15 min) look like the ingestion of them during the activity. In addition, a rebound hypoglycemia in the initial phase of exercise seems not to influence exercise performance (24). This implies that there is no need to escape carbohydrate intake pre exercise. However, carbohydrate ingestion during exercise has also been proven to increase exercise performance even in high intensity exercise and relatively short duration, and it has become clear that mechanisms for the effect during this type of exercises is not metabolic, but it is through the central nervous system (27). There is different instruction for different endurance sports. Carbohydrate ingestion results in improved performance in cycling and running, although the mechanism may not necessarily be the same (28).

Although in another study (29) it was reported that exercise performances improved with mouth rinse, Whitham and McKinney (30) did not find the same outcome of 6% maltodextrin solution in a running procedure. One possible reason for differences between the results from Rollo and Williams (31) and Whitham and McKinney (30) depends on nutritional status of the runners in each study. While the subjects of Rollo’s study went to the laboratory after an overnight fasting, standardization of the subjects’ diet has been done in the study by Whitham and McKinney and they requested athletes to drink it 4 hours prior the trial.

In contrast to the studies that have reported improvements in cycling time trial performance of fasted cyclists after mouth rinsing with a carbohydrate solution (27, 32, 33), it has been reported by Beelen et al. (34) that there was no improvement in cycling performance when the cyclists were fed rather than faceted. Also in the current study, there were no differences in the time of performances between the carbohydrate solutions and placebo trials. Consequently, it is hard to evaluate the potential effectiveness of glucose ingestion due to the significant effect only under conditions where the liver’s glycogen may be depleted.

A cycling study reported that the improvement of endurance capacity when fluid was ingested maybe a result of heart rate reduction, core temperature and utilization of muscle glycogen in comparison with cycling without fluid ingestion (35). Ingesting (31) and mouth rinsing CHO can independently improve endurance performance (29, 33). However, the potential performance benefit of ingesting carbohydrate solutions appears to be influenced by the CHO status of the participant before exercise.

It is possible to assume that feeding before exercise may have an impact on the brain responses to an oral CHO stimulus during exercise because it activates the brain regions associated with feeding and reward and is controlled by the physiological status of the body a homeostatic regulation (36). In this context, it can be supposed that the
nutritional status has a direct impact on the ergogenic effectiveness of CHO solutions.

**CONCLUSION**

Oral 6%-sugar solution increased the time of swimming compared with oral glucose and placebo solutions in the 200-m course. Overall, this study indicates that there is a difference in glycemic index between glucose and sugar (sucrose), and therefore blood glucose availability may have important consequences for subsequent exercise capacity. So far, no studies have examined the relative advantages of glucose and sucrose administration, during recovery from swimming, in terms of subsequent endurance exercise capacity. Based on the available indications, it appears to be no reason not to ingest glucose before exercise as it does not appear to have negative effects on performances. Athletes who have symptoms that are often associated with reactive hypoglycemia can find solutions to avoid it. These solutions could include choosing low GI carbohydrates, ingesting carbohydrate just pre-exercise or during a warm-up or alternatively, avoiding carbohydrate in 90 min before exercise altogether (28). In addition, CHO solutions may have an impact on the mechanisms of fatigue that has not been evaluated among swimmers yet. However, more controlled studies on the actual role of oral CHO solutions in different nutritional status are required. Furthermore, further studies should evaluate if the same trial could improve exercise performance in other sports.

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اثر مصرف محلول‌های قندی خوراکی بر عملکرد شناگران

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چکیده
مشخص شده است که محلول‌های قندی می‌تواند عملکرد ورزشکار را در ورزش طولانی مدت بهبود ببخشد. هدف از این مطالعه مقایسه اثر محلول شکر (ساکاروز) و گلوکز بر عملکرد ورزشی شناگران بود. دوازده شناگر مرد نوجوان ایرانی در رده سنی 17-12 سال از تیم واترپلوی صنعت نفت اهواز در یک مطالعه متقابل شرکت کردند. آن‌ها محلول کربوهیدرات خالص 6% را به عنوان گلوکز، شکر و دارونما (آسپارتام) در سه روز غیرمتوالی مصرف کردند. در هر روز شناگران دو مرحله شنا 200 متر کرال سینه را با فاصله 15 دقیقه انجام دادند و در این فاصله محلول قندی یا محلول خالص را مصرف می‌کردند. رکورد هر یک از دو شنا و نیز سطح قند خون قبل و بعد از هر شنا ثبت شد. تعداد افراد مصرف شکر و گلوکز در هر شنا در دو سطح و در دو تا میزان زمان انجام دادند و در این فاصله نیز نتایج مشابهی ثبت شد. نتایج نشان داد که مصرف محلول 6% شکر موجب افزایش زمان شنا در دو شنا شد، ولی بستگی زیادی به شاخص‌های گلیسمی نداشت. نتایج نشان داد که مصرف محلول 6% گلوکز نتیجه‌بری کلمه‌ایی نداشت.

واژگان کلیدی: محلول کربوهیدرات، هرکلمه کلمه‌ای، قند خون، زمان شنا.

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