A Sports Drink Based on Highly Branched Cyclic Dextrin Generates Few Gastrointestinal Disorders in Untrained Men during Bicycle Exercise

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Received April 5, 2004; Accepted August 21, 2004

Gastrointestinal disorders after ingesting a sports drink were investigated during bicycle exercise. The experiment consisted of a preliminary exercise, a 10 min rest, and 30 min of exercise. Seven healthy untrained volunteers ingested either water or a sports drink based on highly branched cyclic dextrin (HBCD), commercially available dextrin of DE16 or glucose immediately after the preliminary exercise. The mean gastric emptying time after ingestion of the HBCD-based sports drink was significantly faster than that of the glucose-based drink. Gastrointestinal disorders were monitored by a questionnaire. The mean degree of subjective flatulence and the mean number of belches were few with the HBCD-based drink during exercise. When volunteers drank the sports drink based on 10% HBCD during bicycle exercise, they experienced few gastrointestinal disorders and consequently could continue the exercise comfortably with little fatigue.

Keywords: highly branched cyclic dextrin, glucose, sports drink, gastrointestinal disorder, gastric emptying time

Introduction

Fluid balance plays a key role in maintaining optimal bodily functions, particularly when an activity that induces large fluid loss is performed. Fluid loss of as little as 2% of body weight decreases endurance performance (Craig & Cummings, 1966; Armstrong et al., 1985). With a water loss of 4–5% of body weight, physiologic function is impaired (Buskirk et al., 1958; Ribish & Herbert, 1970). The water lost as sweat comes from the blood, and intracellular and interstitial pools (Costill & Sparks, 1973; Costill et al., 1974), and causes a reduction in circulatory capacity, cooling, and exercise efficiency (Åstrand & Saltin, 1964). Therefore, drinking fluids is advised to achieve optimal performance and feelings of well-being during prolonged exercise.

Participants in endurance events frequently suffer from gastrointestinal (GI) disorders such as belching, flatulence, heartburn, nausea, abdominal pain, lateroabdominal stitches, regurgitation, an urge to defecate, and diarrhea. These symptoms suggest that exercise may influence GI function. The type of exercise and the type of food ingested prior to and during exercise influence GI disorders during exercise (Brouns et al., 1987; Rehrer et al., 1992). During strenuous physical exercise, sports drinks are the major energy source consumed. Liquids are also necessary for rehydration. Therefore, it is important to investigate the relation between the type of drink consumed and its gastric emptying time (GET) during exercise. We previously reported that a 10% highly branched cyclic dextrin (HBCD)-based sports drink was significantly (p < 0.05) transferred from the stomach to the small intestine faster than 10% commercially available dextrin of a dextrose equivalent 16 (DE16)-based sports drink, or any other 10% carbohydrate (CHO) solutions, such as glucose, maltose, or sucrose at rest (Takii et al., In press).

The purpose of this study was to clarify the GET of HBCD-based sports drink in comparison with other CHO-based sports drink during exercise. The effects of ingesting the HBCD-based sports drink on GI disorders and fatigue during exercise were also investigated.

Materials and Methods

Subjects The subjects were 7 untrained men. Their mean ± SD values for age, body weight, and height were 34.3 ± 2.8 year, 65.4 ± 9.0 kg, and 171.7 ± 5.8 cm, respectively. All procedures were performed according to the Helsinki Declaration of 1964 (revised in 1989).

Sports drinks used as test fluids Water and three prototype sports drinks based on HBCD, DE16, and glucose were used as test fluids in the experiments. The sports drinks were composed of 10% CHO, 1.4% fructose, 0.01% stevia, 0.2% ascorbic acid, 0.1% sodium ascorbic acidate, 0.04% vitamin mixture, 0.02% sodium chloride, and 0.01% aroma. The osmolality of the test drinks was determined by freezing-point depression (Advanced Wide-Range Osmometer 3W2, Advanced Instrument Co., Ltd., MA, USA).

Exercise protocol Experiments were started at 14:00 each day, with several days of rest between trials. All subjects consumed udon, flour noodles in dried-bonito soup (250 kcal), 3 h before the onset of the test. All subjects

Abbreviations: HBCD, highly branched cyclic dextrin; GI, gastrointestinal; DE, dextrose equivalent; DE16, commercially available dextrin of a dextrose equivalent 16; CHO, carbohydrate; GET, gastric emptying time; RPE, rate of perceived exertion

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were allowed to consume only a cup of water or green tea up to 1.5 h before the onset of the test. The exercise room was kept at 25°C, and conversation was allowed during the experiment. However, no information on the test drink was given to the subjects. Each subject completed a standardized warm-up, consisting of 3 min of cycling at each of 3 loads (56, 71, and 85 W) on a cycling ergometer (Lode, Groningen, The Netherlands). After the subject consumed a given fluid as quickly as possible (within 1 min), he was allowed to rest for 10 min. Exercise was then continued for 30 min, consisting of three 10-min blocks at each of 3 loads (71, 85 and 99 W). The subjects maintained an approximate pedaling rate of 60 revolutions/min. Every 5 min after drinking the test fluid, the subject was asked to assess feelings of flatulence; the feeling of remaining fluid was expressed using a 6-point scale: 5, 100% of test fluid remaining; 4, 80%; 3, 60%; 2, 40%; 1, 20%; 0, no fluid present. The rate of perceived exertion (RPE) was expressed using a 15-point scale: for example, 6, sedentary; 7, very easy; 11, easy; 13, somewhat severe; 15, severe; 17, very severe; 20, all out (Noble et al., 1983). The number of belches after the test fluid was consumed was also recorded.

Measurement of the gastric emptying time of the test solution The relaxed cross-sectional area of the pylorus antrum was measured by an extracorporeal ultrasonic echo-image analyzer (SSA-200A, Toshiba Co., Tokyo, Japan) in a sitting position every 10 min after the test fluid had been consumed (Nagao et al., 1998). During exercise, this area was measured after 1 min of rest to give the stomach time to stop moving. The gastric emptying characteristics of the test solutions are shown as the mean GET derived from gross half-gastric volumes. The measurement was conducted three times in succession, and the average value was calculated (Takii et al., In press).

Statistics Results are expressed as mean ± SEM. One-way analysis of variance (ANOVA) with Fisher’s PLSD post hoc test was used to assess the statistical significance of differences, with a p value of <0.05 used to indicate significance.

Results Gastric emptying time and GI disorders during exercise The osmolality of the HBCD-, DE16-, and glucose-based sports drink was 150, 269, and 787 mOsm, respectively. The GET was shortest when subjects ingested the HBCD-based sports drink (Fig. 2). The HBCD-based sports drink emptied faster than the glucose-based sports drinks during exercise (Fig. 2). The HBCD-based sports drink was also associated with a lower flatulence value than the glucose- and DE16-based sports drinks from 5 min after the start of exercise (15 min after ingestion) to the end of exercise (Fig. 3). The total number of belches for all subjects after drinking water or the HBCD-, glucose-, or DE16-based sports drinks to the completion of exercise was 11, 9, 23 and 24, respectively. Thus, the HBCD-based sports drink induced the fewest belches. The mean number of belches per subject with the HBCD-based sports drink was significantly lower (p < 0.05) than with the glucose- or DE16-based sports drinks (Fig. 4). Although no significant difference was observed in the RPE between water and the sports drinks, the RPE with the HBCD-based sports drink tended to be lower in the later stage of exercise (data not shown). Postprandial blood glucose increased with the sports drinks containing CHO, but decreased with water (Fig. 5). There was no difference in the increase in postprandial blood glucose among the three sports drinks containing CHOs.

Discussion We previously reported that a HBCD-based sports drink was transferred from the stomach to the small intestine faster than a 10% DE16-, or glucose-based sports drink and 10% CHO (glucose, maltose, and sucrose) solutions.
at rest (Takii et al., In press). Therefore, we additionally investigated the GET of a HBCD-based sports drink and the effects of ingesting such a drink on GI disorders during exercise. The HBCD-based sports drink tended to be transferred faster than glucose- and dextrin-based sports drinks during exercise (Fig. 2). Moreover, GI disorders, such as flatulence and the mean number of belches, after ingesting the drink, were significantly (p < 0.05) attenuated compared with other drinks (Figs. 3, 4). In addition, RPE in the later stage of exercise tended to be lower with the HBCD-based sports drink (data not shown), which suggests that subjects felt little fatigue after ingesting the HBCD-based sports drink.

As noted above, it is reasonable to investigate the relationship between the type of drink and its gastric emptying rate to control GI disorders during exercise. From previous experimental evidence, it may be expected that the incidence of GI disorders will increase if liquid remains in the stomach for a long time.

In this study, we were interested in investigating GI disorders in untrained men who ingested several sports drinks just before low-intensity exercise. GI disorders are induced by altered GI blood flow, changes in gut permeability, disturbed GI-tract motility, psychological effects ('stress') and pharmacological agents (Green, 1992). One of the most common theories includes an exercise-induced reduction in blood flow. The HBCD-based sports drink was associated with the shortest GET (Fig. 2) and the least flatulence (Fig. 3) among the test drinks.

Postprandial blood glucose increased with the ingestion of the sports drinks containing CHO, but decreased with the ingestion of water (Fig. 5). There were no obvious differences in the increase in postprandial blood glucose levels among the three sports drinks. These results suggested that HBCD was digested and absorbed easily as well as other CHOs (Fig. 5). Therefore, with the HBCD-based sports drink, the decrease in the volume of blood due to perspiration during exercise was thought to be reduced. This result should lead to a reduction in GI disorders. Moreover, if liquid stays in the stomach for a long time, the stomach itself could swing with a large amplitude. This leads to stretching of ligaments in the abdominal area. If there is a large amount of residual liquid in the stomach,
A Sports Drink Based on Highly Branched Cyclic Dextrin

belching and lateroabdominal stitches will be easily generated (Peters et al., 1993; Plunkett & Hopkins, 1999). In this experiment, the fewest number of belches was observed with the HBCD-based drink (Fig. 4). These results suggest that subjects who ingested a HBCD-based sports drink might have experienced few GI disorders because the HBCD-based sports drink was transported from the stomach faster than other drinks.

The present results regarding GET during exercise coincided with those at rest, as reported previously (Takii et al., In press). HBCD is a polymer of 900 glucose residues with an average molecular mass of 160,000 Da. HBCD contains few glucose, di-, and oligo-saccharides (DE less than 2) (Takata et al., 1996, 1997), since it has a very narrow molecular distribution. The osmotic pressure of 10% HBCD solution is only 9 mOsm. Therefore, it can be used to produce a sports drink without greatly increasing the osmotic pressure. Since the GET of an ingested drink is mainly influenced by its osmotic pressure, we prepared a sports drink using HBCD. The results of this study suggest that the minimal GI disorders in subjects who ingest a HBCD-based sports drink might due to its short GET.

We found that the HBCD-based sports drink had a short GET and scarcely induced any GI disorder. When consumed during exercise, the number of belches was significantly low (Fig. 4). A shorter GET (Fig. 2) and a lower flatulence score (Fig. 3) were also observed. Furthermore, the subjects showed a lower RPE during exercise (data not shown). We previously reported that HBCD could enhance the endurance capacity of mice (Takii et al., 1999). Our present results suggest that HBCD might be an excellent ingredient as a sports ergogenic aid. Further investigations are needed, since an exercise performance test was not performed in athletes in this study.

In conclusion, the present results suggest that, similar to the previous results at rest (Takii et al., In press), an HBCD-based sports drink generated few GI disorders in untrained men during exercise due to its short GET.

Acknowledgements We thank all of the subjects who participated in the experiments. We also thank Dr. Shigetaka Okada for his kind advice and Dr. Takashi Nakae for his technical assistance.

References