Evaluation of tolerability, efficacy and taste of a sports drink for athletes with fructose malabsorption

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Summary (English (USA))

To ensure the highest exogenous carbohydrate oxidation, popular sports drinks are usually based on glucose and fructose. Due to the fructose contents, these drinks are poorly tolerated by athletes with fructose malabsorption and can cause varying degrees of gastrointestinal side effects.

The aim of this pilot study was the evaluation of a novel fructose free sports drink with a carbohydrate content of 8% and 548 mg Sodium/l, which additionally offers the advantage of a basic pH of 7.328 in order to avoid enamel erosion.

This drink was tested by 20 recreational athletes with diagnosed fructose malabsorption. During endurance training lasting at least one hour, tolerability, efficacy and taste were observed and assessed by a standardized questionnaire.

All terms can be seen as positive. Tolerability was assessed according to school grades (1-5) with 1.43 ± 0.67, taste with 2.48 ± 1.12. Overall 90% of participants would use and recommend the drink.

Keywords: sports drink, fructose malabsorption, fructose-free, carbohydrate requirement, training

Introduction

Endurance sports and participating in events such as marathons, triathlons, cycling tours, or even ultra-long events are increasing in popularity. Due to the massive effort being made over several hours, energy and sweat loss is to be balanced accordingly or exhaustion counteracted.
The reduction in physical fitness is certainly due to a sum of factors: in particular hyperthermia, hypernatremia, dehydration and carbohydrate depletion or hypoglycemia are to be mentioned. An adequate fluid and carbohydrate intake during exercise can improve endurance capacity, increase the time to exhaustion and also enhance exercise performance during endurance exercise lasting more than two hours (1).
According to the present state of evidence, a high exogenous carbohydrate oxidation can be achieved by the intake of multiple carbohydrates, which uses different intestinal transport mechanisms. Through a combination of glucose and fructose for example, the rate of oxidation is increased up to 50% compared with glucose alone (2,3). This is the reason that popular sports drinks are produced on a glucose-fructose base to ensure the highest exogenous carbohydrate oxidation during exercise.

In case of a fructose malabsorption or a high sensitivity to fructose, these beverages are not tolerated and after drinking sports drinks based on fructose; the athletes suffer from more or less severe gastrointestinal side effects like flatulence, bloating, abdominal pain, diarrhea, nausea, reflux, etc. (4-6).

Fructose is a monosaccharide that is closely removed by GLUT 5 transporter from the intestinal lumen into the enterocytes (4). Due to the limited capacity and the slow absorption of fructose, there is a physiological carbohydrate malabsorption, as soon as more than the tolerance limit of 35-50 g of fructose is consumed. Symptoms of a "fructose malabsorption" are only unphysiological when less than 25 g of fructose can be tolerated (4,5,7,8).
According to a review by Gibson et al. (9) from 2007, up to 50% of North Americans are not capable of absorbing pure fructose. In Europe and North America one of three adults is affected by fructose malabsorption (every second one is symptomatic) (5).

A new sports drink without fructose was developed to offer people with fructose malabsorption the possibility to cover adequately the fluid, carbohydrate and sodium requirement in appropriate osmolality during endurance exercise.

Integrating evidence-based recommendations the drink resulted in a carbohydrate content of 8% (glucose and maltodextrin), a sodium content of 548 mg Na/l in form of sodium

bicarbonate, and a basic pH of 7.328, to simultaneously ensure protection against tooth enamel erosion (10-13).

Most sports drinks have a pH value of an average of 3-4 due to the added citric acid, which is to improve the taste of the beverages, and are therefore in the acidic range (14,15). The acidity and thus the change of the milieu in the mouth may lead to a demineralization of tooth enamel (14,16). Based on these considerations, the pH of the fructose-free sports drink moves into the basic range. Even if there is still not enough evidence for a correlation between the intake of sports drinks and dental erosion available, there are numerous studies, showing a negative impact of food and beverage containing acid on dental health (17-21). The basic range of the fructose-free sports drink is one of the special characteristics of the drink.

Regarding the osmolality sports drinks should ideally be isotonic or slightly hypotonic because a high osmolality increases gastric and intestinal secretion, may delay gastric emptying and also reduce water absorption (15,22).
This novel sports drink has an osmolality of 240.7 ± 2.66 mosmol/kg and this hypotonic range ensures that optimum absorption is guaranteed.

The purpose of the study was to investigate the tolerability, efficacy and taste of this drink.

Material and methods

Subjects

Seven male and thirteen female recreationally active subjects with a diagnosed fructose malabsorption (ICD10: E74.9) participated in this study. Their characteristics are presented in Table 1. Each of them was fully informed of the purpose and risks associated with the procedures and a written informed consent was obtained. Except for the fructose malabsorption all of the subjects were healthy as assessed by a general health questionnaire. The study was approved by the Ethics Committee of the Medical University of Graz.

Design

The athletes consumed 750 ml (1) of the fructose-free sports drink within 60 minutes in an endurance training lasting at least one-hour (running, bicycling, step-training, mountaineering, fitness training). After the training tolerability, efficacy and taste were

assessed by a standardized questionnaire. Parameters examined after the intervention were: type of sports and duration, intensity / effort factor, flatulence, bloating, abdominal pain, nausea, diarrhea, reflux or heartburn, general compatibility, efficiency, muscle spasms, taste, sweetness, fruitiness, refreshing factor, potability, habitual sports drink consumer and the recommendation of the sports drink. Side effects were clarified in form of an open question.

Diet and physical activity prior to testing

All of the subjects received the same information. Food and drinks known to cause abdominal discomfort should be absolutely avoided. In addition, the test should be conducted on a day when no gastrointestinal problems have been experienced.

Statistics

This was a qualitative study, the individual parameters were collected by a standardized questionnaire and data are reported as mean and standard deviation (M±SD) or frequencies and correlations by using SPSS for Windows.
Because of the group size it could be assumed that the spread was comparable or homogeneous and normally distributed. Thus, for analysis, a T-test was used, assuming a confidence interval of 95% and the statistical significance was set at $p<0.05$.
If the variances found to be non-homogeneous, or in extreme cases (for example, distribution of the group in 1:19 persons) to verify the differences between means, a Mann-Whitney U-test was carried out, wherein, in relation to the significance of "p" the "exact 1-sided significance" was always specified.

Results

The intensity of the training conducted was moving in a range between 2 (minimum) and 4.5 (maximum); the effort factor was judged that 1 means a "low effort" and 5 a "huge effort". The subjects felt the effort factor as 3.3 ± 0.68, which could be compared with an average effort.
Considering the time operated in total aerobic exercise, the subjects trained 120.2 ± 51.55 minutes on average. The shortest training period corresponded to a training of 1 hour, while the maximum activity period is specified with 4.5 hours.

Compatibility of the fructose-free sports drink

The questions about abdominal complaints (flatulence, bloating, abdominal pain, nausea, diarrhea, belching or heartburn, general compatibility of the sports drink) were assessed using a 5-point scale.
These included the following terms: no (1), light (2), moderate (3), strong (4) and very strong (5) and in the case of general compatibility school grades.
Mean was about the incidence of flatulence 1.3 ± 0.43, of bloating 1.08 ± 0.24, of abdominal pain 1.1 ± 0.31, of nausea 1.15 ± 0.49, of diarrhea 1.08 ± 0.34, of heartburn or regurgitation 1.25 ± 0.47 (see Table 2 and Figure 1).
Taken together, the compatibility of the fructose-free sports drink was evaluated with 1.43 ± 0.67 (based on the school grading system), which is also shown in Table 2 and Figure 1.

In general, after drinking the sports drink 12 subjects (60%) felt no flatulence although the data in medical history questionnaire showed that 80% of subjects often suffer from flatulence. 18 subjects (90%) noticed no bloating although the data in medical history questionnaire showed, that 30% of subjects often suffer from bloating. 18 subjects (90%) had no abdominal pain although the data in medical history questionnaire showed, that 35% of subjects often suffer from abdominal pain. 18 subjects (90%) had no signs of nausea although the data in medical history questionnaire showed that 15% of subjects often suffer from nausea. 19 subjects (95%) had no problems with diarrhea although the data in medical history questionnaire showed that 15% of subjects often suffer from diarrhea and 14 subjects (70%) noticed no reflux although the data in medical history questionnaire showed that 10% of subjects often suffer from reflux.
Most participants with reflux suspected to have problems with heartburn or regurgitation due to the relatively high amount of liquid (750 ml).

See Figure 2

To judge from the data given above in detail, it can be stated in general that a good tolerability of the sports drink can be expected. 12 subjects (60%) assessed the general compatibility with "very good", 3 subjects (15%) rated the tolerability of "1.5" (school grades), other 3 subjects (15%) rated as "good" and each 1 subject (5%) gave it as "2.5" and "3.5".

The question of "side effects" was answered with "Yes" by only one person. The athlete described the occurrence of nausea due to the aversive taste of the sports drink as he perceived it. .

There was no significant relationship or significant correlation between the occurrence of abdominal symptoms (flatulence, bloating, abdominal pain, nausea, diarrhea, belching or heartburn, general compatibility of the sports drink) prior to testing and after drinking the fructose-free sports drink.

Further there was no correlation between exertion and all the abdominal problems previously named.

There was a middle positive correlation between bloating and reflux (p=0.16), between abdominal pain and diarrhea (p=0.001), diarrhea and poor compatibility of the sports drink (p=0.000) and between abdominal pain and poor compatibility of the sports drink (p=0.001)

Effectiveness of the fructose-free sports drink

The effectiveness of carbohydrate, sodium and fluid intake as part of endurance training has been proven by many studies (1,2,10,11,13,23,24). With regard to that, only two parameters were investigated in this pilot study.
Muscle spasms were affirmed by only one subject, who attributed this to the intensive training. 95% reported that they did not have any muscle spasms.
With respect to the impact on performance, the mean was calculated with -0.85 ± 0.87, where "zero" for "no effect" and "-1" stands for "positive impact". 30% of the subjects considered the impact of the fructose-free sports drink as very positive, 35% as positive, 30% described no effect and one subject (5%) reported a negative effect, because of nausea due to the aversive taste.
A detailed list of the impact of the sports drink on performance is shown in Table 3.

Taste of the fructose-free sports drink

After consuming the sports drink the taste was assessed with 2.48 ± 1.12 according to school grades (1-5).

Three subjects (15%) described the taste as "excellent" and 1 person (5%) gave the note 1.5. Six people (30%) graded the drink as "good", three subjects (15%) as 2.5 four (20%) gave a grade of "satisfactory", one (5%) 3.5 and two people (10%) described the taste as "insufficient".
The question regarding the fruitiness had similar results.
Five subjects (25%) awarded the grade "excellent," four people (20%) described the fruitiness as "good", six (30%) as "satisfactory". Each two athletes (10% each) rated at 3.5

and "sufficient" and one subject (5%) evaluated the fruitiness as "insufficient". This resulted in a mean of 2.55 ± 1.18.
The refreshing factor was detected with an average of 2.41 ± 1.23. This in turn would be composed of five (25%) "excellent", six (30%) "good", three (15%) 2.5, two (10%), "satisfactory", two (10%) "sufficient" , one (5%) 4.75 and one (5%) "insufficient".

Regarding the potability 10 subjects (50%) found drinkability was "excellent". Due to the fact that within one hour a fluid intake of 750 ml was required, this result is very positive.

Four volunteers (20%) assessed the drinkability as "good", two subjects (10%) as "satisfactory", one (5%) 3.5, two athletes (10%) "sufficient" and one (5%) rated with "insufficient".

This resulted in a mean of 2.03 ± 1.28.

The sensory score of the fructose-free sports drink is shown in Table 4 and 5.

The sweetness was qualified on the basis of a "just about right scale". This means that with a mean of 0.3 ± 0.8 the sweetness was evaluated from just right to slightly sweet, which can be described as very positive review.

In detail, it can be said that 12 people (60%) felt the sweetness of the drink to be optimal, 2 people (10%) considered it to be "too little sweet", 4 people (20%) assessed the sports drink "a little too sweet" and 2 participants(10%) described it as "much too sweet".

In general, 90% of the subjects would recommend the novel sports drink and stated that they would use it regularly.

Discussion

In the past few years there has been a rapid increase in consuming sports and energy drinks and it is a rapidly growing segment of the beverage industry. The drinks contain substantial amounts of carbohydrates like sugars und usually electrolytes, minerals, vitamins and some other nutrients. The fact is that especially people with a higher intake of regular soda, sweetened coffee or tea drinks, fruit drinks, milk, fruit juice and alcohol were those associated with the greater odds for drinking sports and energy drinks. In the United States the daily volume of sports and energy drinks per capita increased from 3.8 ml in 2000 to 41.1 ml in 2010 (25). Considering this fact, it is really important to encourage the consumption of healthier beverages in an adequate composition.

Regarding the evaluated sports drink, the drink integrates evidence-based composition, the hypotonic osmolality is appropriate and because of the basic pH it simultaneously ensures protection against tooth enamel erosion. Due to the mixture of glucose and maltodextrin and the exclusion of fructose, good tolerability is guaranteed.

To ensure the highest exogenous carbohydrate oxidation, popular sports drinks are usually based on glucose and fructose. Because of the fructose, these drinks are poorly tolerated by athletes with fructose malabsorption and can cause varying degrees of gastrointestinal side effects.

Better compatibility is guaranteed with an absence of fructose which was also able to be also seen in the results. All of the questions about abdominal complaints like flatulence, bloating, abdominal pain, nausea, diarrhea, belching or heartburn and the general compatibility of the sports drink had positive feedback. Obviously the fructose-free sports drink offers a good possibility for people with fructose malabsorption to cover the fluid, carbohydrate and sodium-requirement in appropriate osmolality during endurance exercise in an adequate manner.

The effectiveness of the fructose-free sports drink also shows positive results regarding the prevention of muscle spasms and a positive impact on performance.

The taste was also assessed ordinarily as being positive regarding fruitiness, refreshing factor, drinkability, general taste and sweetness.

The present study shows that the tolerability, efficacy and taste of the novel fructose free sports drink can be seen as highly positive and 90% of the noncompetitive volunteers would recommend the drink. These findings have important implications for the further development of a fructose free sports drink.

It is difficult to compare the newly developed fructose-free sports drink with other sports drinks, because, according to the literature research, there is no similar sports drink and no studies exist which examine the compatibility of sports drinks for athletes with fructose malabsorption.

In addition to various diseases, there are many factors such as psychological components, the day’s constitution and change in diet or nutrition errors during the intervention phase, etc., that have an influence on the abdominal well-being. These factors are generally difficult to be elicited and therefore constitute a limitation for the study.

Previous "bad experience" (such as abdominal pain, nausea, flatulence, diarrhea, etc.) with conventional fructose-containing sports drinks could also have an effect on the perceived "wholesomeness" of the fructose-free sports drink.

Since, due to the sodium content, sports drinks have a typical flavor, a question regarding the regularly consumption of sports drinks was also included. The taste component is judged differently if people are used to sports drinks compared with someone for whom the consumption of sodium-containing beverages is a new experience.

Even though that could not be shown in this study, one should take this into account in case of further studies with a larger sample size. In this context, it should also be mentioned that optimizing the taste of the new sports drink with more flavors should be considered. Inexactness caused by mixing together the dry-substance of the sports drink with a defined amount of liquid by the subjects themselves was accepted, because it corresponds to the reality in everyday life. Fluctuations in relation to the mineral content must also be taken into account when using tap water, since the mineral content of each region varies.

In terms of efficacy two questions were asked. To elicit an actual effect performance tests would have been necessary, but the efficacy of carbohydrate intake is confirmed by many studies (1,2,10,11,23,26-34) and was not the primary aim of this study.

With regard to inclusion and exclusion criteria, there are also some aspects that should be considered in case of further studies.

Diagnosed celiac disease generally presented an exclusion criterion. The "exclusion of celiac disease by biopsy or antibody" as an inclusion criterion was not feasible in the course of this study. This is also true for diagnosed food intolerances. Since the diagnosis of fructose malabsorption is often associated with the diagnosis of lactose intolerance, diagnosed lactose intolerance was also not an exclusion criterion.

The drink is in fact generally fructose, lactose and gluten free, but it would still be interesting to conduct further studies in which a definitely excluded celiac disease is named as an inclusion criterion, and diagnosed lactose intolerance as an exclusion criterion.

Reflections in terms of the evaluation of the pilot study or even subsequent studies should be considered since all of the parameters questioned with regard to tolerability, efficacy and taste are subjective.

In conclusion, this is the first study to show good tolerability, efficacy and taste of a fructose-free sports drink for athletes with fructose malabsorption or fructose sensitive

people who would prefer a sports drink without fructose. The drink offers them the option of adequately covering their carbohydrate and electrolyte needs as part of a physical activity, without the addition of fructose.

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Disclosures

The authors declare that there is no conflict of interest.

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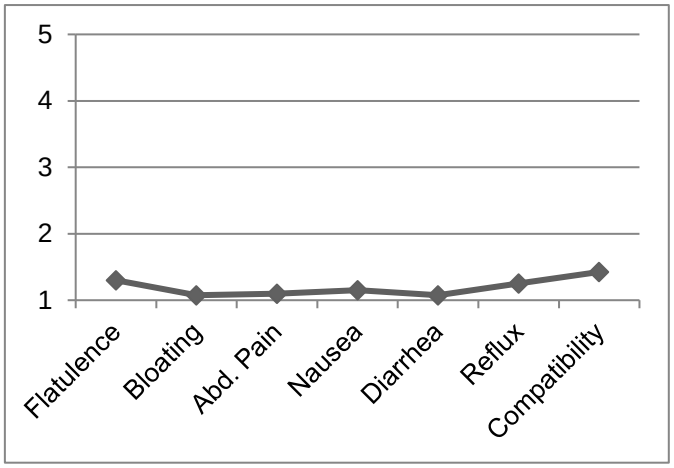
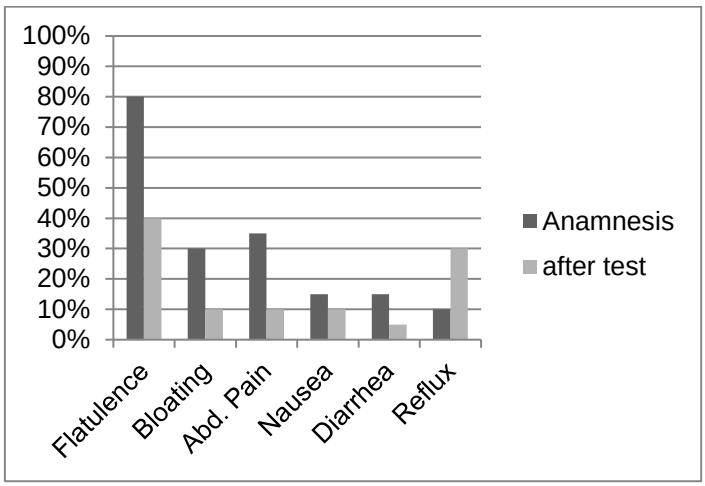
Figures

Figure 1: Evaluation of the compatibility (Mean)



none (1), light (2), moderate (3), strong (4) and very strong (5)

Figure 2: Incidence of symptoms according to the anamnesis and after the test in percent (%)



1 Tables

Table 1: Subject characteristics

	M	SD	Median	Minimum	Maximum
Age (years)	36.25	13.36	33.50	21.00	65.00
Height (m)	1.71	0.08	1.69	1.59	1.85
Body mass (kg)	67.10	12.58	64.00	51.00	97.00
BMI	22.73	2.76	21.84	19.20	29.28
Diagnosis (years)	2.25	2.20	1.50	0.50	8.00
General health condition (school grades)	1.70	0.57	2.00	1.00	3.00

M: Mean, SD: Standard deviation

Table 2: Abdominal complaints after the consumption of 750 ml of the fructose-free sports drink

	M	SD	Median	Modus	Minimum	Maximum
Flatulence	1.30	0.43	1.00	1.00	1.00	2.00
Bloating	1.08	0.24	1.00	1.00	1.00	2.00
Abdominal pain	1.10	0.31	1,00	1.00	1.00	2.00
Nausea	1.15	0.49	1.00	1.00	1.00	3.00
Diarrhea	1.08	0.34	1.00	1.00	1.00	2.50
Reflux	1.25	0.47	1.00	1.00	1.00	2.00
Compatibility*	1.43	0.67	1.00	1.00	1.00	3.50

none (1), light (2), moderate (3), strong (4) and very strong (5); * Compatibility score is based on school grades 1-5 (with 1 indicating the best and 5 indicating the least degree)

Table 3: Impact of the sports drink on performance assessed by subjects in percent

	Very positive	Positive	No effect	Negative	Very negative
Impact on performance	30%	35%	30%	5%	0%

Table 4: Taste evaluation of the fructose-free sports drink by subjects in percent

	Excellent	Good	Satisfactory	Sufficient	Insufficient
Taste	20%	45%	25%	0%	10%
Fruitiness	25%	20%	40%	10%	5%
Refreshing factor	25%	45%	10%	15%	5%
Potability	50%	20%	15%	10%	5%

Table 5: Sensory score based on school grades 1-5 (with 1 indicating the best and 5 indicating the least degree)

	M	SD	Median	Modus	Minimum	Maximum
Taste	**2.48**	1.12	2.25	2	1.00	5.00
Fruitiness	**2.55**	1.18	3.00	3	1.00	5.00
Refreshing factor	**2.41**	1.23	2.00	2	1.00	5.00
Potability	**2.03**	1.28	1.50	1	1.00	5.00

M: Mean, SD: Standard deviation