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THE EFFECT OF TWO CARBOHYDRATE-ELEKTROLYTE DRINKS ON GASTROINTESTINAL COMPLAINTS AND PHYSICAL PERFORMANCE IN ROWERS

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Abstract

The aim of study: The aims of the studies were to evaluate the incidence of gastrointestinal (GI) complaints and blood glucose and lactate concentrations after consumption of two different electrolyte–carbohydrate beverages in rowers.

Material and methods: A total of 18 male professional rowers (aged 20 ± 2.0 years, body weight: 82.6 ± 10.2 kg, height: 186.0 ± 7.3 cm, $\dot{V}O_2$max: 60.4 ± 5.0 ml/kg b.w./min) participated in a two-way randomized crossover design experiment. The exercise test was performed at 70% $\dot{V}O_2$max (2 x 25 min with a 5-minute break). During the test athletes on separate days (with a 1-week washout period) received either P" or "I" ("P" was first then "I"). The athletes consumed the test drinks as follows: twice 0.5 dm^3 of each drink, 60 min before and immediately after the exercise test, and twice 0.15 dm^3 of each drink immediately before the start of the test, and after the first 25 min of exercise (during a 5-minute break). The incidence and intensity of GI complaints during and after the exercise test were scored on a standardized questionnaire. Blood samples were collected before and after the exercise test, with glucose and lactate levels determined.

Results: Significant ($p<0.05$) changes were observed in post-exercise blood lactate levels in athletes supplemented with both electrolyte–carbohydrate drinks ("I": 26%, "P": 25%). A significantly ($p<0.05$) higher blood glucose level was noted only when athletes received "P" (on average by 12%). The consumption of the "P" drink ("P": 83%, 1.9 ± 0.9 points) led to a more serious gastroesophageal reflux compared to "I" ("I": 22% 0.2 ± 0.4 points). Significant differences were observed for sweet taste in mouth ("P": 83% and I: 28%, $p<0.001$) and the sensation of an overfilled stomach ("P": 89% and "I": 39%, $p<0.01$). The use of both tested carbohydrate-electrolyte drinks did not protect athletes against the occurrence of typical problems appearing after exercise (general exhaustion, muscle cramp, hand trembling, tachycardia).

Conclusion: Serious discomfort in the gastrointestinal tract caused by reflux after the consumption of the "P" drink results in "I" being a more advisable drink for rowers.

Key words: *carbohydrate-electrolyte drinks, rowers, gastrointestinal complaints, physical performance*

Introduction

Gastrointestinal (GI) complaints are commonly experienced by athletes who exercise, during both training and competition periods. It was shown that these complaints may significantly decrease physical performances of athletes, and thus have a negative effect on their sport results (1,2,4,9,11). In their study Peters et al. found that as many as 2/3 marathon runners complained of gastrointestinal complaints (1). Van Nieuwenhoven et al. reported that not only do triathletes and long-distance runners specifically suffer from these complaints, but also swimmers, cyclists and rowers (11). It was also found that discomfort, caused by gastrointestinal complaints, is declared more commonly by females than males as well as young athletes (2,4,11). A variety of complaints may occur during exercise, which may be attributed to disorders of the upper (esophagus and stomach) and the lower (small bowel and the colon) GI tract. Upper GI complaints include: reflux, nausea, bloating, and upper abdominal cramping. Lower GI complaints comprise: lower abdominal cramping, the urge to defecate, an increased frequency of bowel movements, flatulence and diarrhea (1,2,4). Etiology of the above mentioned disturbances has not been fully clarified.

Primary factors crucial in the pathogenesis of these disturbances include mental stress and related neurohormonal disorders, and dietary intake (high fat diet, dietary fiber or protein) (4,11). Another factor promoting gastrointestinal complaints is the shunting of blood flow from the vascular visceral bed to intensively working muscles, and as a result ischaemia of internal organs, including the stomach. There are also indications that intensive physical exercise, over 70% $\dot{V}O_2$max, may significantly slow down gastric emptying and thus cause gastrointestinal complaints (4,18). Moreover, dehydration leads to an increase of blood viscosity (4,14,16). Exercise combined with dehydration may therefore reduce intestinal blood flow a very low level, leading to a slower gastric emptying, which correlates with GI complaints (4,14,16).

Although an advantageous effect of consumed carbohydrate-electrolyte drinks on physical performance has been repeatedly confirmed, it must also be stressed that many athletes complain of gastrointestinal complaints occurring after consumption of such drinks (23). Van Nieuwenhoven et al. stated that the use of carbohydrate-electrolyte drinks during a week-long exercise test (an 18 km run) intensified the incidence of gastrointestinal complaints both those related with the upper and lower GI tract (11). The composition of these drinks also plays a significant role. Carbohydrate content in sport drinks should fall within the 4 – 8% range, while osmolarity should be 200 – 400 mOsm/l (15). Moreover, the type of carbohydrates contained in the drink is also crucial. It is commonly known that frequent consumption of a 6% fructose solution increases the risk of gastrointestinal complaints. Similar disturbances occur after the consumption of amylose. What is more, the consumption of galactose contributes to the sensation of overfilling (flatulence), or even diarhhea, especially when galactose is consumed in considerable amounts (10). It was shown that a combination of maltodextrin and glucose is most advantageous for the rate of stomach emptying and intestinal absorption (18,20). Slower stomach emptying may lead to discomfort caused e.g. by the sensation of overfilling, eructation and reflux (10). Rehrer et al. compared absorption of a 17% maltodextrin solution with that of a glucose solution of an identical concentration. It was shown that stomach emptying for both analyzed drinks and their intestinal absorption occurred within a comparably short time (21). Brouns reported that the temperature of drinks consumed during physical exercise should be 5–10°C. That author reported that drinks with temperatures below 5°C may cause abdominal cramps, whereas drinks with too high temperatures result in slower gastric emptying (23). Moreover, an excessive supply of drinks may cause the sensation of overfilling and serious gastrointestinal complaints (14).

The aims of the studies were to evaluate the incidence of gastrointestinal (GI) complaints and determine blood glucose and lactate concentrations in rowers after consumption of two beverages different in the content of electrolytes and carbohydrates.

Materials and methods

A total of 18 healthy volunteer male rowers (AZS AWF Poznan and Posnania Poznan) were involved in this two-way, randomized, crossover study. All subjects were well-trained. The experiment was conducted in the training season. The athletes were given a detailed description of the experimental procedure. Inclusion criteria for the study were as follows: good health state, a signed consent form and a minimum 2-year training period.

The subjects were excluded if they had any of the following: the history of ingesting supplements enhancing exercise performance within 3 months before the experiment or any medical condition that might be a contraindication for the experimental exercise test.

Before the experiment, the height and body weight of athletes were measured using an anthropometer, coupled with a WPT 200 OC verified medical scale (Rad Wag). A FUTREX 6100/XL body composition analyzer was used to assess body composition, including fat mass (FM) and fat free mass (FFM). Maximum oxygen uptake - $\dot{V}O_2max$ ($ml \cdot min^{-1}$, $ml \cdot min^{-1} \cdot kg^{-1}$) was determined for each subject by an incremental exercise test on a rowing ergometer (Concept II) according to the procedure described by Cosgrove (7). Resting heart rate (HRrest) and maximum heart rate (HRmax) were also determined.

Subjects involved in this study performed a rowing test (2 x 25 min with a 5-minute break) at 70% $\dot{V}O_2max$ on a Concept II ergometer. Each exercise test was conducted in the morning hours (9:00 ± 1:00 h) at room temperature (21 ± 2.0°C), and a mean relative humidity of 60%.

All subjects were asked to consume the test drinks as follows: twice 0.5 dm^3 of each drink, 60 min before and immediately after the exercise test, and twice 0.15 dm^3 of each drink just before the start of the test, and after the first 25 min of exercise (during a 5-minute break). The sport drinks were refrigerated (4 ± 1.0°C) and opened 10 minutes before the experiment, transferred to cups and then passed to athletes. The temperature of drinks consumed during physical exercise was 5–10°C.

Immediately before and after the exercise test body weight, blood lactate and glucose levels were again measured with an Accutrend® Lactate equipment (Roche), while blood glucose level was measured using an Accu – Check Active glucometer (Roche).

Tested drinks differed in their quantitative and qualitative composition. In the drinks carbohydrate concentration was “I”: 7.0% and “P”: 5.6%, respectively. “P” as a source of carbohydrates contained maltodextrin and dextrose, while “I” contained maltodextrin and sucrose. “I” was characterized by a slightly higher sodium content (680mg/dm^3) in comparison to “P” (520mg/dm^3). The composition of tested drinks is shown in Table 1.

At the end of the exercise test athletes filled in a questionnaire proposed by Nieuwenhoven et al., concerning the frequency of incidence and the intensity of gastrointestinal complaints (11). Incidence and intensity of gastrointestinal complaints during the exercise test were determined using a 4-point scale questionnaire. A lack of a perceived complaint was given 0 points, while 1, 2, 3 and 4 points corresponded to a weak, medium, considerable and very high intensity of complaints identified in the questionnaire.

This study was approved by the Bioethics Committee at the Karol Marcinkowski University of Medicine in Poznan (no. 06/08).

Table 1. *The composition of the test drinks*

SELECTED NUTRIENTS	"I" (dm^3)	"P" (dm^3)
Calorie content (kcal; kJ)	300; 1255	240; 1004
Protein (g)	0	0
Carbohydrates (g)	70	56
Monosaccharides (g)	56	34
Fat (g)	0	0
Dietary fiber (g)	0	0
Sodium (mg)	680	520
Potassium (mg)	180	Not determined
Calcium (mg)	320	Not determined
Magnesium (mg)	120	Not determined
Vitamin B_1 (mg)	0,42	11
Vitamin B_6 (mg)	Not determined	1.4
Biotin (μg)	Not determined	0,09
Pantothenic acid (mg)	Not determined	3.8
Vitamin E (mg)	Not determined	8
Osmolarity (mOsm/kg)	270 - 310	286

All data are presented as means ± SD. Comparisons between the two tested drinks for the incidence and intensities of the complaints and parameters of physical performance were carried out using a one–way ANOVA. Statistical analyses were performed using statistical software STATISTICA™ PL 8.0 by StatSoft.

Results

The physical and anthropometric characteristics of the athletes were recorded (Table 2). The mean age of rowers was 20.0 ± 2.0 years, while their mean body weight, at a height of 186.0 ± 7.0 cm, was 82.6 ± 10.2 kg. Fat mass was 10.5 ± 3.2%, while fat free mass was 73.7 ± 7.3 kg. Maximum oxygen uptake ($\dot{V}O_2max$) by rowers was on average 60.4 ± 5.0 ml/kg b.w./min, which corresponded (according to the criteria given by Astrand (8)) to very good physical performance. Resting heart rate of athletes was 62.0 ± 7.0 bpm, while the mean maximum heart rate was 200 ± 2.0 bpm.

Effect of carbohydrate-electrolyte drinks on body weight, blood lactate and glucose level

There was no significant difference in changes of body weight after the exercise test in the group of athletes receiving both analyzed drinks ("I": 0.0 ± 0.3 kg, 0%; "P": 0.1 ± 0.3 kg, 0.2%) (Table 3)

Significant changes were observed in blood lactate levels at the end of the exercise when rowers were supplied both carbohydrate–electrolyte drinks (I: 0.8 ± 0.7 mmol/l; 26%; $p<0.001$; P: 0.7 ± 0.8 mmol/l; 25% $p < 0.05$).

In addition, no significant change in blood glucose level was noted after the exercise test when athletes received the "I" test drink; however, a significantly ($p<0.05$) higher blood glucose level was observed when athletes received "P" (on average by 12%) (Table 3).

Table 2. *Anthropometric and physical efficiency parameters of rowers*

traits	total (n=18)	
	$X_{śr}$	SD
age (years)	20.0	2.0
height (cm)	186.0	7.0
body weight	82.6	10.2
FM (%)	10.5	3.2
FFM (kg)	73.7	7.3
$\dot{V}O_2max$ (ml/kg b.w./min)	60.4	5.0
resting heart rate (beats/min)	62.0	7.0
maximum heart rate (beats/min)	200	2.0

Table 3. *Changes in body weight, blood lactic acid and glucose concentrations in athletes consuming Isostar or Powerade during exercise test*

Analyzed parameters	ISOSTAR (n = 18)			POWERADE (n = 18)		
	$X_{śr} \pm SD$		P_1 vs. P_0	$X_{śr} \pm SD$		P_1 vs. P_0
	P_0	P_1		P_0	P_1	
Body weight (kg)	82.4 ± 10.0	82.4 ± 10.0	0.0 ± 0.3 (0%)[a] ni	82.2 ± 10.3	82.3 ± 10.1	0.1 ± 0.3 (0.2%)[a]ni
Blood lactate (mmol/l)	3.1 ± 1.2	3.9 ± 1.0	0.8 ± 0.7 (26%)[a] $p < 0.001$	2.4 ± 0.6	3.0 ± 0.9	0.7 ± 0.8 (25%)[a] $p < 0.05$
Anaerobic threshold (PPA) (mmol/l)	3.5 – 4.5	–	–	–	–	–
Blood glucose level (mmol/l)	108.5 ± 10.8	114.8 ± 14.5	6.3 ± 18.4 (6%)[a] ni	102.9 ± 15.8	114.8 ± 14.5 ni	12.1 ± 18.8 (12%)[b] $p < 0.05$
Normal range (mmol/l)	60–112	–	–	60–112	–	–

P_0 – before exercise test
P_1 – after exercise test

Effect of carbohydrate-electrolyte drinks on gastro-intestinal (GI) complaints

The incidence and intensity of the reported complaints are presented in Table 4. All athletes, consuming both tested drinks, at the end of the exercise test declared general exhaustion, although with a similar relatively low intensity ("P": 1.2 ± 0.4 points; "I": 1.1 ± 0.4 points). No significant differences could be observed between the sensation of post-exercise muscle cramp after consumption of both tested drinks ("P":1.2 ± 0.6, "I": 0.9 ± 0.6). No considerable difference was observed in the frequency or intensity of heat oedema, accelerated heart beat or hand trembling in athletes. Gastrointestinal complaints such as reflux occurred significantly more frequently ("P": 83% and "I": 22%; $p<0.001$) and they were perceived as more serious by athletes consuming "P" in comparison to "I" ("P": 1.9 ± 0.9 points; "I": 0.2 ± 0.4 points) ($p<0.001$). Also after the consumption of "P" athletes perceived sweet taste in the mouth significantly more often (83%, $p<0.001$) and as a stronger sensation (2.1 ± 1.2 points; $p<0.001$) in comparison to rowers drinking "I": 28%, 0.3 ± 0.5 points. The sensation of stomach overfilling was declared by two times more athletes consuming "P" in comparison to those drinking "I" ("P": 89% and "I": 39%, $p<0.01$). None of the examined rowers declared nausea or heartburn. Moreover, all athletes declared an increased urge to urinate. Athletes assessed this complaint as medium ("P": 2.4 ± 0.8 points, "I": 2.3 ± 0.7 points).

Table 4. *Incidence and intensity of gastrointestinal and general complaints*

ASSESSED PARAMETER	POWERADE		ISOSTAR	
	Incidence rate (%)	Intensity of complaints perception $X_{śr} \pm SD$ (min-max)	Incidence rate (%)	Intensity of symptom perception $X_{śr} \pm SD$ (min-max)
GI complaints				
Reflux	83%	1.9 ± 1.0 (0-3)	22%***	0.2 ± 0.9 (0-1)
Nausea	0%	–	0%	–
Sweet taste in the mouth	83%	2.1 ± 1.2 (0-3)	28%***	0.3 ± 0.2 (0-2)
Heartburn	0%	–	0%	–
Overfilling sensation	89%	1.1 ± 0.6 (0-2)	39%**	0.4 ± 0.5 (0-1)
Urge to urinate	100%	2.4 ± 0.8 (2-4)	100% (NS)	2.3 ± 0.7 (1-4)
General complaints				
Overall exhaustion	100%	1.2 ± 0.4 (1-2)	100% (NS)	1.1 ± 0.4 (1-2)
Muscle cramp	89%	1.2 ± 0.6 (0-2)	83% (NS)	0.9 ± 0.6 (0-2)
Heat oedema	39%	0.4 ± 0.5 (0-1)	33% (NS)	0.4 ± 0.5 (0-1)
Accelerated heart beat	22%	0.2 ± 0.4 (0-1)	16% (NS)	0.1 ± 0.3 (0-1)
Hand trembling	44%	0.4 ± 0.5 (0-1)	50% (NS)	0.5 ± 0.5 (0-1)

Discussion

Commercially available carbohydrate-electrolyte drinks are commonly used by both professional athletes and amateurs. Those drinks are used for a variety of purposes, including supplying carbohydrates to the working muscles, preventing dehydration, allowing replacement of electrolytes lost during sweating, promoting hydration before the event, and encouraging faster re-hydration and glycogen repletion afterwards (27).

In this study a significant 12% increase in blood glucose level was found at the end of the exercise test in a group of athletes consuming "P". In addition, at the end of the exercise test in the group of athletes receiving "I" this parameter did not change significantly. Studies conducted by British researchers showed that the consumption of a drink containing 6.5% carbohydrates during the exhausting exercise made it possible to maintain a high blood glucose level in athletes in comparison to values recorded for athletes consuming liquids with no carbohydrates added (5). In this study a significant 26% increase in blood lactate level was found at the end of the exercise test in the group of athletes consuming "I" and a significant 25% increase in blood lactate level was found at the end of the exercise test in the group of athletes consuming "P". A study conducted by Khanna and Manna (27) showed no significant changes in lactate levels, irrespective of the supplementation of the carbohydrate–electrolyte drink.

In spite of the knowledge that the consumption of electrolyte–carbohydrate drinks contributes to an increase of physical performance, a lots of researchers indicate simultaneously that the use of those drinks may cause gastrointestinal complaints (1,2,4).

Based on the conducted analyses it was found that rowers at the end of the exercise test declared reflux and a sensation of too sweet taste in the mouth, stomach overfilling and an increased urge to urinate. However, reflux occurred significantly more often ("P": 83% and "I": 22%; $p<0.001$) and was perceived as more acute ($p<0.001$) by athletes consuming "P" in comparison to those drinking "I" ("P": 1.9 ± 0.9 points; "I": 0.2 ± 0.4 points). Also after the consumption of "P" athletes perceived the sweet taste in the mouth significantly more often (83%, p<0.001) and for them it was a more acute sensation (2.1 ± 1.2 points; $p<0.001$) in comparison to rowers drinking "I": 28%, 0.3 ± 0.5 points. Also the sensation of stomach overfilling was declared by a two times higher number of athletes consuming "P" in comparison with those consuming "I" ("P": 89% and "I": 39%, $p<0.01$). Results of this study indicated that the sensation of overfilling and an increased urge to urinate were not caused by excessive ingestion of fluid, since body weight results recorded before and after the test exercise in groups of athletes ingesting "I" and "P" did not change significantly. On the other hand, Jeukendrup explained that the discussed discomfort may result from a lack of a habit on the part of athletes to consume adequate amounts of liquids before, during and after exercise (11).

It seems that the explanation for the other reported complaints needs to be looked for in connection with the composition of tested liquids, as well as the possibility to empty the stomach of these liquids. Slower stomach emptying may cause a discomfort of the overfilling sensation, reflux or eructation (4).

Tested drinks differed in the qualitative and quantitative composition of carbohydrates. In "P" maltodextrin was used in combination with dextrose. In contrast, "I" contains a combination of maltodextrin and sucrose. The producers of the tested drinks do not supply information on the concentration at which both saccharides were combined; it is only known that the carbohydrate concentration in "I" is 7%, while in "P" it is 5.6%. Available literature data showed that the most appropriate carbohydrate concentration in drinks for athletes should range from 6 to 8%, while osmolarity should not exceed the upper limit of 330 mOsm/kg (22). Also Morton reported that in order to avoid abdominal pain and bloating, the subject should refrain from consuming fruit juices and beverages high in carbohydrate content and osmolarity, both before and during exercise (26).

Despite the fact that both drinks met the above assumptions, after the consumption of "P", characterized by a lower carbohydrate concentration, athletes complained more frequently and perceived gastrointestinal problems as more acute. Literature data show that in terms of the gastric emptying rate and intestinal absorption the combination of maltodextrin and glucose is most advantageous (12,18). Additionally, maltodextrin is frequently used due to its neutral taste and relatively low osmotic value (10). Wagenmakers et al., using an 8% sucrose concentration during a 2h exercise test on a cycloergometer (intensity 65% $\dot{V}O_2max$), found that sucrose is absorbed in the human organism at a rate very similar to that of glucose (3). Rehrer et al. compared the absorption of 17% maltodextrin with that of a glucose solution of an identical concentration. It was shown that gastric emptying for both tested liquids and their intestinal absorption occurred within a comparably short time (21). In the opinion of Jeukendrup, maltodextrin and sucrose are these carbohydrates, for which the risk of gastrointestinal complaints is low. However, that author did not give any information on dextrose (11). It may thus be suggested that it is the combination of maltodextrin and dextrose used to produce "P" that could have caused the sensation of stomach overfilling in athletes.

Recent studies suggest that slower absorption of fluid may cause GI symptoms, reduced intestinal tract (6,15). Both Glesson et al. (6) and Kovacs and Brouns (15) reported that an addition of sodium to carbohydrate drinks accelerates intestinal water absorption rate.

Similar suggestions concerning an increased absorption rate of liquids containing sodium were proposed by Leiper (17) during the World Conference in Aberdeen concerning sports biochemistry. Thus it may be suggested that it is the higher sodium content in "I" (680 mg/dm^3) which contributed to its higher absorbability and reduced the sensation of stomach overfilling than those of "P", in which Na content was on average 520 mg/dm^3. The authors suggest that significant differences between sodium content in the two tested drinks may have caused differences in GI complaints.

Moreover, several studies showed the effect of magnesium deficiency on disturbances in the motor activity of the GI tract (19). Thus it seems possible that the lack of this element in the tested "P" drink might also be the reason of gastrointestinal complaints in athletes.

We conclude that due to the absence of gastrointestinal problems in athletes practicing endurance sports an isotonic drink "I" may be recommended.

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