

Continuous Sports Drink Hydration Study: Effects of replacing all fluids with a sports drink for 10 consecutive days in healthy subjects.

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Abstract

During natural disasters and/or military exercises lasting between a few days and several weeks where nearby water is not drinkable due to contaminants, could a sports drink be used as the sole exogenous fluid source to replenish necessary losses without gastrointestinal (GI) side effects. There is now an apparatus that uses the natural energy mechanism of osmosis to purify previously undrinkable water sources. The compounds of a sports drink can be used as the driving force drawing undrinkable water across a membrane to produce a drinkable sports drink.

The purpose of this study was to evaluate the tolerance of a sports drink consisting of 6% carbohydrates with standard electrolyte ratios, as the sole source of fluid intake for 10 continuous days.

Methods: 23 healthy active subjects between ages 19-26 (15 male; 8 female) were studied and monitored while maintaining a diet free of fresh fruit. Fluid intake, weight, general health, and a log manual were monitored daily by a physician. The log manual recorded bowel frequency and consistency, nausea, bloating, food intake and daily activity including exercise. Fitness levels varied from average to elite amateur national team members.

Results: Males consumed an average daily intake of 4.35 ltr (daily range 1.5-13.0 ltr) equating to 1150 kcals. Females consumed an average intake of 2.68 ltr (daily range 1.0-4.5 ltr) equating to 708 kcals. Range difference in males was due to the amount and intensity of exercise performed in a relatively hot environment by some of the subjects who are elite amateur athletes. The average fluctuation in body weight over the 10-day study period for the 23 subjects was 1.77%. During 230 days worth of data collected, there were 7 instances of stool alteration. In all of these episodes, the stool consistency was loose and no bouts of diarrhea were recorded. In each of these instances, subsequent stools were normal and daily activity, social interactions, exercise training and diet remained unaltered. There were 2 recorded occurrences of bloating, which did not lead to nausea or stool alteration and as above, lifestyle was unaltered. In the latter 1/3 of the study there were no GI occurrences. This equates to a 3% occurrence of stool alteration and a < 1% occurrence of gastric discomfort.

Conclusion: The sole ingestion of exogenous fluids in the form of a known 6% carbohydrate sports drink for 10 continuous days did not cause statistical or clinically significant gastrointestinal side effects. This suggests that a sports drink of 6% carbohydrate with electrolytes could be used without significant gastrointestinal side effects as the sole fluid source in situations where drinkable water is not available for extended periods of time.

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Introduction

Currently, following a natural disaster or during military exercises, water that is not drinkable due to contaminants requires either adding chemicals to the water or acquiring a power-generated source to purify the water for drinking purposes. In areas of natural disasters where power has been temporarily cut-off, petrol powered generators are brought in to purify the water. This is timely and costly. During military exercises, units may be around contaminated water and limited in their goals or objectives by the amount of physically carried water and the time and distance to a camp where drinkable water can be replenished. There is an apparatus that has been developed which consists of a lightweight plastic bladder with a membrane that allows water from a contaminated source to flow through, but prevents microbiological contaminants from entering. It uses membrane pore size and a sports drink compound to filter and draw the contaminated water into a bladder that one can drink from. This does not require traditional external generator sources and uses the current contaminated water as its source to convert to drinkable water. A concentrated sports drink compound acts as the driving force across a semi-permeable membrane to draw the contaminated water into the empty bladder. Once the water has entered the bladder it mixes with the concentrated sports drink compound and produces a volume of the sports drink equivalent to or lower than a concentration of 6% carbohydrates with electrolyte ratio amounts.

High sweat rates with excessive loss of body fluids can cause a deficit of body water (hypohydration or dehydration). Murray's work (1995) suggests that mild to severe dehydration commonly occurs among athletes despite fluid being readily available. The body prioritizes regulating body temperature over body water. Therefore, a hypohydration can be driven very far and in fact can threaten life if the environment is very hot and water is not available.

Early experiments conducted by Pitts (1944), demonstrated that progressive dehydration during prolonged exertion in the heat can adversely affect cardiovascular function, as reflected by elevated heart rates, and temperature regulation, as indicated by high rectal temperatures and reduced sweat rates. Candas et al., 1988, more recently investigated and subsequently confirmed these observations. Pitts and colleagues (1944) also suggested that thirst was not an adequate stimulus for the subjects to replace all of the water they lost as sweat, a few years later confirmed by Brown (1947) using military recruits exercising in a desert.

The American College of Sports Medicine (ACSM) and the National Athletic Trainers' Association (NATA) caution physically active people against "letting their thirst guide them." After all, research shows that thirst – a physiological response to the stress on our bodies from fluid and sodium loss (via sweat, diarrhea or vomiting) – is not a good indicator of hydration status or the body's fluid levels. Dehydration or hypohydration causes greater heat storage in the body, reducing heat strain tolerance. Sawka (1992) claims that increased heat storage is mediated by decreased sweating rates and decreased skin blood flow for a given core temperature. Diverting or displacing blood to the skin makes it difficult to maintain central venous pressure and an adequate cardiac output to simultaneously support metabolism and thermoregulation during exercise-induced heat stress.

Several studies have documented the positive and negative effects of sports drinks prior, during, and immediately after exercise (activity lasting less than 1 hour and greater than 1 hour). To date there are no known studies using a sports drink as the sole exogenous source of fluid intake for 10 consecutive days. The individual or unit of people who would participate in the recovery of a natural disaster or be involved in a military exercise would require fluid hydration and energy replacement each day. The volume required would be more pronounced if activities are performed in a hot environment. The optimal formulation of a carbohydrate-electrolyte beverage for the soldier or aid worker in the field is an important consideration for the health and combat effectiveness of that aid worker or soldier. This is especially true for soldiers who are exposed to thermal stress that leads to rapid dehydration and for those who are undergoing prolonged physical exertion that leads to both rapid dehydration and exhaustion. This drink would successfully minimize dehydration and supply carbohydrates for the purpose of delaying or preventing exhaustion depending on the activity parameters.

Reduction in body water, availability of carbohydrates, and an inadequate electrolyte balance during prolonged exercise events will hamper performance and may lead, in some cases, to serious medical problems (heat exhaustion or heat stroke). A 1% reduction in body weight due to water loss may evoke an undue stress on the cardiovascular system accompanied by increases in heart rate and inadequate heat transfer to the skin and the environment, increase plasma osmolality, decrease plasma volume, and may affect the intracellular and extracellular electrolyte balance (von Duvillard et al 2004; ACSM 1996).

About 580 kcal is lost for every liter of sweat that is evaporated (Naghii 2000). Loss of body fluid can be determined by changes in body weight resulting from exercise. Each kilogram of body weight loss accounts for about 1 L of fluid loss. Sports drinks with appropriate and adequate concentrations of electrolytes and carbohydrates promotes maintenance of homeostasis, prevents injuries, and maintains optimal performance (Powers et al 1990).

The benefits of a sports drink versus water is known and chronologically studied, prior, during, and post exercise (activities lasting less than 1 hour and those lasting several hours). However, little seems to be known of the effects of drinking an established carbohydrate and electrolyte sports drink for 10 consecutive days as the only source of external fluid ingestion. The aim of this study is to observe and document the effects of drinking a sports drink for 10 consecutive days allowing no other fluids to be ingested.

The present study was designed to evaluate the effects of a commercially available sports drink with a previously studied carbohydrate composition (6%) with electrolyte levels in healthy subjects during a 10-day regime.

Methods

Subjects

The subject population recruited consisted of sponsored high level amateur cyclists (National Cycling Team) and several club racing cyclists, cross country runners, and a few subjects who exercise regularly but are not sport specific. Exercise was daily and ranged from 1-6 hours with varying degrees of intensity. Female subjects were not pregnant or nursing and had to use adequate birth control precautions.

23 healthy subjects (15 male, 8 female) with an age range of 19-26 years (average 22 years) were recruited to participate in the 10-day continuous sport drink hydration study. 10 out of the 15 males were extremely well trained athletes (national cycling team), 5 males were fit and healthy but did not train more than 1 hour per day. The 2/3 male to 1/3 female ratio was to emulate the gender ratio of the combined armed forces. The subjects were not allowed to eat fresh fruits or have dessert foods in their diet, because of the high levels of monosaccharides in the drink. The lack of fresh fruit was also to simulate military issued rations. They were not allowed to ingest any other fluids. Temperatures during the 10-day study ranged from 71-84 deg. F. with humidity reaching 80%. Temperatures were higher in some of the surrounding areas where the subjects exercised.

Design of Study

Screening consisted of a health questionnaire, current activity level, medical examination and weighing. All subjects received a complete written description of the study and signed a form giving informed consent. Upon completion of the study, an exit form and questionnaire was completed by all of the subjects to assess appetite and energy levels throughout the 10 days.

Investigation Protocol

This study was carried out as a clinical trial with a 10-day treatment period. Study protocol, log manual and informed consent forms were reviewed and implemented. Safety was assessed by daily physical examination and history taking with each subject by the same clinician. Each subject had 24-hour access to the principal investigator for any questions or concerns.

For consistency, daily weights were recorded using the same scale with only 1 examiner recording the digital readouts. Each subject kept a daily log, which was discussed and assessed by one investigator throughout the entire study.

Daily fluid bottles in liters were recorded. Used empty bottles were discarded and new ones were provided each day. Subjects were encouraged to drink as normal for them and maintain their usual fluid intake according to their loss from exercise duration and intensity.

Each subject was recorded as a 'sipper' (one who drinks frequently throughout the day) or a 'fluid loader' (one who has a set volume and abstains for several hours before hydrating or loading again) representing their normal fluid behavior prior to the study. Their hydration behavior was reassessed during the study and immediately post study as 'sippers' or 'fluid loaders'.

Bowel movements were discussed and recorded. The categories were frequency (prior to study and during study) and consistency (firm, loose, or watery).

Results

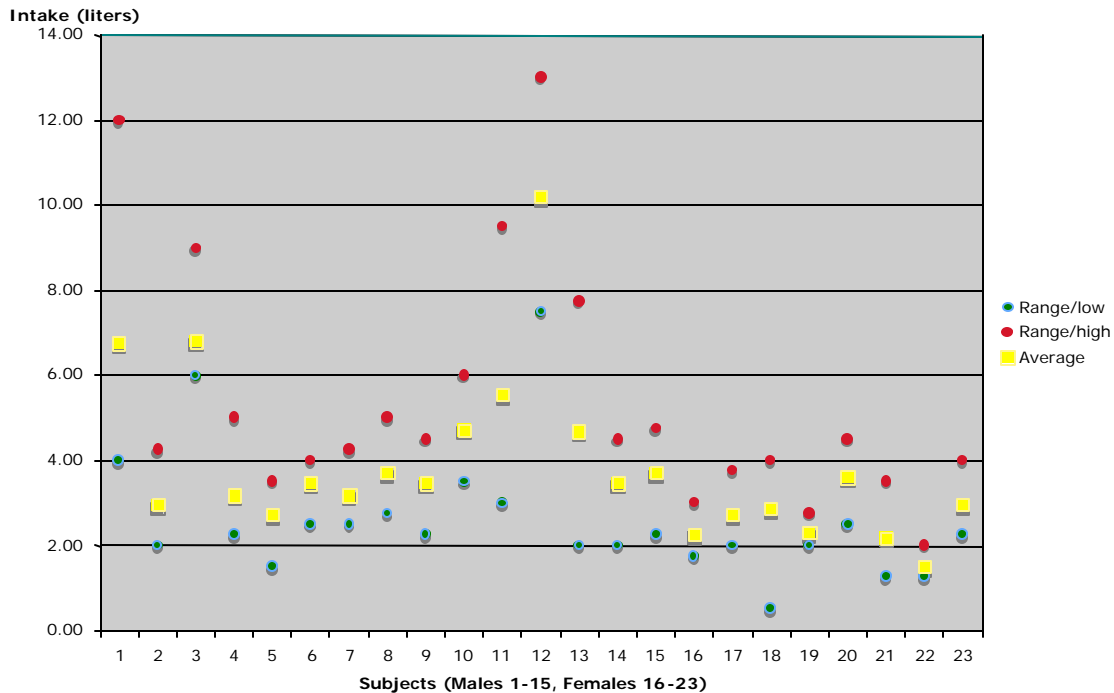
Fluid

The exogenous fluid of dextrose 10.9 g/L, fructose 7.9 g/L, sucrose 40.0 g/L, citric acid 3.0 g/L, tri-sodium citrate 0.53 g/L, sodium benzoate 0.03 g/L, potassium sorbate 0.03 g/L, lemon-lime extract 1.5 g/L, sodium chloride 0.80 g/L, monopotassium phosphate 0.40 g/L was ingested by the subjects throughout the study. For every 8 fl oz (237ml), the caloric value was 63 calories or 264.6 calories per liter.

Fluid Intake

Figure 1 represents the average daily fluid intake with the high and the low for each of the subjects (The average for all males combined was 4.35 ltr per day, in females 2.68 ltr per day). Before the study each subject was categorized as either a sipper (one who drinks frequently throughout the day) or loader (one who has a set volume and abstains for several hours before hydrating again) representing their normal fluid behavior prior to the study. Their hydration behavior was reassessed during the study as sippers or fluid loaders. At the conclusion of the study each subject had become or remained a sipper regardless of what their previous hydration habits had been before the study.

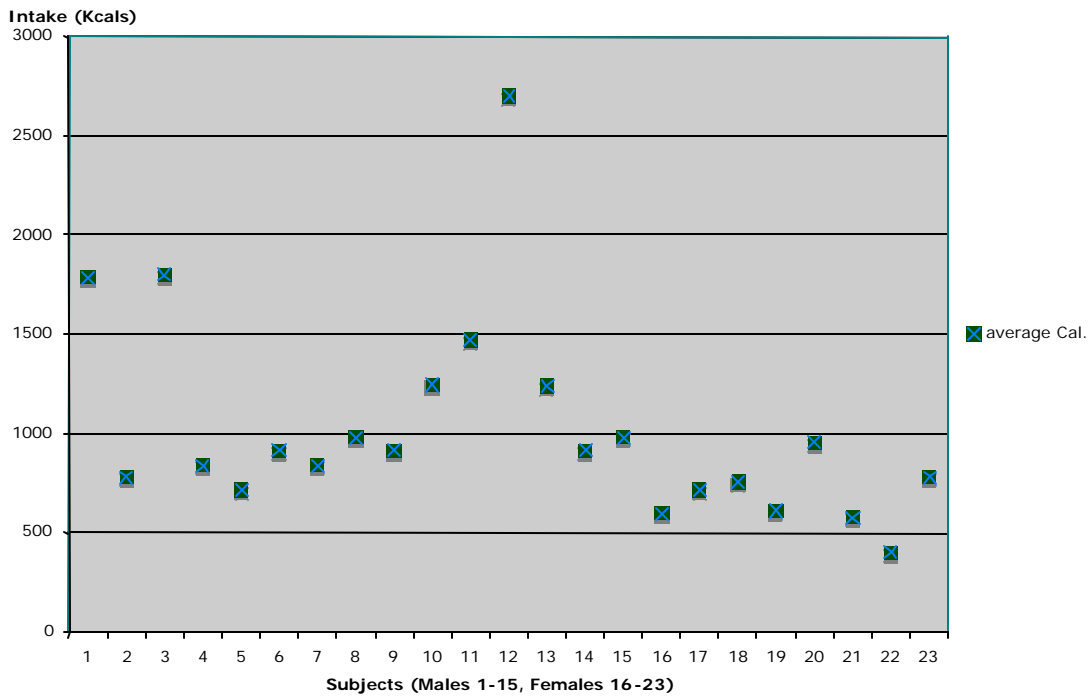
Figure 1. Average fluid intake low and high values



Caloric Intake

Figure 2 represents the average daily caloric value via the exogenous fluid intake (The average for all males combined was 1207.02 kcals per day, in females 706.34 kcals per day).

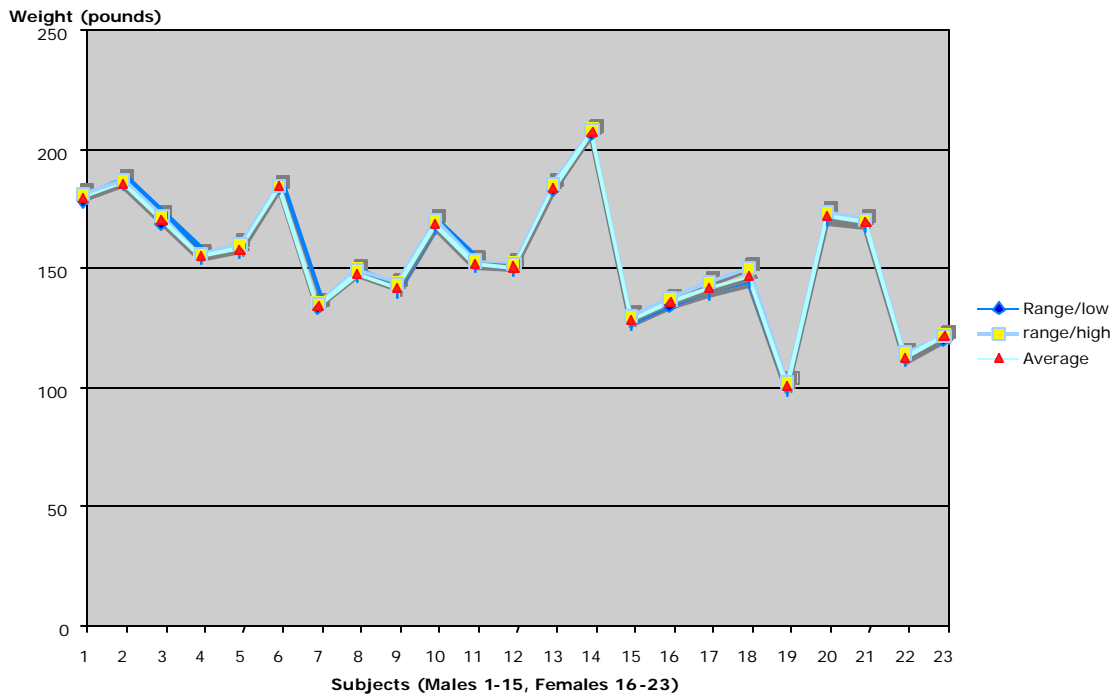
Figure 2. Average caloric intake



Weight

As this was the only fluid to be ingested, weight loss due to dehydration was a concern. Therefore, we checked weight on a daily basis for each of the subjects and found that their weight only fluctuated an average of 1.9% of their body weight over the course of the 10-day study. Figure 3 shows the average weight of each subject with their high and low weight recorded. Their average daily weight suggests that the subjects were hydrated adequately.

Figure 3. Average weight low and high values

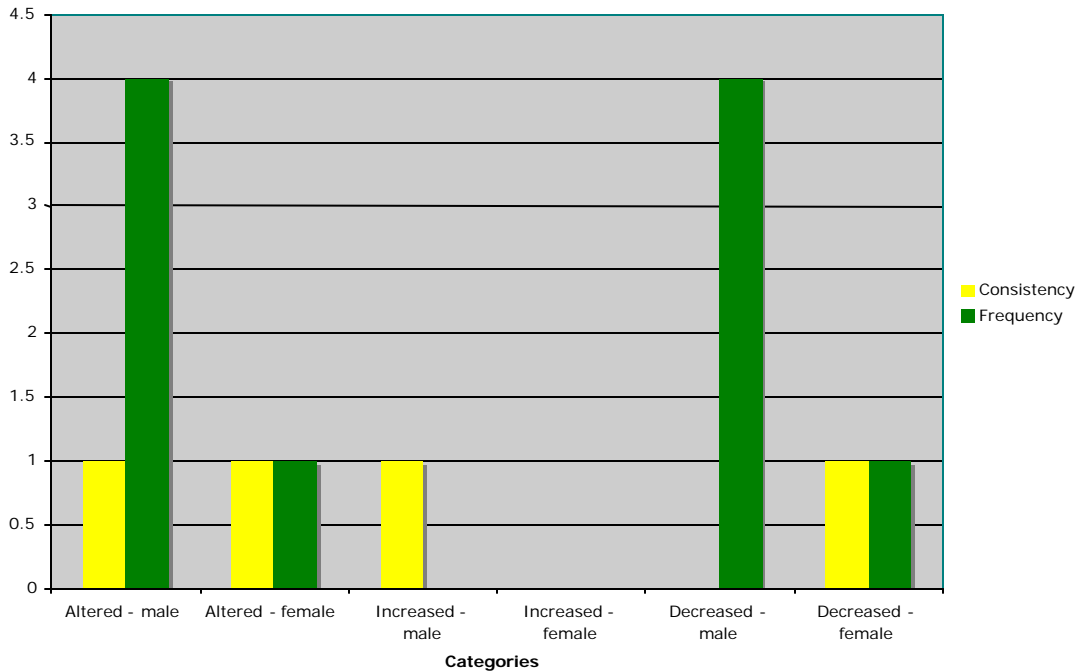


Gastrointestinal Effects

The study was assessing whether individuals would suffer from any gastrointestinal symptoms/side effects in particular changes in stool frequency and consistency as well as bloating or nausea. During 230 days of study data there were 7 occurrences of altered stools and 2 of bloating (Figure 4). Of the altered stools, 2 were a change in consistency from the subjects normal stool to either a firmer stool, a loose stool, or a watery stool, 1 from a male who experienced a looser stool and a female who experienced a firmer stool. The 5 other stool alterations related to the frequency of stools per day. All of these occurrences were of decreased frequency and 4 were experienced by males and 1 by a female subject. In each of these instances, subsequent stools were normal and daily activity, social interactions, exercise training and diet remained unaltered. There were 2 recorded occurrences of bloating, which did not lead to nausea or stool alteration and as above, lifestyle was unaltered. In the latter 1/3 of the study there were no GI occurrences. This equates to a 3% occurrence of stool alteration and a < 1% occurrence of gastric discomfort. All 7 recorded symptoms occurred within the first 7 days. This suggests that once a subject becomes accustomed to a change in diet, these symptoms resolve.

Figure 4. Number of stool alterations during 230 days of study data

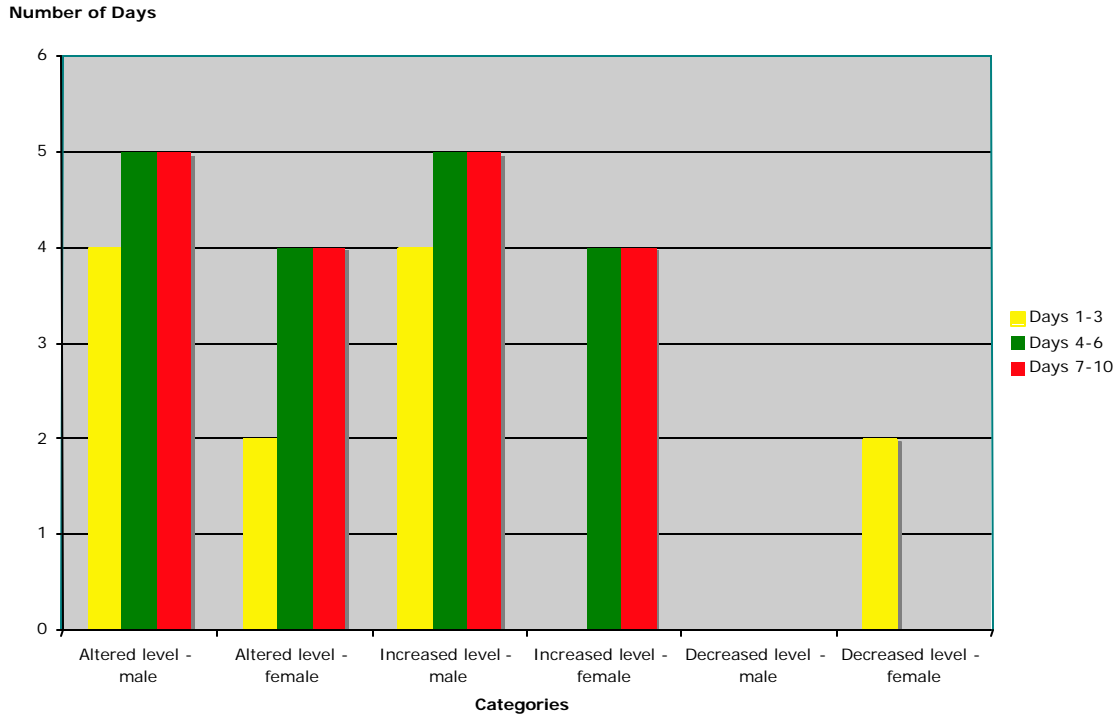
Number of total stool changes



Energy Levels

As Figure 5 shows, there were 24 days, out of the 230 days data collected, where levels of energy changed from the usual for that subject. From these occurrences only 2 were as a result of a decrease in energy. Both of these occurrences were recorded in the 1st 3 days of the study and both from female subjects whose energy levels subsequently increased.

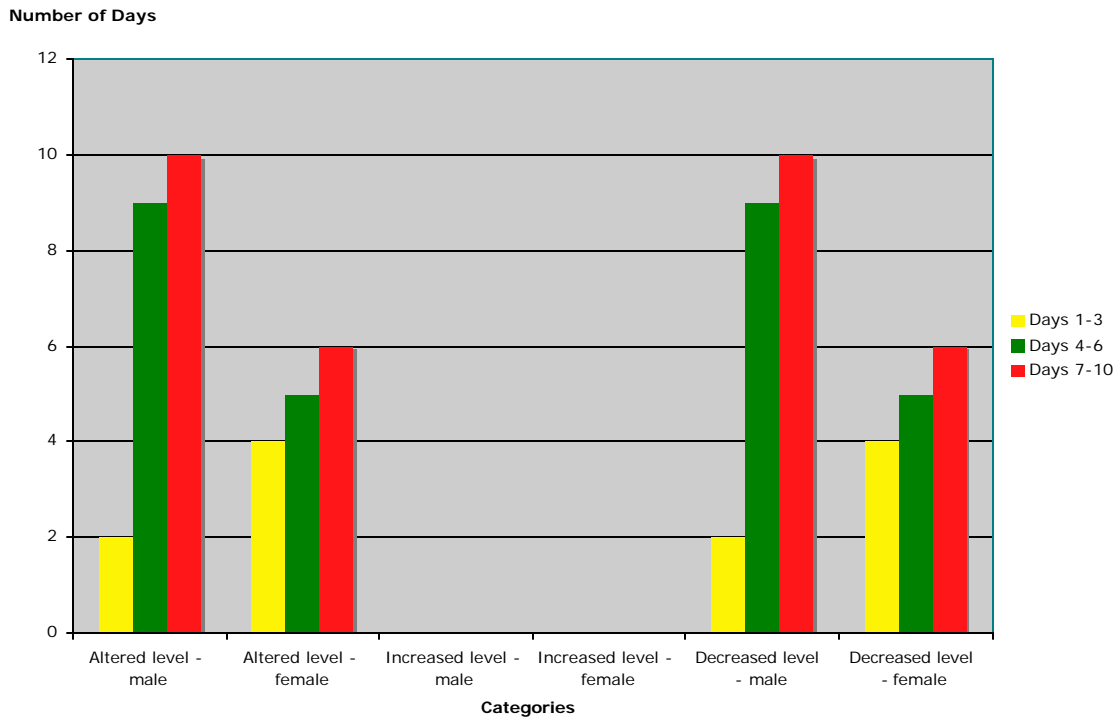
Figure 5. Number of days in which energy levels were altered



Appetite Levels

Figure 6 represents a decrease in appetite levels during the study by both male and female subjects. There were no recorded occurrences of any subjects experiencing an increase in appetite during the study. This suggests that the average daily amount of calories consumed by the subjects from the sports drink may have decreased their appetite.

Figure 6. Number of days in which appetite levels were altered



Discussion

The primary objective of this study was to assess if a carbohydrate-electrolyte sports drink, as the only source of exogenous fluid ingested for 10 consecutive days, caused any gastrointestinal symptoms. The secondary objective was to observe any other findings that would have clinical significance. This study involving the consumption of a sports drink for 10 consecutive days was set up to emulate military personnel. Age and gender were chosen to simulate that of an enlisted soldier in combat today. Subjects were chosen because of their discipline, high fitness level, integrity and somewhat obsessional behavior to detail. Subjects were also chosen based on the expected fluid loss throughout the day to be no less than that of an average soldier in a hot climate during sedentary and exercise activities in a 24 hour period. Diet was to exclude fresh fruit and dessert foods that would not be ingested if a soldier was on a 10 day military exercise in harsh environments. Interestingly, several of the subjects

found that their general energy levels were increased and that the usual appetite cravings were diminished.

Literature thus far, has reported and suggested that for a multiple effect, that being, optimum maintenance of hydration, rehydration, gastric emptying, absorption, maintaining fluids within their respective compartments, maintaining energy levels and storage, prevention of medical problems (hyponatremia, heat exhaustion and stroke, etc), and improving work performance in warm to hot environments, that a carbohydrate (between 4-8%) electrolyte drink, currently best addresses these issues. Therefore, this type of solution was used in this study to assess whether an individual who had access to only one source of fluid (providing the benefits above) could function optimally without unacceptable symptoms or side effects.

Several authors have conducted studies with sports drinks, (carbohydrate and electrolyte solutions), and their effects on hydration/dehydration status, plasma volume changes, gastric emptying, and work performance etc, etc. [Gore, et al., 1992; Twerenbold et al., 2003; Van Nieuwenhoven et al., 2000; Nielsen et al., 1986; Melin et al., 2001; Bilzon, et al., 2002; Chryssanthopoulos et al., 1994; Chryssanthopoulos et al., 1994; Cunningham et al., 1997; Davis et al., 1988; Fallowfield et al., 1995; Fallowfield et al., 1993; Febbraio et al., 1996; Galloway et al., 2001; Glace et al., 2002; Glace et al., 2002; Horswill, 1998; Koulman et al., 1997; Murray, 1995; Murray et al., 1989; Nassis et al., 1998; Oliver et al., 2002; Ormerod et al., 2003; Tsintzas et al., 1996; Tsintzas et al., 1995; Wong et al., 2000; Yaspelkis et al., 1991. Murray et al., investigated the effect of CHO content (carbohydrates) on exercise. They reported that ingestion of a water placebo and beverages containing 6%, 8%, and 10% sucrose (CHO) resulted in similar sensory and physiologic responses. However, they also reported that only beverages containing 6% sucrose increased performance after 60 min of exercise. These have been attributed to sporting events and training sessions that last longer than 90 min, resulting from reduced muscle and liver glycogen stores. In gliding sports such as cycling, skating and swimming, the prevalence of GI symptoms is lower compared with running (Brouns & Beckers 1993).

Initially, all the subjects in this study complained of not having their thirst quenched with their first ingestion of the fluid causing them to drink more than what they normally would have if it were water. Literature tells us that this type of carbohydrate drink stimulates further drinking whereby water inhibits further drinking. The behavior to take a further drink caused by the 6% carbohydrate composition, would better prevent potential dangerous dehydration and its sequelae from occurring. Carbohydrates (sugars) favor consumption and Na⁺ favors retention of water (von Duvillard et al, 2004).

There is overwhelming cumulative evidence that fluid replacement lowers cardiovascular strain and improves thermoregulation when compared with cardiovascular strain and thermoregulation under conditions in which fluid is

withheld during prolonged exertion. Ingestion of a carbohydrate electrolyte drink between bouts of physical activity in a warm environment may therefore alleviate the symptoms of fatigue (Carter and Gisolfi 1989) and assist in the maintenance of performance during subsequent exercise.

Clinically substantial losses of water and electrolytes occur through sweating during prolonged exercise, especially when the ambient temperature is high (Adolph 1947; Lentner 1981). Once dehydration occurs, it decreases blood volume (Harrison 1985), and impairs thermoregulatory function (Pandolf et al. 1994) as well as exercise capacity (Sawka 1992). Previous studies suggest that volitional fatigue during prolonged exercise in a warm environment is directly related to dehydration, thermoregulatory incapacity and hyperthermia (Nielsen et al. 1993; Sawka 1992). Exercising in a warm environment (Febbraio et al. 1994) and progressive dehydration (Hargreaves et al. 1996) have been shown to increase the rate of muscle glycogen degradation. Muscle glycogen depletion may account, at least in part, for physiological fatigue when exercising in a warm environment. Inclusion of carbohydrate within a rehydration beverage may therefore be essential when repeated bouts of exercise are performed in a warm environment, on the same or successive days.

In several countries “sport drinks” are used successfully to maintain physiological homeostasis. Numerous studies have demonstrated the benefits of ingesting a carbohydrate and electrolyte sports drink prior, during, and post recovery of exercise. The benefits of a sports drink compared to water ingestion alone are well documented. Water quenches thirst ‘prematurely’ and therefore inhibits the drive to drink, thus, leading to potential dehydration. Water is unable to replenish electrolytes from sweating and can lead to hyponatremia when excessive water is consumed. Water does not have carbohydrates which allow optimum gastric emptying and fluid absorption, especially when the carbohydrate composition is maintained between 5-8%. Therefore, when fluid loss is high and rehydration needs to be replenished rapidly, a sports drink can aid in rapid absorption and also provide energy.

As a general rule, a 5 to 8% carbohydrate-electrolyte beverage consumed during exercise in the heat contributes the temperature regulation and fluid balance as effectively as plain water. The beverage provides an intestinal energy delivery rate of approximately $5.0 \text{ kcal} \cdot \text{min}^{-1}$; this helps to maintain glucose metabolism and glycogen reserves in prolonged exercise (Duchman et al 1997, Shi, Gisolfi 1998).

There is overwhelming cumulative evidence that fluid replacement lowers cardiovascular strain and improves thermoregulation when compared with cardiovascular strain and thermoregulation under conditions in which fluid is withheld during prolonged exertion.

Noakes (2003) described medical reasons for fluid replacement during marathon

running. He addressed important crucial parameters that determine one's risk of heatstroke, stating that heatstroke is not associated with the levels of dehydration during exercise but, more importantly, with the rate at which the athlete produces heat and the capacity of the environment to absorb that heat. He reported that several factors more important than dehydration are responsible for heat stress, heat illness, or heatstroke. One of these factors is determination of when the rate of heat production exceeds the rate of heat loss. The rate of heat production is determined by the athlete's rate of energy expenditure, which is a function of the athlete's mass and intensity of effort or running speed. Noakes further explained that the risk of heatstroke is likely to be greater in athletes who run 10-km races than in marathon runners because the 10-km race pace is faster than the marathon race pace. Thus, marathon athletes should drink ad libitum and aim for ingestion rates of about 800 mL/h. Heavier athletes are also at greater risk for heat-related conditions than are lighter athletes when both run at the same speed. The dangers of dehydration during exercise were further addressed by Noakes. He disputed the fact that dehydration is the cause for heatstroke in all cases of collapse in endurance athletes, as has been alluded to historically. He further described that there is good evidence that even mild levels of dehydration impair performance. Much greater levels of dehydration are required to produce renal failure or even death. He suggested that athletes can safely maintain low levels of dehydration by drinking enough but not too much during exercise. Athletes should be aware that very high rates of fluid ingestion (>1.5 L/h) sustained for many hours can lead to hyponatremia with a potentially fatal outcome. Excessive water intake may evoke signs and symptoms of hyponatremia. Hyponatremia is usually caused by increased intake and retention of dilute fluids concurrent with large losses of sodium through sweat.

Exercise, athletic competition, prolonged workouts, and long training sessions in hot, hot and humid, or cold environments challenge physiologic function. Dehydration, thermoregulation, fluid balance, rehydration, electrolyte changes, plasma volume, and cardiovascular challenges, to name a few, accompany most physical activities, exercise, training, and competition. This is especially true during prolonged endurance exercise and competition. Loss of body fluids inherently leads to a performance decrease, especially if the exercise is performed in hot environment. Thus, it is recommended that all individuals who exercise, train, and/or compete attempt to rehydrate and replace fluids and electrolytes that have been lost during exercise, mostly as a result of sweating. Maintaining proper hydration is not only a physiologic necessity but also adds to a performance advantage and reduces risks of medical problems or injury due to fluid losses. Ingestion carbohydrate-electrolyte drinks between bouts of physical activity in a warm environment may therefore alleviate the symptoms of fatigue (Carter and Gisolfi 1989) and assist in the maintenance of performance during subsequent exercise. Fallowfield and Williams 1993; Fallowfield et al. 1995 Previous demonstrated that ingesting carbohydrate-electrolyte solutions during short-term (4 h) and long-term (22.5 h) recovery periods enhances subsequent endurance capacity when exercise is performed in a cool (20 C) environment.

Ingesting carbohydrate-electrolyte solutions during recovery from prolonged running in a warm environment improves the endurance capacity 4 h later, compared to flavored, sweetened water.

Bilzon et al. (2000), also support that ingesting a carbohydrate electrolyte drink in sufficient quantities to replace body mass loss following prolonged, constant pace running in a warm environment improves endurance capacity 4 h later. The 6.9% carbohydrate electrolyte drink facilitated rehydration as effectively as the flavored, sweetened water solution. Adding of carbohydrate and electrolytes to a rehydration solution will delay the onset of fatigue during a subsequent bout of prolonged sub-maximal running in a warm environment.

The information above supports our decision to choose a hydration fluid drink with carbohydrate (6%) and electrolytes. The results demonstrated no statistical or clinical significance with regards to gastrointestinal symptoms or side effects. Any symptoms acquired during the study appear to be related to the adjustment of one's diet from a previous regime to one that includes a higher caloric fluid intake and with lower fiber. It's important to note that each of the occurrences were isolated events that did not alter the individual's daily activity, exercise regime, and social commitments. On direct questioning regarding the isolated occurrences all subjects referred to the symptom as mild (scale mild, moderate, severe). The subjective measurement of mild was evidenced by no disruption of daily routine. Interestingly, the subjects had an increase in energy with subsequent decrease in appetite during the final third of this 10-day study. Following activity with initial rehydration, all subjects described a sensation that their thirst was not quenched which required them to ingest more fluid to satisfy their thirst. This supports the literature of using a carbohydrate electrolyte solution rather than water to satisfy hypohydration or dehydration conditions. All subjects described having more energy during their work or exercise activity. Several subjects noted that their usual muscle ache or cramp during or after exercise was either diminished or absent during this 10-day study.

Conclusion

The study has shown that a sports drink (6% carbohydrate composition with electrolytes) consumed as the only external fluid allowed for 10 consecutive days during moderate and hot temperatures, was well tolerated with no statistical or clinically significant side effects in healthy active subjects.

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