Journal of Thermal Biology 77 (2018) 62–66

Contents lists available at ScienceDirect

Journal of Thermal Biology

journal homepage: www.elsevier.com/locate/jtherbio

Effects of pre-exercise sucrose ingestion on thermoregulatory responses to near-maximal 5-km running

Patrick B. Wilson*

Human Movement Sciences, Old Dominion University, Norfolk, VA 23529, USA

ARTICLE INFO

Keywords:
Carbohydrate
Endurance exercise
Running
Sport nutrition
Thermoregulation

ABSTRACT

Research has shown that carbohydrate consumption can increase body temperature at rest and, in some cases, during exercise. Most exercise studies, however, haven't matched exercise intensity between carbohydrate and placebo conditions. The purpose of this randomized, double-blind, placebo-controlled trial was to examine whether pre-exercise carbohydrate consumption independently accelerates the usual temperature rise with intense exercise. Twenty-eight runners self-reported 5-km performance (16–23 min) and were randomized, using a matched-pairs design, to 750 ml water containing 100 g sucrose or 0.8 g aspartame. Beverages were consumed 60 min before running at 93% of maximum 5-km speed in temperate conditions. Gastrointestinal temperature, Thermal Sensation Scale (TSS) and Feeling Scale (FS) were recorded before ingestion, every 10 min during 60 min of rest, and every 1-km during the 5-km run. Rating of Perceived Exertion was recorded every 1-km. Independent samples *t*-tests and two-way mixed ANOVAs with repeated measures assessed whether there were baseline differences or treatment effects. Gastrointestinal temperature didn't differ between carbohydrate (38.7 ± 0.4 °C) and placebo (38.6 ± 0.4 °C) by the end of the 5-km ($p = 0.49$). No group x time interactions or main group effects were found, except for a modest interaction for TSS ($F = 2.1$, $p = 0.02$, partial $\eta^2 = 0.075$). Time effects were found for all outcomes, with temperature, TSS, and RPE increasing, and FS decreasing, during the run. Ingesting 100 g of sucrose prior to intense running lasting < 25 min didn't influence gastrointestinal temperature and therefore doesn't likely impact on the risk of heat illness.

1. Introduction

Managing the thermoregulatory response to exercise is imperative to maintaining performance and preventing heat illnesses (Casa et al., 2015). During laboratory-based, fixed-intensity endurance exercise in the heat, fatigue occurs at a nearly identical body temperature in most athletes (esophageal temperature of 40.1–40.2 °C; González-Alonso et al., 1999), although several other factors are known to influence the relationship between core temperature and fatigue (e.g. dehydration, the type of exercise task, individual variation; Nybo and González-Alonso, 2015). That being said, slowing this rise in body temperature during exercise can delay fatigue in some situations (Siegel et al., 2010). Beyond performance, heat illnesses—a group of conditions caused by excessive heat production, an inability to dissipate internal heat, or a combination of both—are major health and safety concerns for athletes and sports medicine practitioners (Casa et al., 2015). Examples include heat syncope, exertional heat exhaustion, and heat stroke. Improperly treated exertional heat stroke can be fatal, which, sadly, still occurs more often than necessary (Casa et al., 2012).

Many of the underlying causes of exertional heat illnesses are well-documented, chief among them being exercise intensity. The generation of internal heat and core body temperature increases during exercise are strongly correlated with measures of absolute and relative exercise intensity (Cheuvront and Haymes, 2001). Thus, when an athlete exercises intensely, the surge in heat production overwhelms the body's capacity to dissipate heat, ultimately leading to a rapid increase in body temperature if exercise intensity is sustained (Casa et al., 2015). Consequently, sustained exercise carried out at high absolute work rates is a risk factor for exertional heat illnesses.

A common nutritional strategy to enhance performance involves consuming dietary carbohydrate before and/or during competition. While carbohydrate ingestion can be an ergogenic strategy, human and animal evidence suggests it may increase core body temperature, at least in non-exercise settings (Mizobe et al., 2006; Yatabe et al., 2014). This increase in temperature is thought to result from the energy expenditure associated with the digestion, absorption, and metabolic processing of dietary carbohydrate. Interestingly, non-exercise studies have shown that ingesting fructose (or sucrose, which contains

---

* Correspondence to: 2003A Student Recreation Center Norfolk, VA 23529, USA.
E-mail address: pbwilson@odu.edu.

https://doi.org/10.1016/j.jtherbio.2018.08.006
Received 6 July 2018; Received in revised form 14 August 2018; Accepted 14 August 2018

fructose) results in a greater thermogenic effect than other carbohydrates (Blaak and Saris, 1996; Tappy and Jéquier, 1993). In one study, for example, ingesting 75 g of sucrose resulted in a roughly 30% greater increase in energy expenditure after 60–90 min in comparison to an equal dosage of glucose or starch (Blaak and Saris, 1996). It's noteworthy that sucrose and fructose are found in many carbohydrate-based sports supplements (Wilson et al., 2015).

A number of studies have investigated the thermogenic effects of carbohydrate consumption during exercise, with several finding greater temperature increases with carbohydrate (Davis et al., 1988; Fritzsche et al., 2000; Millard-Stafford et al., 2005). However, work rates were not always matched between conditions, meaning that the increases in temperature with carbohydrate consumption may have simply been due to differences in exercise intensity. Attempting to address this concern, Horswill et al. (2008) used a 60-min cycling protocol at 65% VO_2max and found similar increases in body temperature when participants were given carbohydrate or placebo beverages. While Horswill et al. (2008) showed that carbohydrate ingestion doesn't affect body temperature during moderate-intensity exercise, several issues remain unaddressed. The use of a moderate-intensity protocol, as well as the spacing of feedings into small doses (15–20 g) over 15-min intervals, may have limited increases in heat production. Indeed, non-exercise studies that have found increased dietary thermogenesis have often fed participants a single, large bolus of carbohydrate (Blaak and Saris, 1996). In addition, there is delay between feeding and peak thermogenesis (Blaak and Saris, 1996), which means that an increase in temperature may be more likely when carbohydrate is fed 1–2 h before exercise. Notably, the first dose of carbohydrate in Horswill et al. (2008) was administered 30 min before exercise.

The purpose of this study was to investigate the thermoregulatory and perceptual responses to a bolus of carbohydrate—in the form of sucrose—fed 60 min prior to exercise. To induce a rapid and substantial increase in temperature, a near-maximal 5-km run was used. It was hypothesized that ingestion of a sucrose beverage would result in a larger increase in body temperature than a placebo beverage.

2. Materials and methods

2.1. Design

This study employed a randomized, double-blind, parallel-groups, matched-pairs design. Participants were assigned to one of two beverages based on their self-reported 5-km running ability. Beverages were made of 750 ml water with 100 g of sucrose or 0.8 g of aspartame (Ajinomoto Co., Tokyo, Japan), and both contained 0.4 g of NaCl and 15 g of lemon juice to further match flavor.

Once a participant was enrolled in the study, he or she was randomized to one of the two beverages. The next participant to enroll with a similar 5-km time (and of the same gender) was then automatically assigned to the opposite beverage. The randomization sequence for each pair was determined by an assistant that picked slips out of a sealed envelope; this assistant also made the beverages in a blinded fashion. The trial was approved by Old Dominion University's institutional review board and registered at clinicaltrials.gov (NCT02814188) prior to enrollment.

2.2. Participants

Individuals aged 18–65 years, running at least 10 miles/week, and with a projected maximal 5-km run time of 16–23 min were eligible for the study. Individuals also had to be free of cardiometabolic or pulmonary diseases, signs/symptoms of cardiovascular disease, and any gastrointestinal disorders that could cause swallowing problems or nausea/vomiting. All participants went through a consent process in accordance with the Declaration of Helsinki and signed a consent document.

Table 1
Background characteristics and pre-beverage data by treatment group.

	Carbohydrate (n = 14)	Placebo (n = 14)	*p*-value
Age (years)	32.6 ± 9.6	37.9 ± 9.0	0.15
Running experience (years)	12.1 ± 11.1	12.9 ± 7.5	0.81
Running volume (km/week)	43.5 ± 24.9	48.0 ± 22.3	0.62
Body fat (%)	18.1 ± 5.1	16.9 ± 4.9	0.86
Weight (kg)	75.7 ± 11.0	74.5 ± 9.7	0.76
Height (cm)	176.3 ± 8.2	177.8 ± 8.2	0.63
BSA (m^2)	1.9 ± 0.2	1.9 ± 0.2	0.99
5-km run speed (km/h)	13.8 ± 1.0	13.8 ± 1.0	0.98
Pre-beverage gastrointestinal temperature (°C)	37.4 ± 0.2	37.4 ± 0.2	0.82
Pre-beverage FS (− 5 to + 5)	3.5 ± 1.5	2.8 ± 1.7	0.25
Pre-beverage TSS (0.0–8.0)	3.6 ± 0.6	3.8 ± 0.7	0.32

BSA, body surface area; FS, Feeling Scale; TSS, Thermal Sensation Scale.

A total of 37 individuals were enrolled in the study. Six participants were lost to follow-up and one was unable maintain a sufficient pace during a familiarization run. Two participants completed the study but a suitable match wasn't ultimately found for them. Thus, 28 participants (26 men, 2 women) were included in the analysis (Table 1).

2.3. Procedures

During their first visit, participants completed paperwork inquiring about demographics, running experience, and training volume. In addition, participants reported how fast they could finish a maximal 5-km run. The participant's projected 5-km finishing time was converted to a speed, and that value was subsequently multiplied by 0.93 to determine the speed for the 5-km run. The objective of setting the protocol at 93% of maximal 5-km speed was to ensure that it was challenging but not so difficult that a significant number of participants wouldn't finish.

Next, participants completed a 5-min warm-up on a treadmill (HP Cosmos T170, Cosmed, Rome, Italy) at 75% of their projected 5-km speed. Participants then completed a 5–10 min familiarization run at the anticipated protocol speed. During this familiarization run, participants could request the speed be slightly reduced (i.e., 0.15–0.30 km/h) if they thought finishing a full 5-km at that pace would be problematic.

Participants were given pre-testing instructions for their second visit and supplied with an ingestible capsule for monitoring gastrointestinal temperature (CorTemp®, HQInc., Palmetto, FL, USA). Commercially-available ingestible sensors show strong agreement and small differences with esophageal measurements (0.1–0.2 °C; Byrne and Lim, 2007). Participants were instructed to consume the capsule 5 h before their second visit, a timeframe chosen to reduce the influence of ingested fluid temperature on measurements (Wilkinson et al., 2008). Participants were also instructed to: 1) avoid exercise within 12 h of the visit; 2) avoid alcohol, caffeine, and tobacco within 8 h of the visit; 3) drink ~ 16 ounces of water 4 h before; 4) avoid calorie-containing foods or beverages within 4 h of the visit; and 5) avoid fluid within 1 h of the visit.

At visit two, height and weight were measured with a stadiometer and digital scale. Given its impact on thermoregulation, body surface area (BSA) was calculated from height and weight using the formula from Du Bois and Du Bois (1916). Participants had body composition measured via air displacement plethysmography (Bod Pod, Cosmed USA Inc., Concord, CA, USA), and body fat was calculated using a race-specific equation (Siri or Schutte) and predicted thoracic gas volume.

After anthropometric data were collected, a baseline gastrointestinal temperature reading was recorded with a CorTemp® Data Recorder. Two back-to-back measurements were taken at each time point and the average was used. Participants gave ratings on two perceptual scales: Feeling Scale (FS; Hardy and Rejeski, 1989) and Thermal