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***FUEL UTILIZATION IN RESPONSE TO TWO COMMERCIALY AVAILABLE
BEVERAGES DURING EXERCISE IN THE HEAT***

By

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Undergraduate Thesis
presented in partial fulfillment of the requirements
for the University Scholar distinction

Davidson Honors College
University of Montana
Missoula, MT

May, 2017

Approved by:

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Health and Human Performance

ABSTRACT

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Exercise Science

Fuel Utilization in Response to Two Commercially Available Beverages During Exercise in the Heat

Faculty Mentor: Chuck L. Dumke, PhD.

INTRODUCTION: Wildland firefighters (WLFF) use sports drinks to retain fluid, and provide electrolytes and carbohydrates during long duration exercise in the heat. **PURPOSE:** The purpose of this study is to compare two commercially available beverages, DD (60.9 mM Na⁺, 3.4% CHO) vs G (18.4 mM Na⁺, 5.9% CHO) on their ability to affect fat and carbohydrate metabolism during submaximal exercise in the heat. **METHODS:** Ten aerobically fit males (22.5± 3.9 yrs, 82.2± 10.1 kg, 53.9± 5.9 ml•kg⁻¹•min⁻¹ VO₂ max) completed two 90-minute heat stress trials (39° C, 30% RH) walking at 50% VO₂ max followed by a 30-minute rest period. Respiratory gases were collected mid (45 min) and post-exercise (90 min). At 45 minutes, subjects consumed either G or DD with volume equivalent to 150% of the weight lost. Blood glucose was measured pre- and post-exercise, and post-trial. **RESULTS:** Ventilation (V_E) did not differ between G and DD (72.1 ± 8.4 vs. 69.4 ± 7.5 L•min⁻¹; p=0.5). Oxygen consumption (VO₂) was not different between trials (2.4 ± 0.1 vs. 2.4 ± 0.2 L•min⁻¹; p=0.3). Carbohydrate oxidation was not significantly different between the beverages (2.1 ± 0.2 vs. 1.8 ± 0.2 g•min⁻¹; p=0.2) for G vs. DD respectively. Significant differences in fat oxidation and respiratory exchange ratio (RER) were found (0.38 ± 0.03 vs. 0.47 ± 0.05 g•min⁻¹; p=0.049, and 0.89 ± 0.02 vs. 0.87 ± 0.01; p=0.04) in GG vs. DD respectively. Blood glucose was significantly greater post-trial in G vs. DD (116.0 ± 5.7 vs. 103.1 ± 3.9 mg•dL⁻¹; p=0.01). **CONCLUSION:** Following the consumption of a bolus of G (5.9% CHO) resulted in increased RER and reduced fat oxidation compared to a bolus of DD (3.4% CHO). Blood glucose was greater following ingestion of G. These data may prove critical for WLFF during work in the field.

Fuel Utilization in Response to Two Commercially Available Beverages During Exercise in the Heat

Background

There has been interest in sports nutrition and exercise science communities to find the best formula for the perfect sports drink that can maintain hydration status during exercise. When euhydrated, exercise performance is optimized. The goal of these beverages is an optimal balance of fluid and electrolytes. Two factors determine fluid balance: excretion and absorption of water and solutes.

Perspiration is the body's primary means of heat dissipation, and is necessarily increased during exercise. During high intensity exercise, sweat rate can range from 0.5–2 L•Hr⁻¹. When exercising in high temperature environments (85°– 110°F), sweat rate can well exceed 2 L•Hr⁻¹.² Research shows that water loss of 2% of body weight can decrease physical and mental performance¹ while water loss of 9% of body weight can be fatal.² While water excreted as sweat comes primarily from extracellular fluids, as hypohydration progresses water is pulled from intracellular fluid causing cell dysfunction and/or death. Although the loss of water in sweat is a major limiting factor to exercise performance, the loss of sodium can be equally detrimental. Sodium concentration in sweat ranges from 40–60 mmol•L⁻¹, or around 1.15g Na⁺ per liter of sweat.⁴ Since sodium is the major extracellular solute involved in osmolality between semipermeable membranes in the body, a very specific concentration must be maintained. As such, water and solute intake is crucial to maintaining physiologic function during exercise, especially in the heat.

If aerobic athletes are able to consume, and absorb the same volume and concentrations of fluids and solutes that they are excreting, they can delay dehydration and ameliorate their performance. But not all fluids consumed are retained for purposes of heat dissipation. Some water and solutes are used to remove metabolic byproducts in urine, even during states of dehydration. Therefore, a volume greater than lost must be consumed to match fluid balance.³ Certain properties of a the ingested fluid can increase or decrease the rate and effectiveness of absorption. Rate of gastric emptying, osmolality, carbohydrate concentration, solute concentration, and sodium concentration all effect the ability for the gut to absorb ingested fluids and solutes.³ Beverages of low osmolality increase absorption. Typical sports drinks have a

moderately low osmolality (280-380 mOsm•kg) while an oral rehydration solution is significantly lower (245 mOsm•kg). Carbohydrates in a beverage can increase passive water absorption, but concentrations exceeding 8% results in a decreased rate of gastric emptying. 20-30 mmol•L⁻¹ of sodium and 2-5 mmol•L⁻¹ of potassium are optimal concentrations for a hydration fluid.¹

Introduction

The prolonged duration of physical exertion for occupational athletes such as wildland firefighters (WLFF) produces a challenge in maintaining euhydration, especially in high temperature environments. With less ability to regularly consume hydrating beverages throughout a work shift, firefighters rely on intermittent, large bolus' in an attempt to replace fluid and electrolytes lost in perspiration, urination, gas exchange, etc. Since a loss of body mass greater than 2% can decrease performance both physically and mentally⁴, it is crucial that hypohydration, is avoided. There is debate among researchers about the optimal ingredients and concentrations within a sports drink that will best drive fluid and solute absorption and retention during exercise. The ideal concentrations of each ingredient may vary depending on their use before, during or after exercise. In this study, two commercially available beverages, Gatorade and DripDrop were compared by their ability to rehydrate during a bout of exercise in the heat. Gatorade (5.9% carbohydrate, 423 mg•L⁻¹ Na⁺, 300 mOsm•L⁻¹) is a popular sports drink readily available to WLFF. DripDrop (3.4% carbohydrate, 1330 mg•L⁻¹ Na⁺, 235 mOsm•L⁻¹) is a new oral rehydration solution (ORS) that claims greater sodium and water absorption during exercise.

The purpose of this study therefore, was to investigate DripDrop and Gatorade on their ability to affect fat and carbohydrate metabolism during submaximal exercise in the heat.

Methods

Male subjects were voluntarily selected providing they met inclusion criteria (18-35 years old, $VO_2 \geq 45 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) set prior to recruitment. Before testing, each subject agreed to and signed an informed consent form approved by the University of Montana Institutional Review Board. Each subject was paid for their time following completion of the last trial. Subjects participated in a preliminary visit in which $VO_{2\text{max}}$ and hydrostatic body composition tests were performed. Then, each subject participated in two subsequent trials, each separated by two weeks to avoid heat acclimation affects. Each trial began with a bladder void and urine collection, a nude body weight, fasted blood glucose, hematocrit, hemoglobin, and resting heart rate. Following baseline data collections, the subjects were put in a heat chamber at 39°C and 30% relative humidity. (see figure 1)

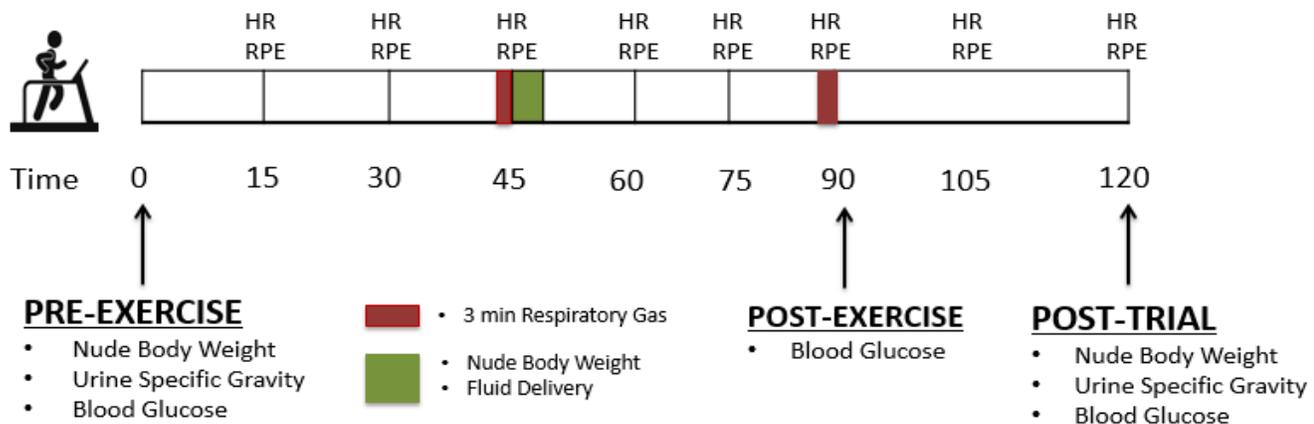


Figure 1: Schematic of Heat Stress Trial protocol for two sessions.

In the chamber, the subjects performed a 45-minute bout of treadmill walking at a speed of 3.0 miles per hour and at a grade calculated to elicit 50% of subject's $VO_{2\text{max}}$. Heart rate (HR) and rate of perceived exertion (RPE) were recorded every 15 minutes. A metabolic cart was used to collect respiratory gases during the final 3 minutes of the 45-minute bout. At this time subjects were weighed nude and then returned to the heat chamber. Subjects were given a bolus of either Gatorade or DripDrop at a volume equivalent to 150% of weight lost during their exercise bout. The subjects returned to the treadmill after 10 minutes of rest and fluid consumption. They performed another 45-minute bout on the treadmill with the same criteria as the first bout. Following completion of the second bout, subjects sat in a chair inside the heat

chamber for an additional 30 minutes. HR, RPE, hematocrit, hemoglobin, and blood glucose measurements were collected before and after the 30-minute rest period. After 30 minutes of rest in the heat, urine was collected as well as nude body weight. Each subject performed an identical trial two weeks later, however consuming a different beverage. Data was analyzed using analysis of variance (ANOVA) with significance set at $p < 0.05$.

<i>Characteristics</i>	<i>Mean ± SEM</i>
Age (years)	22.5 ± 1.2
Weight (kg)	82.2 ± 3.2
Height (cm)	182.1 ± 2.9
Body Fat (%)	14.2 ± 1.7
VO ₂ max (ml*kg ⁻¹ *min ⁻¹)	53.9 ± 1.9

Table 1: Subject Characteristics (N=10).

Results

Rate of Perceived Exertion: There was a significantly lower RPE 15 and 30 minutes post-exercise (8.0 ± 0.6 and 6.7 ± 0.3 vs 10.4 ± 1.1 and 8.1 ± 0.8) for Gatorade than DripDrop ($p = 0.015$).

Heart Rate: Time had a significant effect on HR (142.5 ± 6.3 at 15 min, vs 175.4 ± 4.7 b•min⁻¹ at 90 min; $p < 0.001$).

Hemoglobin: Hemoglobin was also significantly effected by time post-trail (15.8 ± 0.4 vs 16.3 ± 0.4 g•dL⁻¹; $p < 0.01$).

Plasma Volume: No significant difference between trials ($p = 0.4$).

Urine Specific Gravity: No significant difference between trials ($p = 0.8$).

Urine Volume: No significant difference between trials ($p = 0.5$).

Sweat Rate: No significant difference between trials ($p = 0.9$).

Percent Dehydration: No significant difference between trials ($p = 0.8$).

Ventilation (V_E): Gatorade (72.1 ± 8.4 L•min⁻¹) and DripDrop (69.4 ± 7.5 L•min⁻¹) showed no significant difference ($p = 0.5$).

Oxygen Consumption (VO₂): There was no significant difference in VO₂ between beverages ($p = 0.3$). Gatorade trials yielded averages of 2.4 ± 0.1 L•min⁻¹ while DripDrop yielded averages of 2.4 ± 0.2 L•min⁻¹.

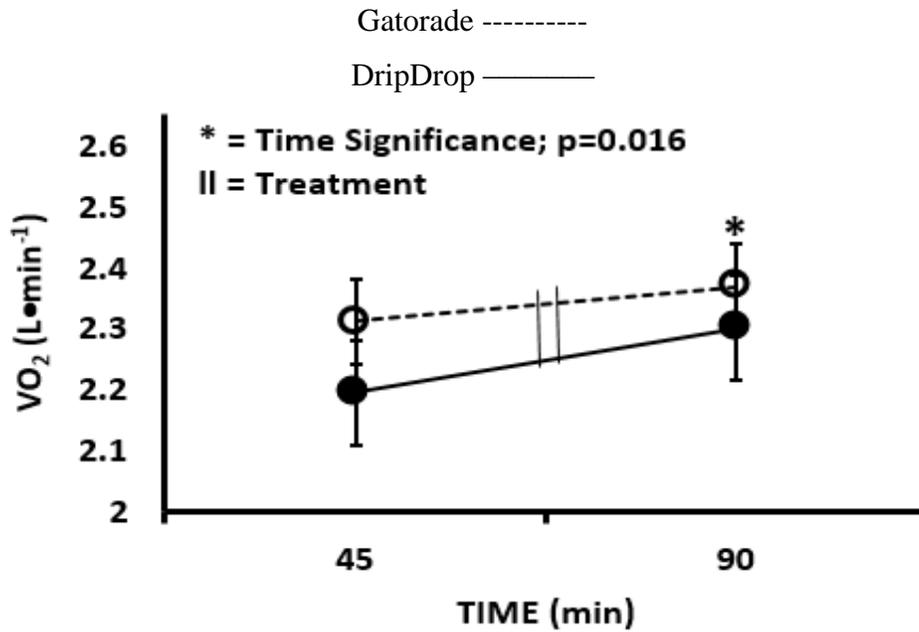


Figure 2: VO₂ during heat stress trial.

Carbohydrate Oxidation: The rate at which carbohydrates were oxidized was similar between beverages ($p = 0.2$). Gatorade trials averaged $2.1 \pm 0.2 \text{ g}\cdot\text{min}^{-1}$, and DripDrop trials averaged $1.8 \pm 0.2 \text{ g}\cdot\text{min}^{-1}$.

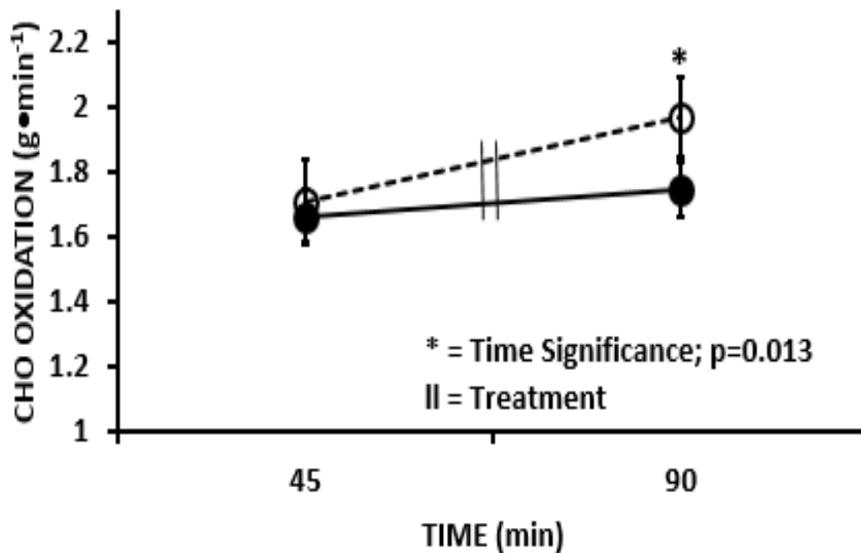


Figure 3: Carbohydrate oxidation during heat stress trial.

Fat Oxidation: Gatorade ($0.38 \pm 0.03 \text{ g}\cdot\text{min}^{-1}$) did show a significant decrease in fat oxidation ($p = 0.049$) compared to DripDrop ($0.47 \pm 0.05 \text{ g}\cdot\text{min}^{-1}$).

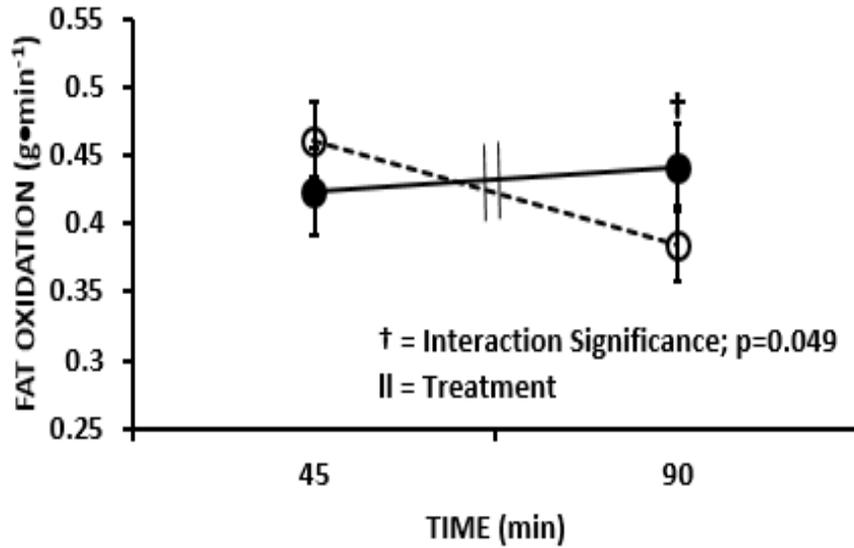


Figure 4: Fat oxidation during heat stress trial.

Respiratory Exchange Ratio: There was also a significant difference in RER ($p = 0.04$) between Gatorade (0.89 ± 0.02) and DripDrop (0.87 ± 0.01).

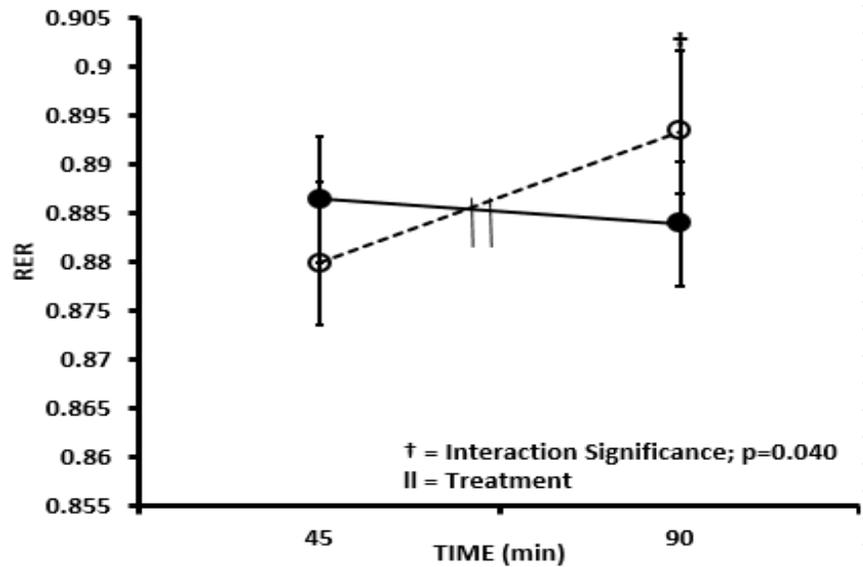


Figure 5: Respiratory exchange ratio during heat stress trial.

Blood Glucose: A significant difference in blood glucose post-trial was found, $p = 0.01$.

Gatorade yielded an average blood glucose of $116.0 \pm 5.7 \text{ mg}\cdot\text{dL}^{-1}$ while DripDrop yielded an average of $103.1 \pm 3.9 \text{ mg}\cdot\text{dL}^{-1}$.

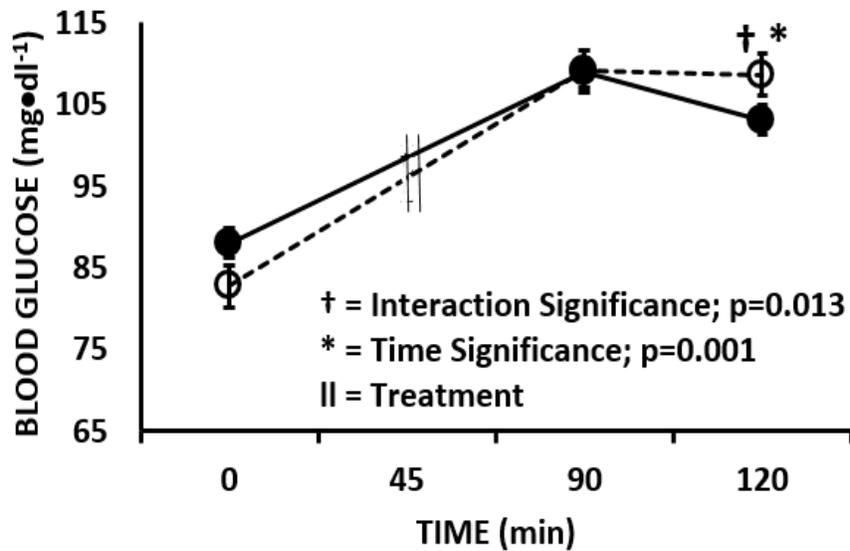


Figure 6: Blood glucose during heat stress trail.

Discussion

Small, frequent boli of sports drink is better for gastrointestinal absorption than a single large bolus.² Had we administered several smaller doses of the drinks throughout the exercise bouts, there is evidence to suggest we may have found better rehydration results from either drink. However, we wanted to simulate the day-to-day habits of WLFF. They don't have the convenience of consuming hydrating fluids frequently throughout their shift as they cannot always carry fluids in the field. By administering one bolus half way through the exercise bout, we are simulating a WLFF who is on his/her rest or lunch break, consuming copious amounts of fluid midway through their shift. The amount of fluid consumed was set at 150% of weight lost during the first 45 minutes because we wanted to ensure maximal rehydration. Research shows that 150-200% is an optimal volume for rehydration.⁴

There were anecdotal reports of gastrointestinal distress following consumption of DripDrop. Although the volume itself is enough to cause GI distress, the high sodium concentration, and low carbohydrate concentration in DripDrop may have slowed gastric emptying leading to nausea during exercise. Although we were not able to add a GI distress scale to our list of evaluation parameters, if DripDrop does cause gastric discomfort, caution is warranted for use on firefighters.

Conclusion

Following the consumption of a bolus of Gatorade, RER increased and fat oxidation was reduced compared to a bolus of DripDrop. Blood glucose, when measured post-trial, was greater following ingestion of Gatorade. These data may prove critical for WLFF during extended periods of work in the field.

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