WATER VERSUS AN ELECTROLYTE-CARBOHYDRATE REPLACEMENT IN THE INDUSTRIAL ENVIRONMENT

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INTRODUCTION

Prolonged exposure to work in a warm environment leads to progressive water and electrolyte loss from the body as sweat (1). In this situation, subsequent dehydration and thermoregulatory problems may produce fatigue (2). Bishop observed that simulated industrial work conditions produced mean sweat rates (n = 50) of 2.25 $L \cdot h^{-1}$ (3). At high levels of sweat production, workers can quickly dehydrate (4). Since hyperthermia, dehydration, and glycogen depletion impairs performance, proper fluid replacement is essential (2). However, voluntary dehydration due to inadequate thirst drive has been well documented and is a major cause of thermoregulatory impairment and heat related injury (5,6,7,8). Thus, maintenance of the drinking response is important.

The majority of hydration studies have been aimed at the athletic competitor and not the industrial worker. Clapp showed that in a simulated industrial situation, workers wearing impermeable protective clothing consumed smaller amounts and experienced greater weight loss when provided water (W) versus an electrolyte-carbohydrate (ECHO) beverage when drinking *ad libitum* (9). Industrial workers, as compared with the athlete, operate at a lower metabolic rate, work more frequently and endure longer periods of work. Many industrial workers wear protective clothing that restricts thermoregulation, increases body temperatures and increases sweat rates.

Optimal rehydration can be enhanced by a fluid that is both beneficial and appealing (9,10). However, the relative importance of flavor or composition and its role in the stimulation of voluntary drinking over prolonged periods in industrial situations is unknown (8). The purpose of the present study was to: (1) Compare the rate of rehydration during simulated industrial work between W and a commercially-available ECHO beverage in repeated trials, (2) Examine the physiological effects of dehydration and (3) Assess taste preference changes over 4 hours of work.

MATERIALS AND METHODS

This laboratory study examined palatability and drinking rate in 12 subjects wearing impermeable protective clothing (PC) working in 2 identical simulated industrial trials at a fixed WBGT temperature of 33°C (± 0.6). Subjects ranged in age from 19 to 32 with mean age of 24.5 years (± 3.0), mean weight of 81.9 kg (± 6.7), and mean height of 180.0 cm (± 8.3). Subjects performed 2 work trials 1 week apart and were advised to report rested and well hydrated. Protocols consisted of 12 min of walking at 3 mph and at a grade that elicited a metabolic rate of 330 $Kcal \cdot h^{-1}$ (oxygen uptake of 1.1 $L \cdot min^{-1}$) and 3-min arm curls with an 11.5 kg curl bar at a rate that elicited a metabolic rate of 180 $Kcal \cdot hr^{-1}$ (0.6

L·min^{-1}) repeated twice for a total of 30 min. The time-weighted mean workload for this work regimen was 300 Kcal·h^{-1} (moderate work in the industrial setting). Each 30-min work phase was followed by 30 min of seated rest in which the subjects were allowed to remove their gloves, mask, and Saranex 23-P 1-piece impermeable coveralls with hood, which was lowered to knee level. While seated, a 2.5-m·s^{-1} breeze from a 36" barrel fan was provided. Subjects performed up to four 1-h phases.

Subjects completed a palatability taste test prior to the series of work/rest cycles and immediately following the series of work/rest cycles. They rated 5 different commercially available fruit punch ECHO beverages as displayed in Table 1, utilizing a 9-point hedonic scale. They sampled 20 ml of each beverage

Table 1. Components of beverages sampled

Beverage	Sodium	Potassium	Kcal	Sugars	Total Carbohydrates
Drink#1	110 mg	30 mg	50	14 g	14 g
Drink#2	55 mg	30 mg	70	15 g	19 g
Drink#3	55 mg	50 mg	70	19 g	20 g
Drink#4	55 mg	45 mg	50	14 g	14 g
Drink#5	50 mg	30 mg	50	14 g	14 g

(random order). After each sample they would rate the taste on 2 aspects: flavor and overall acceptance. A rating of 1 indicated "extremely dislike," 5 "neutral" and 9 "extremely like." Subjects were weighed in their underwear and then again fully clothed. They were instrumented with a rectal thermistor, a heart rate monitor, and 3 skin thermocouples. Subjects wore a T-shirt and jeans under a Saranex 23-P 1-piece impermeable coverall (with hood) with glove liners, a full-faced respiratory protective mask, Tyvek shoe covers and nitrile over-gloves. In one session, subjects were provided lime-colored W, in another they were provided a lemon-lime ECHO beverage (Sqwincher Corporation; Columbus, MS). The beverages were served at 6-9°C by means of non-dilutional reusable ice container positioned within reach at all times. All fluids in and all voids were measured. Upon completion of the test, subjects were removed from the environment and weighed both clothed and undressed. Sweat production, fluid loss and weight changes were calculated from the difference between the clothed and unclothed weights (pre minus post). A repeated measures ANOVA was performed to analyze changes.

RESULTS

Body fluid losses through sweat and urine were similar between the 2 trials, 765 (± 306) ml for the W and 811.8 (± 258) ml for the ECHO ($P > 0.05$). Mean changes as a percent of total body weight (pre minus post) for W was 0.93

(± 0.13) and -0.02 (± 0.14) percent for the ECHO ($P < 0.05$). Mean voluntary consumption during work at 33°C WBGT was 673 (± 210) ml·h^{-1} for the W and 772 (± 258) ml·h^{-1} for the ECHO trial ($P < 0.05$). Elevated core temperatures resulted in mean work stoppage at min 203 (± 31.2) for the W and at min 203 (± 40.3) for the ECHO ($P < 0.05$). Mean changes in heart rate (HR) following the final work phase were significantly higher during W, 150 (± 26.4) bpm as compared with 140 (± 29.4) bpm during the ECHO ($P < 0.05$). Tsk observed following the final work phase were significantly higher during the W (37.6 ± 0.5) as compared with ECHO (37.3 ± 0.5). Mean flavor ratings for Drink#4 were consistently higher than that of the other ECHO beverages ($P < 0.05$). Mean overall acceptance ratings for Drink#4 were consistently higher than for the other ECHO beverages ($P < 0.05$). For flavor and acceptance, the mean scores for Drink#4 fell somewhere between 6 (slightly liked) and 7 (moderately liked) while the remaining beverages mean scores were closer to 5 (neither liked nor disliked).

DISCUSSION

The results of this study were consistent with those previously reported (9,11,12). However, previous research had examined groups of industrial workers, or individuals engaged in rigorous exercise in the heat. This study focused on rehydration following repeated trials in a simulated industrial setting. Subjects lost more weight during work with W (0.46 kg) than with ECHO (0.2 kg). For the first 3 work periods of both trials, subjects produced identical HR responses and HR recovery levels. During the 4th work period of W, HR was higher and had a greater change following the recovery period. It is important to acknowledge that half of the subjects were unable to work into the 4th work phase and the sample size had been reduced (n = 6). Subjective responses were not significantly different for RPE, wetness sensation and thermal sensations ($P > 0.05$). It has been recommended by organizations such as The National Athletic Trainers Association and the American College of Sports Medicine that fluid ingestion during work should provide a source of carbohydrate, water and electrolytes to replace the losses incurred by sweating (11,12). The mounting evidence suggests that subjects prefer a flavored, sweetened, beverage over plain water and thus, will consume greater quantities of fluid and mitigating dehydration (5,6,7,8,9,10).

There were no significant changes in the palatability of the 5 beverages pre- to post-work. However, there were significant differences among the 5 beverages. Drink#4 was rated significantly higher in flavor than the other 4 beverages. Drink#4 was also rated significantly higher in overall acceptance than Drinks#1, 3 and 5 ($P = 0.03$) but was not significantly higher than Drink#2 ($P = 0.06$). Drink#4 was the commercially available fruit-punch flavored ECHO provided by the Sqwincher Corporation. The contribution of palatability to hydration maintenance is presently unclear. Palatability contributes to fluid ingestion but the relative importance of osmolality and sweetness remains to be elucidated. Future studies with additional controls and comparisons are needed.

CONCLUSIONS

The intent of an ECHO beverage is to promote fluid rehydration to enhance performance. In this study of *ad libitum* consumption during simulated industrial work, subjects consumed greater quantities of ECHO than W. The use of an ECHO beverage may have maintained the osmotic thirst drive while encouraging greater fluid ingestion compared to water alone. This should enhance worker safety. Cumulative effects across sequential days of work should be investigated.

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