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Original Research

Hydration Efficiency of a Protein Beverage Consumed in a Bolus vs. Metered Pattern during Recovery

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ABSTRACT

International Journal of Exercise Science 13(2): 1476-1486, 2020. This study compared hydration efficiency of a carbohydrate-protein (CHO-PRO) beverage consumed in a bolus (BOL) vs. a metered (MET) drinking pattern during recovery from exercise induced hypohydration. Participants (n = 10) lost 2 - 2.5% of body mass from sweating during a morning exercise session. Participants were then assigned to either consume a carbohydrate/electrolyte/protein beverage in a bolus (BOL) or metered incremental consumption (MET) (counterbalanced) pattern post exercise. Total rehydration beverage administered during recovery equaled 125% of fluid lost during exercise. BOL was administered within the first hour of recovery, MET was administered 25% during the first 30 min, then 12.5% every 30 min for the next 4 hours. Mean (±SD) intake was 2475 ± 324 mL (MET) and 2525 ± 293 mL (BOL) (p = 0.22). Mean urine production was significantly greater for BOL (1167 ml ± 293 ml) than MET (730 ml ± 324 ml) (p = 0.003). Hydration efficiency (fluid ingested vs. fluid retained as percent) was significantly greater for MET (69.1 ± 15.4) than BOL (53.7 ± 9.7) (p = 0.004). Results indicate that, across a ~ 6-hour recovery, a metered drinking pattern improves fluid retention and therefore, hydration efficiency when a carbohydrate-protein beverage is consumed. More research is needed in paradigms characterized by unlimited fluid availability.

KEY WORDS: Fluid retention, post workout fluid recovery patterns

INTRODUCTION

According to the National Athletic Training Association position stand, replacing fluids post-exercise is critical to rehydration. Additionally, insufficient fluid consumption or poor fluid retention may contribute to hypohydration post-exercise (4). When fluid supply is limitless during recovery, consuming fluid volumes greater than what was lost is recommended to optimize rehydration efforts (14). The National Athletic Trainers' Association guidelines recommend consuming 1.5 L of fluid per kg of bodyweight lost over time (4). However, in some situations, fluid availability may be limited, and it is comparatively more important to optimize rehydration efforts by enhancing fluid retention in these paradigms.

Previous research (14) indicated that beverage composition and volume are important to efficacy of rehydration; however, drinking patterns may be just as critical but have not been investigated in depth. Jones et al. (8) examined hydration efficiency (percent fluid retention) during recovery. After 2% body mass exercise-induced hypohydration, participants consumed water in a metered or incremented (8 servings of 12.5% across 4.5 hr) vs. bolus (100% consumed in 1 hr after exercise) pattern. The metered approach resulted in significantly greater hydration efficiency (75%) vs. the bolus (large dose) approach (55%) during an 8-hr recovery period, suggesting a metered drinking pattern is superior when volume consumed equals 100% of that which is lost (8). Kovacs et al, (9) compared a high drinking rate (60%, 40%, and 20% over 3 hr) vs. a low drinking rate (24% every hr over 5 hr). In both patterns the amount of administered fluid had to be consumed within 20 mins of the hr. Results indicated no significant difference in net fluid balance and rehydration levels between high (82 ± 5%) and low (79 ± 6%) drinking patterns. To optimize hydration, the use of protein and carbohydrate may be beneficial to increase fluid intake and retention.

The benefits of adding protein to a carbohydrate beverage on subsequent performance remain unclear. Studies have found the addition of protein to a recovery beverage enhanced performance (cycling, running) when two beverages were matched for carbohydrate content (2,13). In contrast, Highton et al. (6) found no significant difference between intermittent sprint performance when recovery involved consumption of a 6% carbohydrate + 2% protein beverage vs. 8% carbohydrate. While performance effects are equivocal, recent evidence suggests the addition of protein to fluids may improve rehydration efficiency. Researchers (17) compared a carbohydrate beverage, a carbohydrate-protein beverage (similar Na^+), and water for fluid retention over a 3 hr period. The carbohydrate-protein beverage (CP) resulted in significantly greater fluid retention (88.0 ± 4.7 %,) vs. carbohydrate (CHO) (74.9 ± 14.6 %,) and water (WA) (53.2 ± 16.1%). Participants consumed 100% of volume lost during exercise (WA lost 1.73 ± 0.68 kg, CP 1.73 ± 0.66 kg, and CHO 4.66 ± 0.52 kg) within 20 min of exercise cessation (i.e. a 'bolus' approach). Similarly, other researchers studied the effect of milk protein concentration on rehydration after exercise in the heat (7). Participants consumed 150% of fluid losses within 1 hr of exercise completion. Results showed a beverage containing 2% carbohydrate and 4% protein or another with 4% protein and 2% carbohydrate both resulted in lower urine output and greater net fluid balance after 4 hr vs. a 6% carbohydrate only beverage. Research indicates the addition of protein to a recovery beverage improves fluid retention, but more work is needed to determine whether a metered vs. bolus rehydration pattern of drinking can further improve hydration efficiency of such beverages. Therefore, this study assessed hydration efficiency of a CHO-PRO beverage consumed in a bolus vs. metered pattern during 6 hr recovery following exercise-induced hypohydration.

METHODS

Participants

Aerobically fit men, according to ACSM guidelines, (1) (n = 10), (age 23.7 ± 2.6 y), height (178 ± 7 cm), body mass 84.3 ± 11.6 kg) and body fat (11.4 ± 4.7%) volunteered as participants. A power analysis for hydration efficiency using alpha = 0.05, beta = 0.8, a standard deviation of 10 and an effect size of 8%, indicated 10 participants were needed. All procedures were approved in accordance with the local institutional review board prior to data collection and written consent was obtained from each participant prior to data collection. This research was carried out in accordance to the ethical standards of the International Journal of Exercise Science (11). Participants completed a Physical Activity Readiness Questionnaire (PAR-Q) (3) and health status questionnaire before testing. Only 'low risk' individuals (based on known risk factors) were permitted to serve as participants. Height to the nearest cm and mass to the near 0.1 kg was assessed with a stadiometer (Detecto, Webb City, MO) and digital scale (Tanita Corporation, Japan). Body fat percentage was estimated using Lange skin calipers (Cambridge, Maryland) and a 3-site method (chest, abdomen, and thigh) (12).

Participants recorded food and fluid intake 18 hr prior to the first hypohydration trial and replicated these prior to the second trial. In addition to voluntary fluid intake, participants were instructed to drink 1000 mL of water the evening before each trial (500 mL ~1800 hr + 500 mL ~2100 hr) to ensure euhydration upon reporting to the lab the mornings of testing. Participants abstained from any fluid or food outside except that provided on the day of testing and abstained from strenuous exercise on the day before and the day of testing.

Protocol

On arrival to the laboratory (~0800), participants consumed a breakfast bar (Kellogg's NutriGrain), 354 mL of sports beverage (Accelerade, Pacific-Health Labs, Matawan, NJ) and a banana for breakfast (consistency for the influence of hydration). After consuming this standardized breakfast (~97g of sugar), participants were weighed prior to exercise wearing shorts only. Participants then exercised on an outdoor asphalt track immediately outside the laboratory (initiated approximately 15 min after pre-exercise meal). Participants were instructed to run at a self-selected comfortable pace they felt they could continue for up to 120 min. After 45 min, and every 15 min thereafter, participants stopped, dried themselves with a towel, and were weighed wearing shorts only until 2-2.5% hypohydration was achieved. To hasten fluid loss, participants had the option to wear an impermeable sweat suit during exercise (replicated within participants). Once a body mass loss equal to 2.0% was achieved, exercise was terminated, and participants began one of two rehydration trials (described below). One hr following exercise termination for both trials, participants received a peanut butter and jelly sandwich with a 1 oz. serving of potato chips (Frito Lay).

Subjects ingested a carbohydrate/electrolyte/protein beverage (CHO-PRO) containing 6 g carbohydrate, 1.5 g protein, 53 mg sodium, and 18 mg potassium per 100 mL (Accelerade, Pacific-Health Labs, Matawan, NJ) in a bolus or metered approach (counterbalanced). BOL equaled 125% of fluid lost consumed within 60 min of exercise termination. MET consisted of

25% consumed within the first 30 min, then 12.5% every 30 min thereafter for 4.5 hr (totaling 125% of fluid lost). Each trial was conducted approximately the same time of day with minimum 48 hr recovery between BOL and MET. Participants remained in the lab for ~30 min following exercise termination for assessment of weight.

Following 30 min recovery, participants left the laboratory and collected all of their urine voids for the next 6 hr of daily living in 4 urine collection containers to asses fluid retention and hydration efficiency. Urine voids within the first 1.5 hr and each subsequent 1.5 hr period were collected in a labeled container. Participants verbally acknowledged full integrity of the collection of their urine voids post exercise trial. Every 30 min after exercise termination participants estimated stomach discomfort by marking on a 10 cm scale and estimated their feelings of thirst using a 10-point thirst scale (5) during the 6 hr recovery period.

At the conclusion of each rehydration period, participants reported back to the laboratory to return urine collection containers and be assessed for fluid loss. A final void was taken, and subjective thirst and stomach discomfort ratings were also recorded.

Statistical Analysis
A paired t-test was used to compare hydration efficiency and fluid intake for MET vs. BOL. Urine volume was compared using a 2 (trial) x 4 (time point) repeated measures ANOVA. Paired T-tests were used at specific time points as follow up tests when appropriate. Stomach discomfort and thirst sensation were analyzed using independent 2 (trial) x 11 (time point) repeated measures ANOVA with paired t-tests as follow ups when appropriate. Alpha was set at $p \leq 0.05$ to establish significance.

RESULTS

Mean weight loss among participants was 2.0 ± 0.3 kg. Mean fluid intake for BOL (2525 ± 293 ml) and for MET (2475 ± 324 ml) were not significantly different. There was a significant trial x time point interaction for urine volume. Follow up tests showed significantly higher urine volume at time points; other time points were not significantly different (Table 1). Mean urine production for BOL (1129 ± 164 ml) was significantly higher than MET (865 ± 190ml) (Figure 1). Mean hydration efficiency was significantly lower for BOL (53.7 ± 10.2%) vs. MET (69.07 ± 16.3%) (p = 0.004) (Figure 2). For thirst sensation there was a significant trial x time point interaction. Follow up tests showed significantly greater thirst sensation for time points 1-4 for MET but significantly greater for BOL at time points 9 and 10 (Figure 3). There was a significant trial x time point interaction for stomach discomfort. Follow up tests showed significantly greater stomach discomfort for BOL at time points 1, 2 and 3 with no significant differences at other time points (Figure 4).

Table 1. Urine volume (ml) after four void attempts over 6 hr.

		Bolus					Metered				
		Void 1	Void 2	Void 3	Void 4	Total	Void 1	Void 2	Void 3	Void 4	Total
ID1	volume	105	416	286	116	923	0	136	522	224	882
ID2	volume	72	274	150	266	762	0	162	352	192	706
ID3	volume	0	432	272	386	1090	0	0	276	0	276
ID4	volume	0	640	310	176	1126	0	0	708	1602	2310
ID5	volume	120	722	272	106	1220	66	0	150	460	676
ID6	volume	126	886	408	0	1420	0	228	0	192	420
ID7	volume	54	488	600	474	1616	0	180	0	920	1100
ID8	volume	230	242	330	370	1172	138	120	0	592	850
ID9	volume	278	364	0	184	826	0	144	0	0	144
ID10	volume	187	602	218	130	1137	0	370	428	488	1286
	mean	117.2	506.6	284.6	220.8	1129	20.4	134	243.6	467	865
	SD	92.6	204.3	156.8	149.2	259	46.2	116.2	255.2	489.4	618
	p-value	0.006	0.0006	0.696	0.147	0.22					

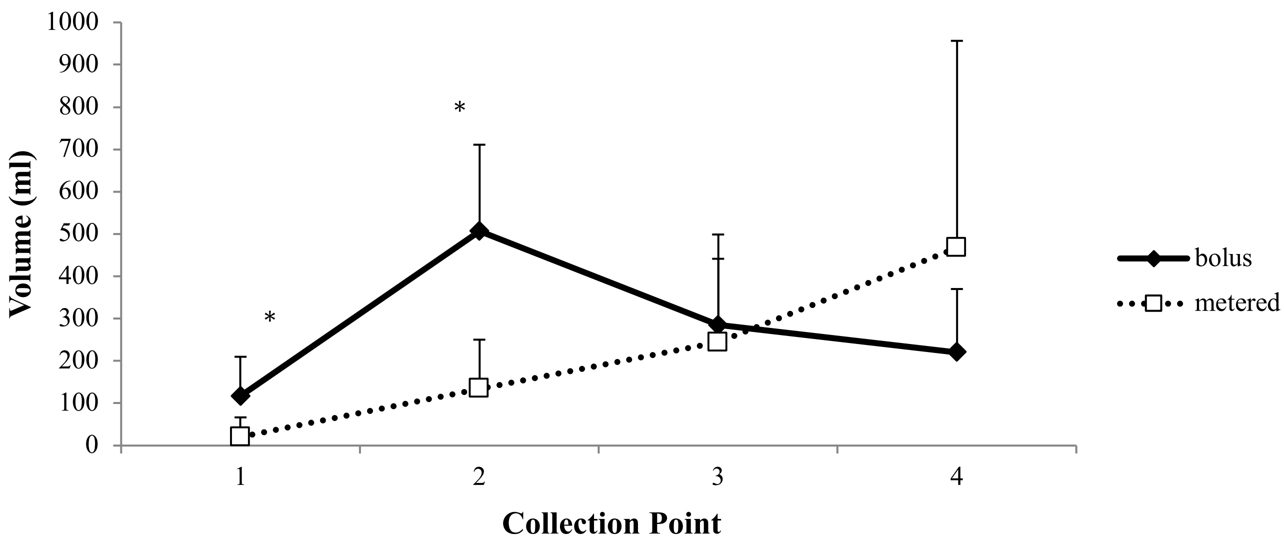

Figure 1. Mean Urine Output– an average of urine output for bolus and metered are represented at each of the four time points during recovery. * $p \leq 0.05$ MET vs. BOL

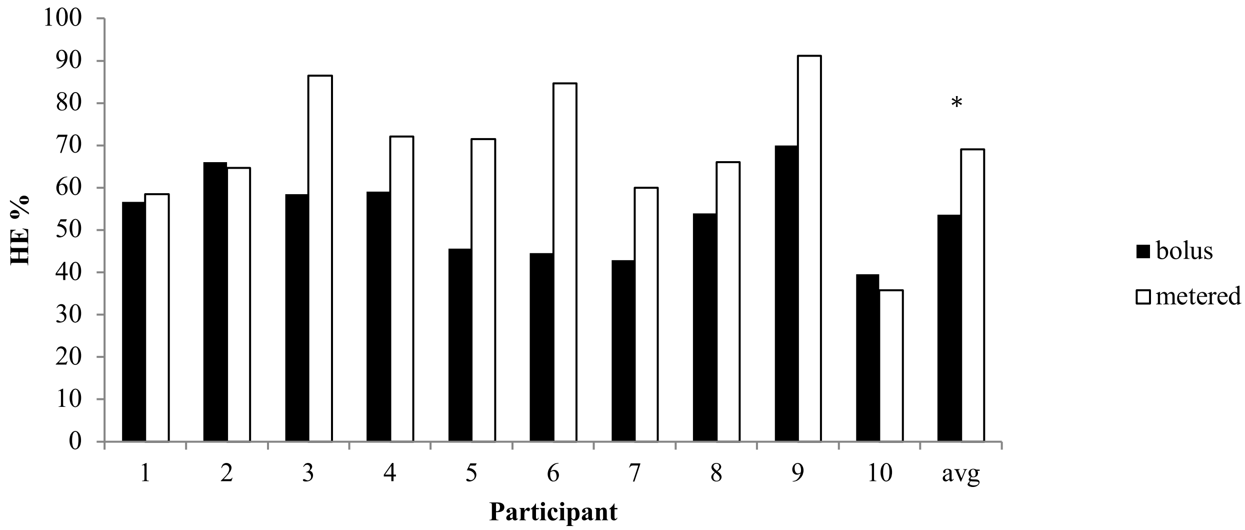

Figure 2. Hydration efficiency for each individual and group data calculated at the end of recovery (6 h). * $p \leq 0.05$ MET vs. BOL

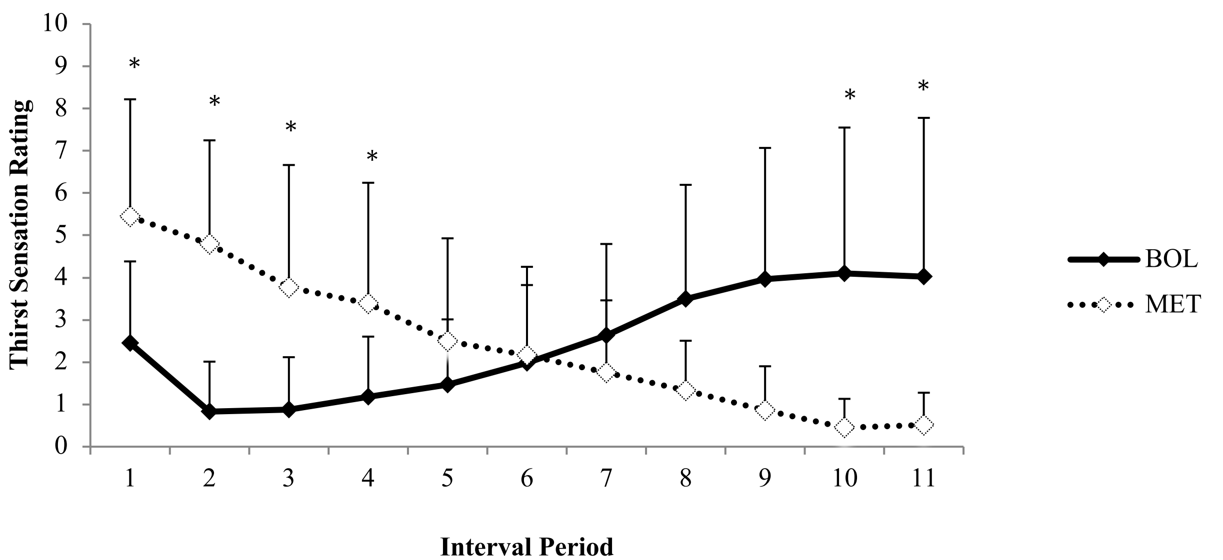

Figure 3. Thirst Scale – an average was recorded at each time point. Thirst scale was assessed every 30 minutes during recovery. Greater value reflects greater thirst. * $p \leq 0.05$ MET vs. BOL

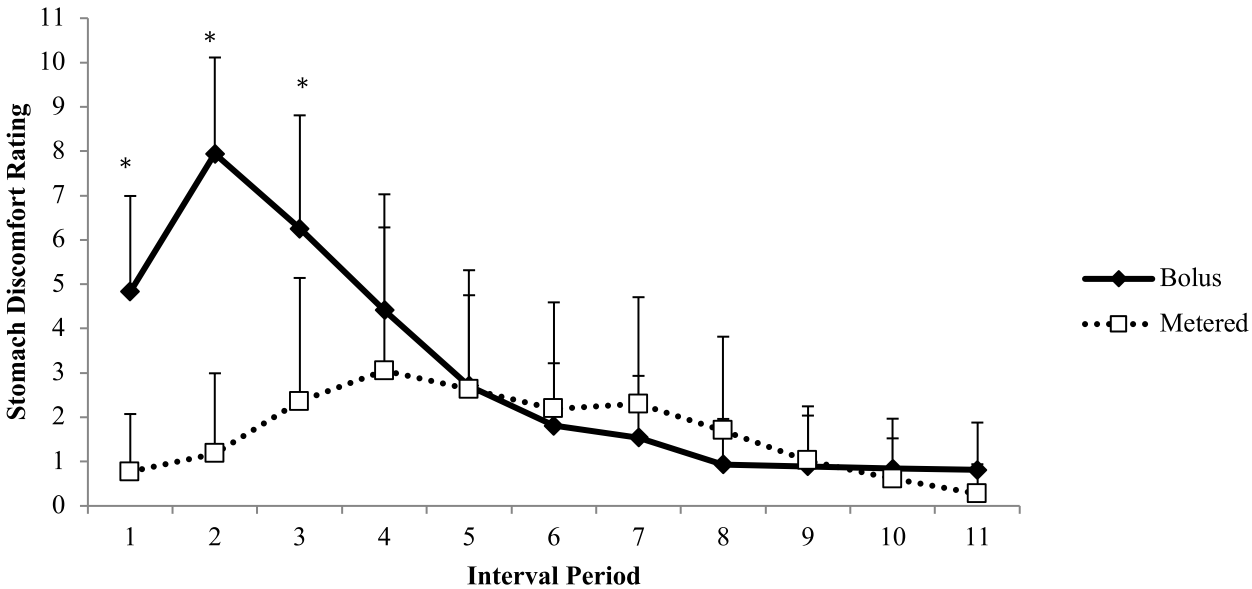

Figure 4. Stomach Discomfort Scale - an average was recorded at each time point. Stomach discomfort was assessed every 30 minutes during recovery. Greater value reflects greater discomfort. * $p \leq 0.05$ MET vs. BOL

DISCUSSION

Hydration Efficiency: This study compared hydration efficiency of a CHO-PRO beverage consumed in a BOL vs. MET pattern during 6 hr recovery from exercise-induced hypohydration of 2-2.5% body mass. Results revealed significantly greater average hydration efficiency for MET vs. BOL, suggesting a CHO-PRO beverage results in greater hydration efficiency if the same volume of beverage is ingested in smaller portions across time rather than a single portion in a shorter time period (Figure 2). This study corresponds with previous results using water as the recovery beverage where drinking pattern was implicated as an important consideration for optimizing rehydration efforts (8). These results are particularly important in situations of limited fluid availability. Within recovery, it is important to consider inter-individual variability. Despite participants consuming fluid relative to body mass loss, some individuals respond better to acute fluid consumption. James et al. (7) found no significant difference between milk proteins of 20g/l and 40g/l suggesting that past a certain point, amount of protein per liter may not be influential in rehydration after exercise. It does reveal that protein is important in rehydration as both doses were superior to carbohydrate alone. Current results and Jones et al. (8) found a metered approach enhances fluid retention.

Jones, et al. (8) found 75% hydration efficiency during MET compared with 55% hydration efficiency in BOL. Siefert et. al (17) compared CHO-PRO beverage, a carbohydrate only beverage and water following 2.5% body weight loss replacing 100%. When comparing current results with those from Jones et. al (8) and Seifert et. al (17), it appears that a large amount of fluid consumed over a short period of time may prompt the kidney to overcompensate and remove what it views (due to the bolus consumption pattern) as excessive fluid (8,17). In other words, urine production is an attempt to correct what is perceived by the kidney (incorrectly) as an excess of fluid. This may impair fluid retention/hydration efficiency and therefore rehydration efforts during recovery. Volume of fluid consumed is important; however, the amount retained is of equal importance as excreted fluid contributes nothing to rehydration efforts. Complete rehydration is achieved when the body's hydration level is restored to the same or greater level prior to subsequent exercise bouts. The kidney's acute hyper-response to a large amount of fluid will impair fluid retention even when the intake has been high thus leading to a miscalculation regarding the effectiveness of recovery hydration efforts.

Previous studies (8) have evaluated various beverages including water with hydration efficiency, however, few studies have addressed the benefit of fluid retention of a carbohydrate protein beverage. Wapnir et al. (18,19) found that proteins aid in absorption of water and sodium in the intestines. Sodium must be sufficient to co-transport amino-acids during rehydration, otherwise the addition of amino acids may result in incomplete absorption. Seifert et al. (17) looked at rehydration after exercise with a carbohydrate + protein beverage during recovery. Current results for a protein beverage were similar to Seifert et al. (17) with a carbohydrate + protein beverage showing fluid retention significantly greater for carbohydrate protein (88 ± 4.7%) than carbohydrate (75 ± 14.6%) and water (53 ± 16.1%). Similar to Kovacs et al. (9), participants in Seifert et. al (17) consumed the fluid within the initial 20 min during recovery. After the first hr of recovery, urine output was greater for water, and less for carbohydrate protein (17). A difference between the current study and Seifert et al. (17) was the participants were given a volume equal to body mass lost whereas in the current study participants consumed 125%. Second, we observed 6 hr whereas Seifert et al. (17) assessed 3 hr of recovery. The current study suggests a volume of 125% of total body weight lost still had an average urine output of 505 ± 153 ml during the last 3 hr of recovery. Longer than 3 hr may be required for the kidneys to process the fluid, otherwise it may lead to an increase in urine production due to over stimulation of the kidneys.

It has been suggested that 150% of ingested fluid is adequate for returning to a euhydrated state (10, 14,15,16). Although, the current study used 125% of body weight lost, which is less than previously published work in returning to a euhydrated state, it should be noted that three participants returned to a euhydrated state during MET. Due to the fact that our study used a carbohydrate protein beverage, it is unclear if the composition of the beverage or the administration of the beverage leads to the euhydrated state at 125% fluid replacement. This warrants further inquiry. It is clear however, that MET (vs. BOL) was superior with regard to hydration efficiency when the recovery beverage contains protein. It was equally clear that inter-individual variability exists with regard to fluid retention across differing patterns of consumption.

Subjective Ratings: Thirst sensation ratings for BOL showed participants were immediately "satisfied" during recovery (Figure 3). This quenched feeling waned across time with ratings reflecting progressively greater thirst (Figure 3) associated with restricted fluid intake and greater fluid loss. For MET, thirst was greater earlier in recovery with smaller fluid volumes. However, greater initial thirst was alleviated across time as fluid was consumed. At the end of recovery, participants reported a higher thirst rating for BOL (Figure 3) even though 125% of fluid lost was consumed. During BOL, participants had a greater fluid deficit coupled with greater thirst which reflects the effectiveness of the thirst mechanism in attempting to prompt fluid intake. As recovery continued, participants' thirst gradually increased as fluid was discarded, and the fluid deficit grew. In situations of limited fluid availability, to optimize rehydration the focus should be on retention of the fluid ingested. Based on current results and Jones et. al (8), avoiding the temptation to overdrink early in the recovery period to satisfy acute thirst and enhance hydration efficiency, the MET pattern is favored when fluid availability is limited. This 'thirst-based' approach more closely mimics a bolus pattern of ingestion, which fails to optimize hydration efficiency and results in greater thirst in later portions of the recovery period again, if fluid availability is limited. Based on the current study, intentionally avoiding the temptation to quench thirst and rather, following a metered approach leads to great fluid retention. It is emphasized again, however that, this recommendation applies only to situations of limited fluid availability. When unlimited fluid is available and thirst sensations are followed, thirst may be acutely quenched with large fluid intake. However, large urine production associated with acute fluid intake will result in elevated thirst across time. The consequence of this may be large fluid intake and large urine production. However, with unlimited fluid availability it is expected the thirst mechanism and healthy kidney function will ultimately result in adequate rehydration given adequate time.

Stomach ratings showed a high level of stomach discomfort during the initial recovery for BOL (Figure 4). The first 3 hr of recovery show a significantly greater discomfort rating for BOL (Figure 4). During MET, stomach discomfort was comparatively lower as fluid was administered in smaller volumes. Stomach discomfort during the terminal portion of recovery was extremely low and similar for both trials. The hyper-response for the kidneys for BOL resulted in increased urine production and was coupled with greater stomach discomfort during early portions of this trial (Figure 1, Figure 4). If fluid is administered in a MET rather than BOL manner, not only is hydration efficiency enhanced but stomach discomfort is mitigated. These benefits outweigh magnified acute thirst associated with a metered drinking pattern.

Conclusions: Current results indicate the pattern in which a CHO-PRO beverage is consumed influences hydration efficiency, stomach discomfort and thirst. A metered consumption pattern resulted in greater fluid retention and hydration efficiency than a bolus pattern. A carbohydrate protein beverage may be superior with regard to fluid retention when compared with other beverages (17), although, the current study did not provide a direct assessment of different beverages. Current results do indicate, for a CHO-PRO beverage, a metered approach enhances hydration efficiency, results in less stomach discomfort and more effectively mitigates thirst when viewed long-term. Large inter-individual variability may be observed with regard to fluid retention and recovery; however, current results show consistently higher hydration efficiency for MET vs. BOL. These results are most important in paradigms characterized by limited fluid availability. More research is warranted regarding optimizing fluid retention by employing varying drinking patterns as well as the influence of beverage composition.

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