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Fluid, Energy and Nutrient Recovery via *Ad Libitum* Intake of Different Commercial Beverages and Food in Female Athletes

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Abstract:

Purpose: This study investigated the effect of consuming different commercial beverages with food *ad libitum* post-exercise on fluid, energy and nutrient recovery in trained females. **Methods:** On 4 separate occasions, 8 females (body mass [BM]: 61.8±10.7 kg; VO_{2max}: 46.3±7.5 $mL\cdot kg^{-1}\cdot min^{-1}$) lost 2.0±0.3% BM cycling at ~75%VO_{2max} before completing a 4 h recovery period with *ad libitum* access to one of 4 beverages: Water, Powerade® (Sports Drink), Up & Go Reduced Sugar™ (Lower Sugar [LS]-MILK) or Up & Go Energize™ (Higher Protein [HP]-MILK). Participants also had 2×15 min opportunities to access food within the first 2 h of the recovery period. Beverage intake; total water/nutrient intake; and indicators of fluid recovery (BM, urine output, plasma osmolality [P_{OSM}]), gastrointestinal (GI) tolerance and palatability were assessed periodically. **Results:** While total water intake (from food *and* beverage) (Water: 1918±580g; Sports Drink: 1809±338g; LS-MILK: 1458±431g; HP-MILK: 1523±472g; *p*=0.010) and total urine output (Water: 566±314g; Sports Drink: 459±290g; LS-MILK: 220±53g; HP-MILK: 230±117g; *p*=0.009) differed significantly by beverage, the quantity of ingested water retained was similar across treatments (Water: 1352±462g; Sports Drink: 1349±407g; LS-MILK: 1238±400g; HP-MILK: 1293±453g; *p*=0.691). Total energy intake (from food *and* beverage) increased in proportion to the energy density of the beverage (Water: 4129±1080kJ; Sports Drink: 5167±643kJ; LS-MILK: 6019±1925kJ; HP-MILK: 7096±2058kJ; *p*=0.014). **Conclusion:** When consumed voluntarily and with food, different beverages promote similar levels of fluid recovery, but alter energy/nutrient intakes. Providing access to food and understanding the longer-term dietary goals of female athletes are important considerations when recommending a recovery beverage.

Key words: Exercise Nutrition; Exercise Recovery; Hydration; Female Athlete; Eating Behavior

1.0. Introduction

Athletes regularly complete competitive events and training sessions that result in substantial sweat loss (O'Neal et al. 2012). Typically, the quantity of fluid consumed during exercise is inadequate to replace these losses (Garth and Burke 2013). Hence, individuals often finish activity in a state of body water deficit (dehydration). Exercise may also be accompanied by the depletion of endogenous substrate stores and damage to skeletal muscle tissue (Moore 2015). Nutritional strategies that maximize recovery ahead of a subsequent exercise session are, therefore, important. Given the frequency with which athletes train, acute recovery strategies also have the potential to influence chronic nutrient/exercise interactions (e.g. metabolic adaptation and body composition changes). Hence, nutritional recovery recommendations should align with an athlete's broader dietary goals.

Nutrient recommendations designed to optimize recovery after exercise have been published by the American College of Sports Medicine and the Academy of Nutrition and Dietetics (Sawka et al. 2007; Thomas et al. 2016). These recommendations encourage individuals to ingest fluid (i.e. 1.25–1.50 L·kg BM lost^{-1}) to restore euhydration and consume carbohydrate (CHO) and protein to promote glycogen and muscle protein synthesis. Recent meta-analyses also highlight the importance of fluid and CHO intake between consecutive exercise sessions to enhance performance on the subsequent task (McCartney et al. 2017; McCartney et al. 2018). Given their ability to deliver both fluid *and* nutrients, beverages have received considerable scientific attention in regard to their influence on recovery.

Most studies investigating the effect of beverage type and composition on fluid recovery following exercise have employed "prescribed" drinking protocols, where participants consume a fixed quantity of fluid at a predetermined rate. Findings generally indicate that beverages with complex nutritional profiles (i.e. milk/milk-based formulations) are more effective rehydration agents than beverages with basic nutritional profiles (i.e. water and sports beverages) (Shirreffs et al. 2007b; Watson et al. 2008; Desbrow et al. 2014; Seery and Jakeman 2016). In addition to fluid, these beverages also typically provide additional CHO and protein, making them ideal candidates to aid post-exercise recovery. However, other factors such as thirst, palatability and gastrointestinal (GI) tolerance, which are likely to influence the volume of fluid consumed in practice, are overlooked in studies where fluid intake is prescribed. A small body of research investigating *ad libitum* fluid consumption behavior suggests that individuals may consume different fluids in different quantities post-exercise (Nose et al. 1988; Wemple et al. 1997; Evans et al. 2009a; Park et al. 2012; Baguley et al. 2016), influencing their effectiveness as a recovery option. In addition to "prescribing" drinking, many studies also deny participants access to food: an approach with limited ecological validity. Findings from studies that have allowed participants to eat as part of the experimental protocol generally suggest that co-ingesting food and fluid improves rehydration, such that the magnitude of difference between beverages with different nutrient profiles (i.e. in terms of their potential to rehydrate) is attenuated (Maughan et al. 1996; Brouns et al. 1998; Ray et al. 1998; Jones et al. 2010; Pryor et al. 2015; Campagnolo et al. 2017; Evans et al. 2017). Still, most studies have prescribed a small number of food items that may not reflect the participants' usual dietary behavior.

To date, one only study (Campagnolo et al. 2017) has investigated the ability of different beverages to rehydrate participants when the drink *and* a variety of foods are consumed *ad libitum* post-exercise. The study, which involved 10 endurance-trained males, demonstrated that fluid recovery was *similar*, regardless of the type of beverage consumed. This suggests that, with the co-ingestion of food, fluid restoration following exercise may not be influenced by beverage choice. The type of beverage did, however, affect nutrient intake during the post-exercise period. Specifically, the provision of a sports beverage or a milk-based formulation increased total (i.e. food *and* beverage) energy (~2500 kJ) and CHO (~200 g) intake compared to water; the milk-based formulation also increased total protein consumption (~70 g) compared to the other beverages. Hence, the choice of post-exercise beverage may affect aspects of recovery and the suitability of certain beverages for athletes with specific dietary goals. Different energy and nutrient requirements, dietary preferences and motives influencing food choice have the potential to limit the generalizability of previous results. Indeed, it is currently unclear if these effects persist in trained females, who may exhibit contrasting dietary behaviors (Leblanc et al. 2015). Furthermore, it remains unclear how beverages with similar sensory characteristics (i.e. taste, aroma, appearance) but with contrasting nutrient profiles affect fluid, energy and nutrient recovery following acute exercise, when consumed *ad libitum* and when access to food is provided.

This study aimed to investigate the effect of consuming different commercial beverages (including milk-based beverages with contrasting formulations) with food *ad libitum* post-exercise on fluid, energy and nutrient recovery in active female subjects. We hypothesized that, when consumed voluntarily and with food, these beverages would result in similar levels of fluid recovery, but different energy/nutrient intakes.

2.0 Materials and Methods

2.1 Participant Characteristics

Female cyclists/triathletes (≥3 h cycling·week^{-1}) aged 18–45 y were eligible to participate in this investigation. Sample size was determined using power calculation software (G*Power Version 3.1.9.2, University Kiel Germany, 2014). A comparable study of male cyclists (Campagnolo et al. 2017) detected a significant effect of rehydration beverage (Water vs. Sustagen Sport® vs. Powerade®) on energy intake (η_p^2=0.62). Using a power (1-β) of 0.95 and α=0.05 with an equivalent effect, we predicted that 8 subjects would be required to detect a significant change. Ten participants were recruited to account for attrition. One participant withdrew after the familiarization because trials conflicted with her training schedule; a second individual withdrew after the first experimental trial due to poor availability. The 8 remaining participants (age: 33.2±7.4 y; $VO_{2\ max}$: 46.3±7.5 mL·kg^{-1}·min^{-1}; PPO: 244±32 W; cycling: 115±60 km·week^{-1}; Mean±SD) completed all 4 experimental trials. This investigation was approved by the University's Human Ethics Committee (GU 2017/730) and procedures were conducted in accordance with principles outlined in the agreement of Helsinki.

2.2 Study Design

The experimental procedures are summarized in Figure 1. Each participant attended the laboratory on 6 separate occasions to complete one preliminary screening visit, one familiarization, and 4 repeated-measures experimental trials (≥5 d apart). Trials were counterbalanced for order using an incomplete Latin square design and scheduled during the first 14 days of the menstrual cycle (follicular phase) to minimize the confounding influence of hormonal changes on appetite and substrate utilization (Dye and Blundell 1997; Zderic et al. 2001). Participants using hormonal contraceptives at the time of the investigation (*n*=3) completed testing whilst administering the active medication. Each experimental trial involved exercise-induced dehydration followed by a 4 h recovery period, with *ad libitum* access to one of 4 commercial beverages: (1) Water, (2) Powerade® Isotonic (Coca Cola Ltd.) (Sports Drink), (3) Up & Go Reduced Sugar^{s} (Sanitarium®, Australia) (Reduced Sugar [RS]-MILK), and (4) Up & Go Energize™ (Sanitarium®, Australia) (Higher Protein [HP]-MILK). Drinking was permitted throughout the 4 h recovery period. Participants also had 15 min to access food at the end of the 1st and 2nd hour. Individuals were unaware that their food intake was being monitored. They were instead told that the purpose of the study was to investigate the influence of different beverages on recovery of cognitive function (sham questions and cognitive function tasks were administered throughout the trials to maintain this deception). Each participant was fully informed of the purpose of the study (and given the opportunity to withdraw their data) once data collection activities for the entire study were complete.

2.3 Eligibility and Participant Screening

On arrival at the initial visit, individuals completed a medical questionnaire and the Eating Attitudes Test-26 (Garner 1982) (Part C only, to deemphasize the importance of dietary behavior to this study). Those with a history of cardiovascular, metabolic and/or kidney disease, or currently taking medications known to influence substrate metabolism were ineligible to participate. Individuals were also excluded if their responses indicated probable disordered eating, as were volunteers who reported an allergy, intolerance or dislike towards the food items or test beverages used in the investigation. Next, a self-reported body mass (BM) history (~6 m) was collected and anthropometric measurements were obtained using digital scales (HW-PW200; A&D Company Ltd, Tokyo, Japan) and a stadiometer. Participants had to be weight stable (BM change ≤5% in 1 m or ≤10% in 6 m) and not followed an energy-restricted diet during the previous 6 m. Once eligibility was verified, participant's drink flavor preferences where recorded and they were trained by a qualified dietitian on how to keep a 24 h diet record. Finally, participants completed a graded exercise test on an electronically braked cycle ergometer (Lode Excalibur Sport; Lode BV, Groningen, Netherlands) for determination of VO_{2max} . The exercise protocol began at 50 W, and increased in 30 W increments every 2.5 min until volitional exhaustion. Participants' respiratory gases were sampled continuously by breathing into a calibrated gas analysis system (Medgraphic Ultima, MGC Diagnostics and Medisoft, USA). Peak sustainable power output (PPO) was also calculated (Jeukendrup et al. 1997) and used to establish the exercise intensity on subsequent trials.

2.4 Familiarization

Participants completed a full familiarization trial which employed a chocolate-flavored milk beverage (different from those used in the experimental trials) as the recovery fluid. This allowed individuals to become accustomed to the research protocol and the effects of consuming milk-products post-exercise.

2.5 Pre-Trial Procedures

Prior to each trial, participants were instructed to: (1) abstain from alcohol for 24 h; (2) avoid caffeine-containing products and moderate-strenuous exercise for 12 h; (3) keep a written record of the food/fluid consumed for 24 h; (4) consume a standardized pre-packaged evening meal (~60 kJ·kg^{-1}) (Campagnolo et al. 2017); and, (5) fast from all food/fluid (including water) for ~10 h (overnight). Food records were submitted to an investigator and analyzed (FoodWorks® Version 8, Xyris Software Pty Ltd, Spring Hill, Australia) by one dietitian using the relevant national food database. Following the initial trial, a copy of the food record was returned to the participant to assist in the replication of the pre-trial dietary intake.

2.6 Experimental Procedures

2.6.1 Pre-Exercise Period

Participants verbally acknowledged compliance to the pre-trial procedures and self-reported the onset of menstruation on arrival at the laboratory (~7 AM). A urine sample was collected to monitor hydration status (Urine Specific Gravity (U_{SG}) (Palette Digital Refractometer, ATAGO, USA). One participant had a pre-exercise U_{SG} ≥1.024 on the familiarization trial, indicating some level of dehydration (Armstrong et al. 2010). This individual was administered water (600 mL) and, when reassessed 30 min later, U_{SG} was <1.024. This practice was repeated on all subsequent trials to ensure consistency. All remaining subjects produced initial U_{SG} samples <1.024 at each attendance. Euhydrated participants rested in the supine position for 15 min prior to respiratory gases (VO_2 and VCO_2) (Medgraphic Ultima, MGC Diagnostic Corporation, USA) being measured continuously for 10 min to determine baseline metabolic rate. Following the respiratory measures, participants provided a blood sample, and completed the cognitive function test and subjective feelings questionnaire (Adaptive Visual Analogue Scale (AVAS); Marsh-Richard et al. (2009)). Individuals then voided their bladder completely and a pre-exercise nude BM measurement was obtained.

2.6.2 Dehydration and Exercise Protocol

Dehydration was induced via passive heat exposure (10 min, ~70°C, sauna) followed immediately by exercise on a cycle ergometer. Exercise commenced at a workload of 60% PPO (24.2±0.9°C; 66±11% RH). However, subjects who expressed likely volitional exhaustion prior to achieving the required BM loss (1.8%) could choose to reduce the workload by 5% PPO after 20 and 40 min of exercise (the minimum allowable workload was

50% PPO). Heart rate (HR) and ratings of perceived exertion (RPE) on the Borg scale (Borg 1998) were collected at 10 min intervals throughout exercise. Respiratory gases (VO_2 and VCO_2) were measured continuously between ~12-20 min, ~32-40 min and ~52-60 min of exercise for determination of energy expended during exercise. Nude BM was measured after 60 min of cycling. If BM loss was <1.8% from baseline, participants were required to continue exercise in 10 min intervals (respiratory gasses were collected across the final 5 min of each additional 10 min block). Once a BM loss ≥1.8% was achieved, exercise ceased. The duration and intensity of the exercise was documented during the familiarization and replicated on all subsequent trials. Participants repeated the cognitive function test and responded to the subjective feelings questionnaire immediately after exercise. Individuals then rested in a supine position and a blood sample was drawn. After resting ~15 min, respiratory gases were collected continuously for a final 10 min. Individuals then showered and dried themselves before a final nude BM measurement was obtained. The change in BM due to fluid loss was calculated by subtracting the final post-exercise BM from the pre-exercise BM.

2.6.3 Nutrition Recovery Period

Participants completed a 4 h recovery period in an observation room adjacent to the exercise laboratory, where they were allowed to undertake sedentary activities. Participants were given immediate access to one of 4 commercial beverages (Water, Sports Drink [Energy: 103 $kJ \cdot dL^{-1}$; CHO: 5.8 $g \cdot dL^{-1}$; Sodium: 28 $mg \cdot L^{1}$; Water: 95.0 $g \cdot dL^{-1}$], LS-MILK [Energy: 279 $kJ \cdot dL^{-1}$; CHO: 8.9 $g \cdot dL^{-1}$; Protein: 3.4 $g \cdot dL^{-1}$; Fat: 1.5 $g \cdot dL^{-1}$; Sodium: 65 $mg \cdot L^{1}$; Water: 84.4 $g \cdot dL^{-1}$], or HP-MILK [Energy: 344 $kJ \cdot dL^{-1}$; CHO: 9.9 $g \cdot dL^{-1}$; Protein: 6.7 $g \cdot dL^{-1}$; Fat: 1.5 $g \cdot dL^{-1}$; Sodium: 100 $mg \cdot L^{1}$; Water: 84.4 $g \cdot dL^{-1}$]) in excess of expected consumption (~3.0 L) . They were told that the two milk-drinks were *different*, but no further product information was provided. (Participants were not permitted to change flavors between milk trials). All beverages were stored in refrigerators (~4°C) in opaque jugs. Participants were instructed to *"self-serve"* into cups and to "*drink as much as they liked*", as additional fluid would be provided upon request. The beverage vessels did not have volume increments. Palatability was evaluated at the onset of drinking and at the conclusion of the recovery period.

After 1 h, participants completed the subjective feelings questionnaire, collected urine output, provided a blood sample, and measured nude BM. They were then given access to a variety of foods for 15 min. Participants entered a private room containing food and a computer (set up for the cognitive function task). They were allowed to bring their beverage, but were asked to refrain from taking other external items. This approach was designed to avoid social interactions which may influence eating behaviors and to reinforce the importance of the cognitive task. Food items included sports bars, fresh fruit, breads and condiments (Supplementary Table S1) with participants being instructed to "*eat as much as they liked"* and that *"more of the same food would be provided in 1 h but no food could be removed from the private room due to health and safety regulations*". Participants were also informed that no food would be provided in the 3rd and 4th hour of recovery. In the final 2 min, participants completed the cognitive function test and then returned to the main observation room. These procedures (excluding blood sampling) were repeated at the end of the 2nd hour of the recovery period. At the end of the 3rd and 4th hour, participants completed the cognitive function test and subjective feelings questionnaire, collected urine output and measured nude BM. Blood sampling was also performed at the end of the 4th hour.

2.7 Post-Trial Procedures

On leaving the laboratory, participants were required to keep a record of the food/fluid they consumed over the remainder of the day, and to capture images of each item using a tablet device (iPad, Apple®, Cupertino, USA). Participants were encouraged to include a fiducial marker in each image, to assist the investigator in the estimation of portion size. Food records and accompanying images were submitted to an investigator and checked for completeness. Diet records were analyzed using the method previously described. A limit of up to two standard alcoholic drinks (20 g alcohol) was imposed on trial days to avoid alcohol's influence on appetitive responses (Poppitt 1996).

2.8 Study Completion Procedures

At the conclusion of the experiment, participants were asked what they believed the true purpose of the investigation was, and, how confident they were that their answer was correct to verify that deception was effective. Individuals also completed the R18 Three-Factor Eating Questionnaire (de Lauzon et al. 2004) to measure influencers of eating behavior.

2.9 Data Collection

2.9.1 Food and Fluid Intake Measures

Energy, macronutrient, sodium and water intake during the recovery period was determined by weighing the food (covertly) and beverages to the nearest 1 g after each hour. Participants were aware that beverage intake was being monitored, but no information was provided to participants on how much fluid they consumed. Nutritional values for packaged foods were taken from the product nutrition information panel; values for fresh food items and product water content were derived from the dietary analysis software.

2.9.2 Estimated Energy Expenditure

Gas exchange data was averaged in 30 s segments over the final ~8 min of each collection period. Estimated energy expenditure (eEE) was then quantified in the following increments: pre-exercise (-20–0 min), exercise blocks 1 (0–20 min), 2 (20–40 min) and 3 (40–60 min), post-exercise (60–80 min), and total trial (100 min). (Where participants continued exercise in 10 min intervals after 60 min, eEE was also quantified at exercise block 4 (60–70 min), such that the total trial time increased to 110 min). Rates and total substrate oxidation were calculated using the equations of Frayn (1983) (assuming negligible protein oxidation). Energy equivalents of 16.75 $kJ \cdot g^{-1}$ of CHO and 37.68 $kJ \cdot g^{-1}$ of fat were utilized to calculate eEE from substrate oxidation (Schubert et al. 2014).

2.9.3 Urine Sampling and Water Retention

At the end of each hour of the recovery period, participants voided their bladder completely into an empty container for measures of hourly urine output and hourly U_{SG}. Participants were permitted to urinate throughout the observation period, and on each occasion, the void was collected and added to the hourly urine output. Total urine loss was calculated as the accumulated urine output from the onset of drinking until the end of the observation period. The proportion of ingested water retained at the end of the 4 h recovery period was calculated as total water intake (i.e. food and beverage) minus total urine output and converted to a percentage of total water intake.

2.9.4 Body Mass (BM) Measurements

Nude BM measures were obtained pre- and ~30 min post-exercise (i.e. after sweating had ceased) and at the end of each hour of the recovery period. All BM measurements were adjusted to account for the non-water mass of the food and beverages consumed.

2.9.5 Subjective Feelings and Beverage Palatability Questionnaires

Visual analogue scales (VAS) were used to measure subjective feelings of hunger, thirst and fullness pre- and post-exercise and at each hour of the recovery period. To distract participants from the primary outcomes of the study, individuals were also required to indicate feelings of alertness, concentration, muscle soreness and energy levels. VAS were also used to assess palatability ('pleasantness') at the onset of drinking and at the conclusion of the recovery period. Beverages were subsequently ranked from most to least palatable (1^{st} – 4^{th}) (based on individual participants' preferences) using the average pre/post-recovery palatability rating. All measures were conducted on a 100 mm scale, with 0 mm representing 'not at all' and 100 mm representing 'extremely' using a computerized modifiable software program (AVAS; Marsh-Richard et al. (2009)).

2.9.6 Blood Sampling

Participants rested for ~5 min in a supine position prior to a 5 mL blood sample being drawn from an antecubital vein. Blood samples were obtained pre-exercise, post-exercise and at the end of the 1^{st} and 4^{th} hour of the recovery period. All samples were collected into pre-treated lithium heparin vacutainers (Becton Dickson vacutainers®) and centrifuged for 10 min (~1350×*g*). Aliquots of plasma supernatant were stored (-80°C) and later analyzed in duplicate for plasma osmolality (P_{OSM}) using a calibrated, freezing-point depression osmometer (Osmomat 030, Gonotec).

2.10 Statistical Analysis

Statistical analyses were completed using SPSS Statistics for Windows, Version 21.0 (IBM Corp. 2012, Armonk, N.Y., USA). All measures were examined for normality (Shapiro-Wilk test) and sphericity (Mauchly's test). Where assumptions of sphericity in repeated measures analyses were violated, the Greenhouse-Geisser statistic was applied. Comparisons between experimental trials for baseline measures (BM, U_{SG}, and P_{OSM}); exercise-induced fluid loss; eEE; previous-day energy and water intake; beverage intake; water intake from beverage ($WI_{Beverage}$), food (WI_{Food}) and beverage plus food (WI_{Total}); energy intake from beverage ($EI_{Beverage}$), food (EI_{Food}) and beverage plus food (EI_{Total}); nutrient intake; urine output; and water retention were performed using one-way repeated measures analysis of variance (ANOVA). The remaining variables were examined using a two-way (Treatment × Time) repeated-measures ANOVA. Pairwise comparisons were performed where significant main effects were present

(Bonferroni). One-way ANOVA (Bonferroni) were used to conduct post hoc comparisons where significant interaction effects were present. Each of the 18 items on the Three-Factor Eating Questionnaire was given a score between 1 and 4 and item scores were summated into raw scores for cognitive restraint, uncontrolled eating, and emotional eating. Raw scale scores were then transformed to a 0–100 scale [((raw score − lowest possible raw score)/possible raw score range) × 100]. Higher scores in the respective scales are indicative of greater cognitive restraint, uncontrolled, or emotional eating (de Lauzon et al. 2004). Effect sizes are reported as partial eta squared (η_p^2). Significant differences were accepted as $p<0.05$. Data are Mean±SD, unless otherwise indicated.

3.0 Results

3.1 Standardization Procedures

All 8 participants verbally acknowledged compliance to the pre-experimental procedures on arrival at the laboratory. Participants' pre-trial records indicated similar energy, F(3,21)=1.78, p=0.182; and water, F(3,21)=0.555, p=0.651; intakes 24 h prior to each experimental trial (Water: 9.2±1.8 MJ, 4.5±0.7 L; Sports Drink: 8.3±2.2 MJ, 4.0±1.3 L; LS-MILK: 8.5±2.0 MJ, 4.3±0.5 L; HP-MILK: 9.0±2.6 MJ, 4.3±1.2 L). Pre-exercise values for BM, U_{SG} and P_{OSM} were also similar across treatments (Table 1).

3.2 Exercise-Induced Dehydration

All participants successfully replicated the same exercise protocol at each experimental trial. For three individuals, the total exercise duration was 70 min; the remainder cycled 60 min to achieve the target BM loss. Gas exchange data indicate that participants exercised at an intensity corresponding to 76±5% VO_{2max}. Neither BM loss nor eEE differed significantly by treatment (Table 1) or by trial order, F(3,21)=0.279, p=0.840; F(3,21)=0.806, p=0.504, respectively. 4 (Treatment) × 6 (Time) analyses of RPE and HR identified a significant main effect of time on each variable, F(1.3,9.1)=16.79, p=0.002; F(1.8,12.5)=16.0, p<0.001, respectively. A significant main effect of treatment was also observed on HR, F(3,12)=3.21, p=0.044; however, pairwise comparisons did not detect any differences across trials (p's>0.05). No main effect of treatment was observed on RPE, F(3,21)=2.07, p=0.134.

3.3 Water Intake from Food and Beverages

Water and beverage intakes are displayed in Table 2; beverage intake for individual participants is provided in Supplementary Table S2. Beverage intake did not differ significantly by treatment (Table 2) or by trial order, F(1.8,12.3)=0.569, p=0.558. However, $WI_{Beverage}$ was significantly lower with LS-MILK and HP-MILK compared to Sports Drink (p=0.040) and Water (p=0.022), respectively. Whilst WI_{Total} also differed significantly across treatments, pairwise comparisons only indicated a trend for a difference in WI_{Total} between HP-MILK and Water (p=0.080); no other differences were observed (p's>0.05). A 4 (Treatment) × 4 (Time) analysis of mean hourly WI_{Total} identified a significant main effect of time, F(3,21)=62.4, p<0.001, η_p^2=0.90; such that WI_{Total} was greater in the 1st hour of recovery (864±195 g) than all subsequent time points (p's≤0.001); WI_{Total} did not differ across the 2nd (315±42 g), 3rd (307±119 g) and 4th (191±140 g) hours of recovery (p's>0.05). No significant treatment × time interaction was observed, F(9,63)=1.66, p=0.118, η_p^2=0.19.

3.4 Urine Output and Water Retention

Total urine output differed significantly across treatments (Water: 556±314 g; Sports Drink: 459±290 g; LS-MILK: 220±53 g; HP-MILK: 230±117 g; F(2.0,14.3)=6.57, p=0.009, η_p^2=0.48). Pairwise comparisons revealed that urine output was elevated with Water compared to HP-MILK (p=0.048) and tended to be elevated compared to LS-MILK (p=0.073); urine output was similar between all other treatments (p's>0.05). A 4 (Treatment) × 4 (Time) analysis of mean hourly urine outputs (Figure 2) indicated a main effect of time, F(3,21)=4.544, p=0.013, η_p^2=0.48; such that mean urine output was greater during the 4th hour of recovery than the 1st hour (p=0.027); but comparable across all other time points (p's>0.05). No treatment × time interaction was observed, F(9,63)=1.25, p=0.281, η_p^2=0.15. A 4 (Treatment) × 4 (Time) analysis of mean hourly U_{SG} (Figure 2) values identified significant main effects of treatment, F(3,21)=17.7, p<0.001, η_p^2=0.72; and time, F(3,21)=5.62, p=0.005, η_p^2=0.45; and a significant treatment × time interaction, F(9,63)=5.70, p<0.001, η_p^2=0.45. Post hoc comparisons revealed that Water decreased U_{SG} compared to LS-MILK and HP-MILK between the 2nd and 4th hours of recovery (p's<0.05); Sports Drink also decreased U_{SG} compared to LS-MILK (p=0.031) and HP-MILK (p=0.032) during the 3rd hour of recovery, and tended to decrease U_{SG} compared to LS-MILK (p=0.084) and HP-MILK (p=0.054) during the 3rd hour of recovery, although this was not at a level of statistical significance. The proportion (%) of WI_{Total} retained differed significantly across treatments (Water: 70.2±13.6%; Sports Drink: 74.2±18.1%; LS-MILK: 84.1±83.7%; HP-MILK: 83.7±9.5%; F(3,21)=5.09, p=0.008, η_p^2=0.42). Pairwise comparisons revealed that water retention increased with

LS-MILK compared to Water (*p*=0.043), but similar across all other treatments (*p*'s>0.05). The overall quantity (g) of WI_{Total} retained at the conclusion of the experimental protocol did not differ significantly by treatment (Water: 1352±462 g; Sports Drink: 1349±407 g; LS-MILK: 1238±400 g; HP-MILK: 1293±453 g; F(3,21)=0.493, *p*=0.691, η_p^2=0.0.7)

3.5 Body Mass Changes

Net BM changes are displayed in Figure 3. All trials concluded with participants in a state of negative net BM relative to pre-exercise values (Water: -91±430 g; SD: -93±470 g; LS-MILK: -260±450 g; HP-MILK: -179±419 g). A 4 (Treatment) × 6 (Time) analysis of BM changes identified a significant main effect of time, F(1.4, 10.0)=51.0, $p<0.001$, η_p^2=0.88; and a trend for a significant treatment × time interaction, F(15,105)=1.65, *p*=0.074, η_p^2=0.19. However, post hoc comparisons failed to detect a difference between treatments at any time points (*p*'s>0.05).

3.6 Plasma Osmolality

A 4 (Treatment) × 4 (Time) analysis of P_{OSM} values identified significant main effects of treatment, F(3,18)=6.41, *p*=0.004, η_p^2=0.52; and time, F(3,18)=46.7, $p<0.001$, η_p^2=0.89; and a significant treatment × time interaction, F(9,54)=15.5, $p<0.001$, η_p^2=0.72. Pairwise comparisons indicated that P_{OSM} increased following the exercise-dehydration protocol (287±5 vs. 297±5 $mOsm \cdot kg^{-1}$, $p<0.001$). Post hoc comparisons suggested that Water elicited lower P_{OSM} values than LS-MILK (*p*=0.001) and HP-MILK (*p*=0.008) after the 1st hour of recovery; Sports Drink also reduced P_{OSM} compared to LS-MILK (*p*=0.012) at this time (Water: 287±5 $mOsm \cdot kg^{-1}$; Sports Drink: 291±8 $mOsm \cdot kg^{-1}$; LS-MILK: 298±7 $mOsm \cdot kg^{-1}$; HP-MILK: 296±4 $mOsm \cdot kg^{-1}$). After the 4th hour of recovery, Water again elicited lower P_{OSM} values than LS-MILK (*p*=0.013) and HP-MILK (*p*=0.004); Sports Drink also reduced P_{OSM} compared to HP-MILK (*p*=0.021) and tended to reduce P_{OSM} compared in LS-MILK (*p*=0.066) at this time (Water: 288±5 $mOsm \cdot kg^{-1}$; Sports Drink: 288±5 $mOsm \cdot kg^{-1}$; LS-MILK: 295±5 $mOsm \cdot kg^{-1}$; HP-MILK: 299±4 $mOsm \cdot kg^{-1}$).

3.7 Food and Nutrient Intakes

Nutrient intakes during the 4 h recovery period and across the entire trial day (trial intake *plus* post-trial diet record) are displayed in Table 2; total energy consumed by individual participants is included in Supplementary Table S2. Mean energy intake (food, beverage and total) differed significantly across treatments during the 4 h recovery period. Pairwise comparisons revealed that EI_{Food} was significantly lower with HP-MILK compared to Water (p=0.005) and Sports Drink (p=0.006); EI_{Food} was also lower with LS-MILK compared to Water (p=0.033) and tended to suppress intake compared to Sports Drink (p=0.086). EI_{Food} did not differ significantly between Water and Sports Drink (p>0.05). Although not statistically significant, EI_{Total} tended to be increased with HP-MILK compared to Water (p=0.071) and Sports Drink (p=0.085). Total CHO and protein intakes also differed significantly across treatments during the 4 h recovery period. Pairwise comparisons revealed that Sports Drink (p=0.004), LS-MILK (p=0.026) and HP-MILK (p=0.014) increased total CHO intake compared to Water; CHO intake was not different between the other beverages (p's>0.05). LS-MILK and HP-MILK also increased total protein intake compared to Water and Sports Drink (p's<0.05); protein intake was also higher with HP-MILK compared to LS-MILK (p=0.006). Participants' post-trial intake of energy, water, CHO, fat and sodium did not differ significantly by treatment (p's>0.05); only dietary protein intake was influenced by the beverage consumed post-exercise. Pairwise comparisons revealed a trend for decreased protein ingestion post-trial with HP-MILK compared to Sports Drink (p=0.065). Nonetheless, 24 h protein intake with HP-MILK was higher than with all other beverages (p's<0.05). 24 h energy, CHO and sodium intakes differed significantly by treatment (p's<0.05). Although pairwise comparisons did not detect differences in total energy intake between trials (p's>0.05), LS-MILK and HP-MILK appeared to increase intake in comparison to Water and Sports Drink. Sports Drink (p=0.076), LS-MILK (p=0.022) and HP-MILK (p=0.087) all tended to increase 24 h CHO intake compared to Water.

3.8 Gastrointestinal Tolerance

A 4 (Treatment) × 6 (Time) analysis of hunger ratings identified a significant main effect of time, $F(5,35)=11.5$, $p<0.001$, $\eta_p^2=0.62$; and a significant treatment × time interaction, $F(15,105)=2.27$, $p=0.008$, $\eta_p^2=0.25$. Post hoc comparisons revealed that LS-MILK and HP-MILK decreased subjective hunger compared to Water and Sports Drink during the 1st hour of recovery (p's<0.05). Hunger ratings were not significantly different at any other point in time (p's>0.05). 4 (Treatment) × 6 (Time) analyses revealed significant main effects of treatment on thirst, $F(1.4,9.7)=34.4$, $p<0.001$, $\eta_p^2=0.83$; and fullness ratings, $F(3,21)=3.81$, $p=0.025$, $\eta_p^2=0.35$; significant main effects of time on thirst, F(5,35)=22.1, p<0.001, η_p^2=0.76; and fullness ratings, F(5,35)=27.9, p<0.001, η_p^2=0.80; and significant treatment × time interactions on thirst, F(15,105)=10.4, p<0.001, η_p^2=0.60; and fullness ratings, F(15,105)=2.12, p=0.014, η_p^2=0.23. Post hoc comparisons demonstrated that LS-MILK and HP-MILK increased subjective fullness compared to Water during the 1st hour of recovery (p's<0.05). Fullness ratings were not significantly different between treatments at any other point in time (p's>0.05). Ingestion of LS-MILK and HP-MILK increased thirst ratings compared to Water and Sports Drink at all stages of recovery (p's<0.05).

3.9 Beverage Palatability

A 4 (Treatment) × 2 (Time) analysis of beverage pleasantness ratings failed to indicate a significant main effect of beverage, F(1.5,10.6)=1.97, p=0.150, η_p^2=0.22; although, pleasantness ratings were generally increased with Water (79 ± 30 mm) and Sports Drink (70 ± 33 mm) compared to LS-MILK (50 ± 16 mm) and HP-MILK (56 ± 15 mm). The analysis identified a significant main effect of time, F(3,7)=10.4, p=0.015, η_p^2=0.60; such that pleasantness decreased between the onset and conclusion of the drinking period (67 ± 9 mm vs. 60 ± 10 mm). Total beverage intake also differed by palatability, F(3,21)=10.6, p<0.001, η_p^2=0.60; such that the participants consumed a significantly greater quantity of their most preferred beverage than their least- (p=0.007) and second-least (p=0.004) preferred beverages (1st: 2057 ± 498 g; 2nd: 1662 ± 370 g; 3rd: 1471 ± 389 g; 4th: 1515 ± 496 g).. Average ratings for the 1st, 2nd, 3rd and 4th most palatable beverages were 95±5 mm, 72±19 mm, 52±14 mm and 34±12 mm, respectively.

3.10 Post-Study Survey

All 8 participants indicated that the purpose of the study was to investigate the effect of consuming different beverages on recovery of cognitive function. Of these, 7 indicated they were either *absolutely* or *very confident* in this response; one subject was *somewhat confident*. Mean±SD (Range) scores for Uncontrolled Eating, Cognitive Restraint and Emotional Eating on the R18 Three-Factor Eating Questionnaire were: 33±11% (19–53%), 23±18% (0–50%), and 25±26% (0–75%), respectively. No participant exceeded clinical thresholds for any of these characteristics.

4.0 Discussion

This study investigated the effect of consuming different commercial beverages (including milk-based beverages with contrasting formulations) with food *ad libitum* post-exercise on fluid, energy and nutrient recovery in females. Overall, results indicate that, when consumed voluntarily and with food, different beverages are likely to elicit *similar* levels of fluid recovery. However, caloric beverages, particularly milk-based formulations, appear to increase energy consumption and alter nutrient provision compared to when water is consumed. Findings from this study suggest that, when food is available post-exercise, the type of recovery beverage ingested will influence daily nutrient intake and nutrient intake immediately post-exercise, rather than acute measures of fluid recovery.

Previous research investigating the impact of beverage type on fluid recovery post-exercise generally indicates that milk/milk-based formulations are more effective rehydration agents than water and sports beverages (Shirreffs et al. 2007b; Watson et al. 2008; Desbrow et al. 2014; Seery and Jakeman 2016). However, the majority of studies have “prescribed” fluid intake and denied participants access to food: an approach with limited ecological validity. The current investigation administered beverages and a variety of foods *ad libitum* in an attempt to simulate real-life post-exercise conditions. Under these circumstances, the different commercial beverages promoted *similar* levels of fluid recovery (Water: 1352±462 g; Sports Drink: 1349±407 g; LS-MILK: 1238±400 g; HP-MILK: 1293±453 g); despite differences in the quantity of water consumed and the proportion of water retained between treatments. The only other study employing directly comparable methodology (Campagnolo et al. 2017) demonstrated similar effects in male participants (fluid recovery was not influenced by the choice of water, a sports beverage [Powerade®] or a milk-based formulation [Sustagen Sport®] when food and fluid were consumed *ad libitum*). This suggests that post-exercise rehydration is complex and likely to be influenced by the type of beverage provided and the availability of food during recovery. However, additional studies employing protocols that better reflect real-life post-exercise conditions are still required to improve our understanding of the interaction between fluid, food and nutrients in rehydration and recovery after exercise.

Previous research suggests that sports drinks, water and milk-based formulations are typically ingested in different quantities when individuals are permitted to consume these beverages *ad libitum* (Maughan and Leiper 1994; Brouns et al. 1998; Park et al. 2012; Baguley et al. 2016; Campagnolo et al. 2017). Indeed, studies consistently report that sports drinks or carbohydrate-electrolyte solutions (CES) increase voluntary fluid consumption by ~30–42% compared to water (Maughan and Leiper 1994; Brouns et al. 1998; Park et al. 2012; Campagnolo et al. 2017) and by >50% compared to milk-based beverages post-exercise (Baguley et al. 2016; Campagnolo et al. 2017). Each of the different test beverages in the present study were consumed in roughly similar volumes. The inconsistency in findings between the current and previous reports may reflect gender differences. That is, the former studies have predominantly been conducted using male participants and some evidence (albeit in older individuals and/or during exercise) suggests sex differences exist in voluntary fluid consumption for different beverages (Baker et al. 2005). Indeed, Baker et al. (2005) observed that females consumed more water but not CES than males relative to BM. Furthermore, males consumed significantly more CES than water, but intakes between the two beverages for females were not statistically different. Whilst this study examined fluid intake during rest periods interspersed throughout an exercise protocol (and is therefore not directly comparable to the present study), similar behaviors may apply post-exercise.

While beverage intakes were similar *on average* in this study, it is worthwhile noting that volumes varied considerably at an individual-level (Supplementary Table S2). This may be due to participants having different taste preferences. On examining the data, we can see that participants who indicated Sports Drink was "more pleasant" than Water (*n*=2) did in fact, consume ~40% more Sports Drink; whilst those who perceived Sports Drink as "more pleasant" than LS-MILK (*n*=5) and HP-MILK (*n*=5) also consumed ~40% more of the preferred beverage. The influence of palatability is further demonstrated by the fact that participants consumed a greater amount of their most preferred beverage than their least- and second-least preferred beverages. These data indicate that palatability is an important determinant of fluid intake and that taste preferences can vary greatly amongst individuals. The importance of thirst and beverage palatability as factors influencing fluid intake post-exercise is further supported by results of the current study, where HP-MILK and LS-MILK were consumed in similar volumes. These two beverages had similar sensory characteristics (flavor, mouth-feel, appearance, aroma), yet contrasting nutrient profiles. Clearly, physiological/psychological cues provided when consuming similar tasting beverages with different nutrition are too subtle or participants are unable to detect them to moderate drinking behavior. Thus, individuals likely revert to consuming the beverage to relieve thirst and/or on the basis that they find it palatable/pleasant, which influences intake volume.

Findings from this study indicate that food plays an important role in mediating fluid recovery following exercise when beverages with basic nutrient profiles are consumed. Although the present investigation did not incorporate a "beverage only" trial for direct comparisons, the available evidence suggests that if food is *not* consumed, just ~30–56% of water (Maughan and Leiper 1995; Shirreffs and Maughan 1998; Shirreffs et al. 2007a; Shirreffs et al. 2007b; Merson et al. 2008; Wong and Chen 2011; James et al. 2014; Stasiule et al. 2014; Tai et al. 2014; Wong et al. 2014; Seery and Jakeman 2016) and ~38–64% of sports drink (Wong et al. 2000; Shirreffs et al. 2007a; Shirreffs et al. 2007b; Watson et al. 2008; Evans et al. 2009b; James et al. 2011; Wong and Chen 2011; James et al. 2012; James et al. 2013; Clayton et al. 2014; Desbrow et al. 2014; Tai et al. 2014; Wong et al. 2014; Li et al. 2015; Seery and Jakeman 2016) is typically retained post-ingestion (1.50 L·kg BM lost^{-1}). Values indicated in the current investigation are noticeably higher (Water: 70.2±13.6%; Sports Drink: 74.2±18.1%). This observation is consistent with results from previous experiments suggesting that the consumption of food (providing energy and nutrients) enhances fluid retention (Maughan et al. 1996; Pryor et al. 2015) by delaying gastric emptying and attenuating osmotic diuresis (Nose et al. 1988). It is important to note that the male subjects in Campagnolo et al. (2017) retained a *very similar* proportion of ingested water (Trial #1: 72±8%; Trial #2: 73±11%) and Powerade® (74±17%) as the female participants in the current study, even though females derived roughly half the amount of energy, CHO, protein and sodium (relative to BM) from food across on all beverage treatments. The fact that individuals retained a similar proportion of Water and Sports Drink is also interesting, as it suggests that water may, in fact (contrary to popular belief), be an appropriate rehydration solution when co-ingested with food; particularly, if the calories delivered in sports beverages are not desired. Collectively, these data suggest that consuming food *ad libitum* after exercise is likely to enhance fluid retention similarly in males and females, despite differences in their dietary behavior.

Results from the present study indicate that the choice of recovery beverage can have a profound effect on overall dietary intake. Total energy intake during the 4 h recovery period increased proportionately to the energy-density of the experimental beverage (even despite an opposing step-wise reduction in energy consumed from food). An analysis of the participants' post-trial diet records revealed that individuals did not modify their dietary behavior over the remainder of the day to offset this difference in energy consumption. While the caloric beverages increased CHO intake post-exercise (Water: 0.4±0.2 g CHO $\cdot kg^{-1}\cdot h^{-1}$; all other treatments: 0.8±0.2 $g\cdot kg^{-1}\cdot h^{-1}$), it is worth noting that ad libitum intake of food and any beverage included in this study failed to meet recommended CHO intakes for "rapid refueling" after exercise; though total daily intakes were within the recommended range (~3.0–5.0 g CHO$\cdot kg^{-1}\cdot d^{-1}$) (Thomas et al. 2016). Protein consumption during the first 2 h after exercise was in excess of recommendations

(0.25–0.30 $g\cdot kg^{-1}$); particularly, when the milk-based beverages were consumed (Water: 0.47±0.17 $g\cdot kg^{-1}$; Sports Drink: 0.39±0.09 $g\cdot kg^{-1}$; LS-MILK: 0.81±0.28 $g\cdot kg^{-1}$; HP-MILK: 1.49±0.41 $g\cdot kg^{-1}$) (Thomas et al. 2016). Total daily protein intakes were generally appropriate (i.e. ~1.2–2.0 $g\cdot kg^{-1}\cdot d^{-1}$), but exceeded recommended levels on the HP-MILK (2.6±0.8 $g\cdot kg^{-1}\cdot d^{-1}$) (Thomas et al. 2016). Hence, the type of beverage consumed may influence aspects of post-exercise recovery and the suitability of certain beverages for individuals with specific dietary goals). For instance, caloric beverages may facilitate rehydration, substrate repletion and positive energy balance in situations where weight gain or large nutritional intakes are required. Whereas, the consumption of water (with food) should be encouraged to facilitate rehydration without excessive caloric intake in circumstances where weight loss or maintenance is desirable.

This investigation (and results from Campagnolo et al. (2017)) provides evidence that different commercial beverages promote similar levels of fluid recovery after exercise. However, it is important to consider that “rapid rehydration” is typically utilized to facilitate recovery *ahead of a subsequent exercise session*. Under these circumstances, individuals may restrict their intake of food/fluid to avoid GI discomfort during exercise; potentially affecting fluid and nutrient recovery. Additional research is required to determine the behaviors of athletes given access to *ad libitum* food and different beverages when they are required to perform a subsequent exercise session; and impact of these behaviors on post-exercise recovery and subsequent exercise performance.

In summary, this study demonstrates that different beverages are similarly effective at replenishing exercise-induced sweat loss, but result in different energy/nutrient intakes, when consumed *ad libitum* with food. An athlete’s acute nutritional requirements to support recovery, broader dietary goals, taste preferences and access to food should therefore inform selection of the most appropriate recovery beverage.

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Tables

Table 1. Pre-trial conditions and exercise-induced dehydration

	Water	**Sports Drink**	**LS-MILK**	**HP-MILK**	**F-ratio**	***p*-value**
Pre-exercise U_{SG}	1.012 ± 0.005	1.014 ± 0.007	1.013 ± 0.005	1.014 ± 0.008	F(3, 21) = 0.547	0.656
Pre-exercise P_{OSM} (mOsm·kg^{-1})	286 ± 5	286 ± 8	287 ± 4	287 ± 3	F(1.4, 8.4) = 0.172	0.770
Pre-exercise BM (kg)	61.98 ± 10.78	61.68 ± 10.86	61.28 ± 10.53	61.56 ± 10.80	F(3, 21) = 1.69	0.201
BM loss (kg)	1.20 ± 0.19	1.21 ± 0.15	1.22 ± 0.16	1.23 ± 0.10	F(3, 21) = 0.151	0.928
BM loss (%)	1.96 ± 0.28	2.00 ± 0.43	2.03 ± 0.31	2.03 ± 0.26	F(3, 21) = 0.388	0.763
Total eEE (kJ)	3241 ± 349	3289 ± 388	3270 ± 457	3164 ± 264	F(3, 21) = 0.805	0.505

BM: Body mass; eEE: Estimated energy expenditure; HP-MILK: Up & Go Energize^{TM}; P_{OSM}: Plasma osmolality; LS-MILK: Up & Go Reduced Sugar^{TM}; U_{SG}: Urine specific gravity. Plasma osmolality values from *n*=7 participants where blood sampling was performed. Values are Mean±SD.

Table 2. Total nutrient intake from food and beverages during the 4 h recovery period and entire trial day (trial *plus* post-trial diet).

	Water	**Sports Drink**	**LS-MILK**	**HP-MILK**	**F-ratio**	***p*-value**	η_p^2
Nutrient Intake From Beverage							
Beverage Intake (g)	1790 ± 540	1801 ± 359	1538 ± 485	1639 ± 587	F(3, 21) = 1.32	0.294	0.16
Water (g)	1790 ± 540^{c}	1711 ± 339^{b}	1299 ± 410	1383 ± 495	F(3, 21) = 5.72	0.005	0.45
Energy (kJ)	0 ± 0^{a,b,c}	1874 ± 371^{b,c}	4282 ±1337	5639 ± 2019	F(1.3, 9.3) = 48.8	<0.001	0.88
CHO (g)	0 ± 0^{a,b,c}	104 ± 21	136 ± 42	162 ± 58	F(3, 21) = 45.8	<0.001	0.87
Protein (g)	0 ± 0^{b,c}	0 ± 0^{b,c}	52 ± 16^{c}	110 ± 39	F(3, 21) = 59.6	<0.001	0.90
Fat (g)	0 ± 0^{b,c}	0 ± 0^{b,c}	23 ± 7	25 ± 9	F(3, 21) = 63.2	<0.001	0.90
Sodium (mg)	0 ± 0^{a,b,c}	504 ± 101^{b,c}	1000 ± 315^{c}	1639 ± 587	F(1.2, 8.7) = 48.3	<0.001	0.87
Beverage Mass (kg)	1.79 ± 0.54	1.80 ± 0.36	1.54 ± 0.48	1.64 ± 0.59	F (3, 21) = 1.32	0.294	0.16
Nutrient Intake From Food							
Water (g)	128 ± 59	98 ± 57	160 ± 75	140 ± 78	F(3, 21) = 1.66	0.206	0.19
Energy (kJ)	4129 ± 1080^{b,c}	3292 ± 633^{c}	1737 ± 1171	1457 ± 797	F(3, 21) = 17.4	<0.001	0.71
CHO (g)	107 ± 34^{b,c}	75 ± 18^{c}	52 ± 25	42 ± 19	F(3, 21) = 17.0	<0.001	0.71
Protein (g)	29 ± 9^{c}	24 ± 8	10 ± 10	8 ± 7	F(3, 21) = 12.4	<0.001	0.64
Fat (g)	47 ± 14^{c}	42 ± 13^{c}	17 ± 21	15 ± 15	F(3, 21) = 11.8	<0.001	0.63
Sodium (mg)	735 ± 334^{b,c}	738 ± 345^{c}	208 ± 241	205 ± 208	F(1.4, 9.7) = 12.9	0.003	0.65
Food Mass (kg)	0.32 ± 0.86^{c}	0.25 ± 0.74	0.25 ± 0.11	0.21 ± 0.88	F(3, 21) = 4.13	0.019	0.37
Total Nutrient Intake (Food & Beverage)							
Water (g)	1918 ± 580	1809 ± 338	1458 ± 431	1523 ± 472	F(3, 21) = 4.92	0.010	0.41
Energy (kJ)	4129 ± 1080	5167 ± 643	6019 ± 1925	7096 ± 2058	F(1.5, 10.4) = 7.37	0.014	0.51
CHO (g)	107 ± 34^{a,b,c}	180 ± 30	188 ± 46	204 ± 47	F(3, 12) = 12.9	<0.001	0.65
Protein (g)	29 ± 9^{b,c}	24 ± 8^{b,c}	63 ± 20^{c}	118 ± 41	F(1.3, 9.1) = 33.8	<0.001	0.83
Fat (g)	47 ± 14	42 ± 13	40 ± 24	40 ± 19	F(1.4, 9.8) = 0.437	0.590	0.06
Sodium (mg)	735 ± 334^{a,c}	1242 ± 322	1208 ± 298^{c}	1844 ± 488	F(1.5, 10.5) = 10.7	0.005	0.61
Total Mass (kg)	2.11 ± 0.57	2.05 ± 0.35	1.79 ± 0.52	1.85 ± 0.55	F (3, 21) = 2.27	0.110	0.25
Nutrient Intake For Entire Trial Day							
Water (L)	4.0 ± 1.4	4.0 ± 1.1	3.9 ± 1.0	3.7 ± 1.4	F(3, 21) = 0.65	0.592	0.09
Energy (MJ)	8.4 ± 2.4	9.9 ± 2.2	11.0 ± 3.1	10.8 ± 2.5	F(3, 21) = 3.71	0.028	0.35
CHO (g)	201 ± 77^{b}	285 ± 65	323 ± 85	295 ± 69	F(3, 21) = 6.83	0.002	0.49
Protein (g)	89 ± 33^{c}	93 ± 35^{c}	110 ± 30^{c}	156 ± 41	F(3, 21) = 10.8	<0.001	0.61
Fat (g)	86 ± 23	84 ± 29	88 ± 34	73 ± 26	F(3, 21) = 0.98	0.365	0.12
Sodium (g)	2.1 ± 0.3	2.5 ± 0.2	3.3 ± 0.5	3.1 ± 0.3	F(3, 21) = 4.68	0.012	0.40

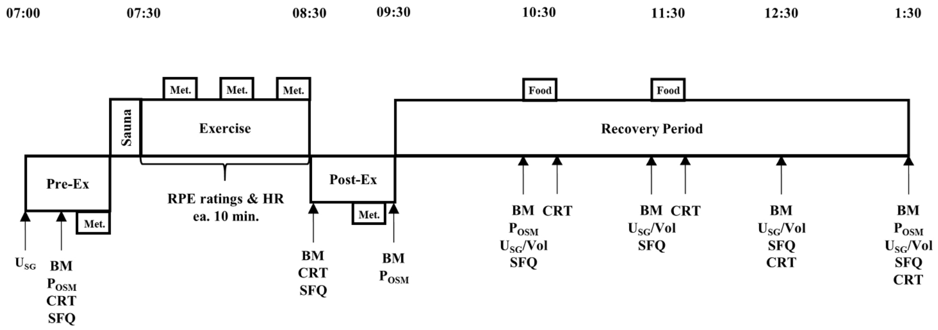
CHO: Carbohydrate; HP-MILK: Up & Go Energize^{TM}; LS-MILK: Up & Go Reduced Sugar^{TM}. Values are Mean±SD. *a*, mean value significantly different from Sports Drink; *b*, mean value significantly different from LS-MILK; *c*, mean value significantly different from HP-MILK.

Figure Captions

Figure 1. Schematic representation of the experimental procedures. BM: nude body mass; CRT: choice reaction time cognitive task (for experimental blinding); Food: *ad libitum* access to snack foods for 15 min; Met: metabolic gas measurements; P_{OSM}: blood collection for plasma osmolality analyses; SFQ: Subjective Feelings Questionnaire; U_{SG}: urine specific gravity.

Figure 2. Hourly urine output (A) and U_{SG} values (B) under each of the experimental treatments. Values are Mean±SEM for Water (●); Sports Drink (○); LS-MILK (■); HP-MILK (□). a, Water significantly different to LS-MILK and HP-MILK; b, Sports Drink significantly different to LS-MILK and HP-MILK; c, Sports Drink trending for a significant difference from LS-MILK and HP-MILK ($p<0.100$). H1–4: Hours 1 to 4 of the recovery period.

Figure 3. Net BM responses under each of the experimental treatments. Values are Mean±SEM for Water (●); Sports Drink (○); LS-MILK (■); HP-MILK (□). H1–4: Hours 1 to 4 of the recovery period.



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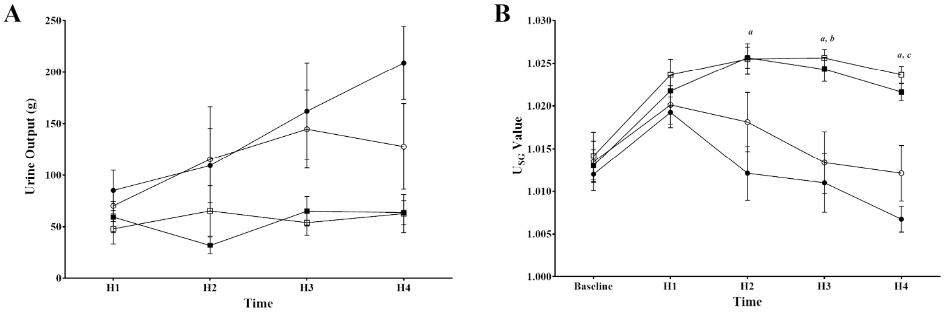

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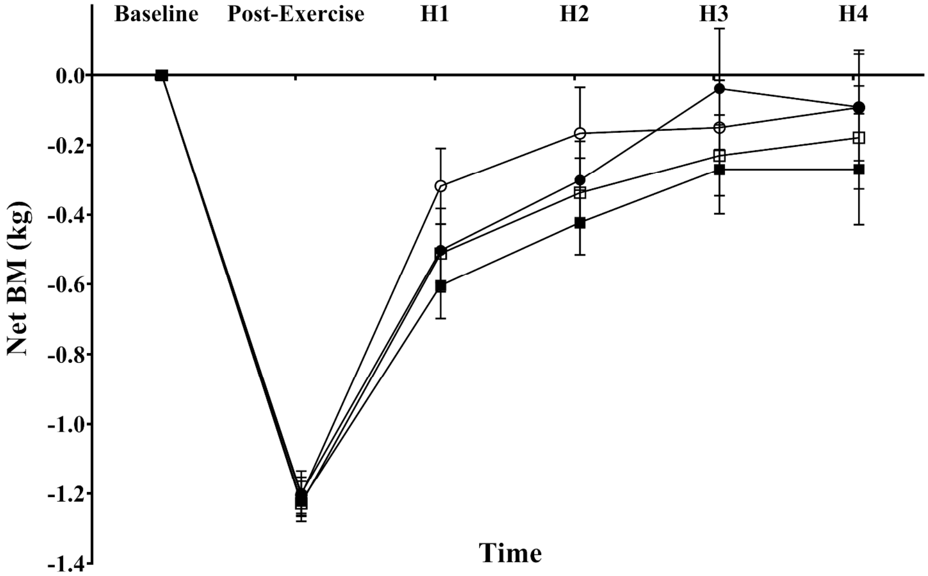

Figure 3. Net BM responses under each of the experimental treatments. Values are Mean±SEM for Water (●); Sports Drink (○); LS-MILK (■); HP-MILK (□). H1–4: Hours 1 to 4 of the recovery period.

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