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

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1   **Fluid, Energy and Nutrient Recovery via *Ad Libitum* Intake of Different**

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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.

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

62 "prescribing" drinking, many studies also deny participants access to food: an approach with limited ecological

63 validity. Findings from studies that have allowed participants to eat as part of the experimental protocol generally

64 suggest that co-ingesting food and fluid improves rehydration, such that the magnitude of difference between

65 beverages with different nutrient profiles (i.e. in terms of their potential to rehydrate) is attenuated (Maughan et al.

66 1996; Brouns et al. 1998; Ray et al. 1998; Jones et al. 2010; Pryor et al. 2015; Campagnolo et al. 2017; Evans et al.

67 2017). Still, most studies have prescribed a small number of food items that may not reflect the participants' usual

68 dietary behavior.

69 To date, one only study (Campagnolo et al. 2017) has investigated the ability of different beverages to

70 rehydrate participants when the drink *and* a variety of foods are consumed *ad libitum* post-exercise. The study,

71 which involved 10 endurance-trained males, demonstrated that fluid recovery was *similar*, regardless of the type of

72 beverage consumed. This suggests that, with the co-ingestion of food, fluid restoration following exercise may not

73 be influenced by beverage choice. The type of beverage did, however, affect nutrient intake during the post-exercise

74 period. Specifically, the provision of a sports beverage or a milk-based formulation increased total (i.e. food *and*

75 beverage) energy (~2500 kJ) and CHO (~200 g) intake compared to water; the milk-based formulation also

76 increased total protein consumption (~70 g) compared to the other beverages. Hence, the choice of post-exercise

77 beverage may affect aspects of recovery and the suitability of certain beverages for athletes with specific dietary

78 goals. Different energy and nutrient requirements, dietary preferences and motives influencing food choice have the

79 potential to limit the generalizability of previous results. Indeed, it is currently unclear if these effects persist in

80 trained females, who may exhibit contrasting dietary behaviors (Leblanc et al. 2015). Furthermore, it remains

81 unclear how beverages with similar sensory characteristics (i.e. taste, aroma, appearance) but with contrasting

82 nutrient profiles affect fluid, energy and nutrient recovery following acute exercise, when consumed *ad libitum* and

83 when access to food is provided.

84

85 This study aimed to investigate the effect of consuming different commercial beverages (including milk-

86 based beverages with contrasting formulations) with food *ad libitum* post-exercise on fluid, energy and nutrient

87 recovery in active female subjects. We hypothesized that, when consumed voluntarily and with food, these

88 beverages would result in similar levels of fluid recovery, but different energy/nutrient intakes.

89

2.0 Materials and Methods

2.1 Participant Characteristics

Female cyclists/triathletes ($\geq$3 h cycling·week^{-1}) aged 18–45 y were eligible to participate in this investigation. Sample size was determined using power calculation software (G*Power Version 3.1.9.2, University Kiel Germany, 2014). A comparable study of male cyclists (Campagnolo et al. 2017) detected a significant effect of rehydration beverage (Water vs. Sustagen Sport$^{®}$ 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 ($\geq$5 d apart). Trials were counterbalanced for order using an incomplete Latin square design and scheduled during the first 14 days of the menstrual cycle (follicular phase) to minimize the confounding influence of hormonal changes on appetite and substrate utilization (Dye and Blundell 1997; Zderic et al. 2001). Participants using hormonal contraceptives at the time of the investigation (*n*=3) completed testing whilst administering the active medication. Each experimental trial involved exercise-induced dehydration followed by a 4 h recovery period, with *ad libitum* access to one of 4 commercial beverages: (1) Water, (2) Powerade$^{®}$ Isotonic (Coca Cola Ltd.) (Sports Drink), (3) Up & Go Reduced Sugar^{s} (Sanitarium$^{®}$, Australia) (Reduced Sugar [RS]-MILK), and (4) Up & Go Energize^{TM} (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

118 function tasks were administered throughout the trials to maintain this deception). Each participant was fully

119 informed of the purpose of the study (and given the opportunity to withdraw their data) once data collection

120 activities for the entire study were complete.

121

122 **2.3 Eligibility and Participant Screening**

123   On arrival at the initial visit, individuals completed a medical questionnaire and the Eating Attitudes Test-26

124 (Garner 1982) (Part C only, to deemphasize the importance of dietary behavior to this study). Those with a history

125 of cardiovascular, metabolic and/or kidney disease, or currently taking medications known to influence substrate

126 metabolism were ineligible to participate. Individuals were also excluded if their responses indicated probable

127 disordered eating, as were volunteers who reported an allergy, intolerance or dislike towards the food items or test

128 beverages used in the investigation. Next, a self-reported body mass (BM) history (~6 m) was collected and

129 anthropometric measurements were obtained using digital scales (HW-PW200; A&D Company Ltd, Tokyo, Japan)

130 and a stadiometer. Participants had to be weight stable (BM change $\leq$5% in 1 m or $\leq$10% in 6 m) and not followed

131 an energy-restricted diet during the previous 6 m. Once eligibility was verified, participant's drink flavor preferences

132 where recorded and they were trained by a qualified dietitian on how to keep a 24 h diet record. Finally, participants

133 completed a graded exercise test on an electronically braked cycle ergometer (Lode Excalibur Sport; Lode BV,

134 Groningen, Netherlands) for determination of VO_{2max}. The exercise protocol began at 50 W, and increased in 30 W

135 increments every 2.5 min until volitional exhaustion. Participants' respiratory gases were sampled continuously by

136 breathing into a calibrated gas analysis system (Medgraphic Ultima, MGC Diagnostics and Medisoft, USA). Peak

137 sustainable power output (PPO) was also calculated (Jeukendrup et al. 1997) and used to establish the exercise

138 intensity on subsequent trials.

139

140 **2.4 Familiarization**

141   Participants completed a full familiarization trial which employed a chocolate-flavored milk beverage

142 (different from those used in the experimental trials) as the recovery fluid. This allowed individuals to become

143 accustomed to the research protocol and the effects of consuming milk-products post-exercise.

144

145 **2.5 Pre-Trial Procedures**

146   Prior to each trial, participants were instructed to: (1) abstain from alcohol for 24 h; (2) avoid caffeine-

147   containing products and moderate-strenuous exercise for 12 h; (3) keep a written record of the food/fluid consumed

148   for 24 h; (4) consume a standardized pre-packaged evening meal ($\sim$60 kJ·kg^{-1}) (Campagnolo et al. 2017); and, (5)

149   fast from all food/fluid (including water) for $\sim$10 h (overnight). Food records were submitted to an investigator and

150   analyzed (FoodWorks® Version 8, Xyris Software Pty Ltd, Spring Hill, Australia) by one dietitian using the relevant

151   national food database. Following the initial trial, a copy of the food record was returned to the participant to assist

152   in the replication of the pre-trial dietary intake.

153

154   **2.6 Experimental Procedures**

155   *2.6.1 Pre-Exercise Period*

156   Participants verbally acknowledged compliance to the pre-trial procedures and self-reported the onset of

157   menstruation on arrival at the laboratory ($\sim$7 AM). A urine sample was collected to monitor hydration status (Urine

158   Specific Gravity (U_{SG}) (Palette Digital Refractometer, ATAGO, USA). One participant had a pre-exercise U_{SG}

159    $\geq$1.024 on the familiarization trial, indicating some level of dehydration (Armstrong et al. 2010). This individual was

160   administered water (600 mL) and, when reassessed 30 min later, U_{SG} was <1.024. This practice was repeated on all

161   subsequent trials to ensure consistency. All remaining subjects produced initial U_{SG} samples <1.024 at each

162   attendance. Euhydrated participants rested in the supine position for 15 min prior to respiratory gases (VO_2 and

163   VCO_2) (Medgraphic Ultima, MGC Diagnostic Corporation, USA) being measured continuously for 10 min to

164   determine baseline metabolic rate. Following the respiratory measures, participants provided a blood sample, and

165   completed the cognitive function test and subjective feelings questionnaire (Adaptive Visual Analogue Scale

166   (AVAS); Marsh-Richard et al. (2009)). Individuals then voided their bladder completely and a pre-exercise nude

167   BM measurement was obtained.

168

169   *2.6.2 Dehydration and Exercise Protocol*

170   Dehydration was induced via passive heat exposure (10 min, $\sim$70°C, sauna) followed immediately by

171   exercise on a cycle ergometer. Exercise commenced at a workload of 60% PPO (24.2±0.9°C; 66±11% RH).

172   However, subjects who expressed likely volitional exhaustion prior to achieving the required BM loss (1.8%) could

173   choose to reduce the workload by 5% PPO after 20 and 40 min of exercise (the minimum allowable workload was

174 50% PPO). Heart rate (HR) and ratings of perceived exertion (RPE) on the Borg scale (Borg 1998) were collected at

175 10 min intervals throughout exercise. Respiratory gases (VO_2 and VCO_2) were measured continuously between ~12-

176 20 min, ~32-40 min and ~52-60 min of exercise for determination of energy expended during exercise. Nude BM

177 was measured after 60 min of cycling. If BM loss was <1.8% from baseline, participants were required to continue

178 exercise in 10 min intervals (respiratory gasses were collected across the final 5 min of each additional 10 min

179 block). Once a BM loss ≥1.8% was achieved, exercise ceased. The duration and intensity of the exercise was

180 documented during the familiarization and replicated on all subsequent trials. Participants repeated the cognitive

181 function test and responded to the subjective feelings questionnaire immediately after exercise. Individuals then

182 rested in a supine position and a blood sample was drawn. After resting ~15 min, respiratory gases were collected

183 continuously for a final 10 min. Individuals then showered and dried themselves before a final nude BM

184 measurement was obtained. The change in BM due to fluid loss was calculated by subtracting the final post-exercise

185 BM from the pre-exercise BM.

186

187 ### *2.6.3 Nutrition Recovery Period*

188 Participants completed a 4 h recovery period in an observation room adjacent to the exercise laboratory,

189 where they were allowed to undertake sedentary activities. Participants were given immediate access to one of 4

190 commercial beverages (Water, Sports Drink [Energy: 103 kJ·dL^{-1}; CHO: 5.8 g·dL^{-1}; Sodium: 28 mg·L^1; Water: 95.0

191 g·dL^{-1}], LS-MILK [Energy: 279 kJ·dL^{-1}; CHO: 8.9 g·dL^{-1}; Protein: 3.4 g·dL^{-1}; Fat: 1.5 g·dL^{-1}; Sodium: 65 mg·L^1;

192 Water: 84.4 g·dL^{-1}], or HP-MILK [Energy: 344 kJ·dL^{-1}; CHO: 9.9 g·dL^{-1}; Protein: 6.7 g·dL^{-1}; Fat: 1.5 g·dL^{-1};

193 Sodium: 100 mg·L^1; Water: 84.4 g·dL^{-1}]) in excess of expected consumption (~3.0 L) . They were told that the two

194 milk-drinks were *different*, but no further product information was provided. (Participants were not permitted to

195 change flavors between milk trials). All beverages were stored in refrigerators (~4°C) in opaque jugs. Participants

196 were instructed to *"self-serve"* into cups and to "*drink as much as they liked*", as additional fluid would be provided

197 upon request. The beverage vessels did not have volume increments. Palatability was evaluated at the onset of

198 drinking and at the conclusion of the recovery period.

199 After 1 h, participants completed the subjective feelings questionnaire, collected urine output, provided a

200 blood sample, and measured nude BM. They were then given access to a variety of foods for 15 min. Participants

201 entered a private room containing food and a computer (set up for the cognitive function task). They were allowed to

202 bring their beverage, but were asked to refrain from taking other external items. This approach was designed to

203 avoid social interactions which may influence eating behaviors and to reinforce the importance of the cognitive task.

204 Food items included sports bars, fresh fruit, breads and condiments (Supplementary Table S1) with participants

205 being instructed to "*eat as much as they liked*" and that *"more of the same food would be provided in 1 h but no*

206 *food could be removed from the private room due to health and safety regulations*". Participants were also informed

207 that no food would be provided in the 3rd and 4th hour of recovery. In the final 2 min, participants completed the

208 cognitive function test and then returned to the main observation room. These procedures (excluding blood

209 sampling) were repeated at the end of the 2nd hour of the recovery period. At the end of the 3rd and 4th hour,

210 participants completed the cognitive function test and subjective feelings questionnaire, collected urine output and

211 measured nude BM. Blood sampling was also performed at the end of the 4th hour.

212

213 **2.7 Post-Trial Procedures**

214 On leaving the laboratory, participants were required to keep a record of the food/fluid they consumed over

215 the remainder of the day, and to capture images of each item using a tablet device (iPad, Apple®, Cupertino, USA).

216 Participants were encouraged to include a fiducial marker in each image, to assist the investigator in the estimation

217 of portion size. Food records and accompanying images were submitted to an investigator and checked for

218 completeness. Diet records were analyzed using the method previously described. A limit of up to two standard

219 alcoholic drinks (20 g alcohol) was imposed on trial days to avoid alcohol's influence on appetitive responses

220 (Poppitt 1996).

221

222 **2.8 Study Completion Procedures**

223 At the conclusion of the experiment, participants were asked what they believed the true purpose of the

224 investigation was, and, how confident they were that their answer was correct to verify that deception was effective.

225 Individuals also completed the R18 Three-Factor Eating Questionnaire (de Lauzon et al. 2004) to measure

226 influencers of eating behavior.

227

228 **2.9 Data Collection**

229 *2.9.1 Food and Fluid Intake Measures*

9

230   Energy, macronutrient, sodium and water intake during the recovery period was determined by weighing the

231   food (covertly) and beverages to the nearest 1 g after each hour. Participants were aware that beverage intake was

232   being monitored, but no information was provided to participants on how much fluid they consumed. Nutritional

233   values for packaged foods were taken from the product nutrition information panel; values for fresh food items and

234   product water content were derived from the dietary analysis software.

235

236   ### 2.9.2 Estimated Energy Expenditure

237   Gas exchange data was averaged in 30 s segments over the final ~8 min of each collection period. Estimated

238   energy expenditure (eEE) was then quantified in the following increments: pre-exercise (-20–0 min), exercise blocks

239   1 (0–20 min), 2 (20–40 min) and 3 (40–60 min), post-exercise (60–80 min), and total trial (100 min). (Where

240   participants continued exercise in 10 min intervals after 60 min, eEE was also quantified at exercise block 4 (60–70

241   min), such that the total trial time increased to 110 min). Rates and total substrate oxidation were calculated using

242   the equations of Frayn (1983) (assuming negligible protein oxidation). Energy equivalents of 16.75 $kJ \cdot g^{-1}$ of CHO

243   and 37.68 $kJ \cdot g^{-1}$ of fat were utilized to calculate eEE from substrate oxidation (Schubert et al. 2014).

244

245   ### 2.9.3 Urine Sampling and Water Retention

246   At the end of each hour of the recovery period, participants voided their bladder completely into an empty

247   container for measures of hourly urine output and hourly U_{SG}. Participants were permitted to urinate throughout the

248   observation period, and on each occasion, the void was collected and added to the hourly urine output. Total urine

249   loss was calculated as the accumulated urine output from the onset of drinking until the end of the observation

250   period. The proportion of ingested water retained at the end of the 4 h recovery period was calculated as total water

251   intake (i.e. food and beverage) minus total urine output and converted to a percentage of total water intake.

252

253   ### 2.9.4 Body Mass (BM) Measurements

254   Nude BM measures were obtained pre- and ~30 min post-exercise (i.e. after sweating had ceased) and at the

255   end of each hour of the recovery period. All BM measurements were adjusted to account for the non-water mass of

256   the food and beverages consumed.

257

258   *2.9.5 Subjective Feelings and Beverage Palatability Questionnaires*

259   Visual analogue scales (VAS) were used to measure subjective feelings of hunger, thirst and fullness pre- and

260   post-exercise and at each hour of the recovery period. To distract participants from the primary outcomes of the

261   study, individuals were also required to indicate feelings of alertness, concentration, muscle soreness and energy

262   levels. VAS were also used to assess palatability ('pleasantness') at the onset of drinking and at the conclusion of

263   the recovery period. Beverages were subsequently ranked from most to least palatable (1st – 4th) (based on individual

264   participants' preferences) using the average pre/post-recovery palatability rating. All measures were conducted on a

265   100 mm scale, with 0 mm representing 'not at all' and 100 mm representing 'extremely' using a computerized

266   modifiable software program (AVAS; Marsh-Richard et al. (2009)).

267

268   **2.9.6 Blood Sampling**

269   Participants rested for ~5 min in a supine position prior to a 5 mL blood sample being drawn from an

270   antecubital vein. Blood samples were obtained pre-exercise, post-exercise and at the end of the 1st and 4th hour of the

271   recovery period. All samples were collected into pre-treated lithium heparin vacutainers (Becton Dickson

272   vacutainers®) and centrifuged for 10 min (~1350×g). Aliquots of plasma supernatant were stored (-80°C) and later

273   analyzed in duplicate for plasma osmolality (P_{OSM}) using a calibrated, freezing-point depression osmometer

274   (Osmomat 030, Gonotec).

275

276   **2.10 Statistical Analysis**

277   Statistical analyses were completed using SPSS Statistics for Windows, Version 21.0 (IBM Corp. 2012,

278   Armonk, N.Y., USA). All measures were examined for normality (Shapiro-Wilk test) and sphericity (Mauchly's

279   test). Where assumptions of sphericity in repeated measures analyses were violated, the Greenhouse-Geisser statistic

280   was applied. Comparisons between experimental trials for baseline measures (BM, U_{SG}, and P_{OSM}); exercise-induced

281   fluid loss; eEE; previous-day energy and water intake; beverage intake; water intake from beverage ($WI_{Beverage}$), food

282   (WI_{Food}) and beverage plus food (WI_{Total}); energy intake from beverage ($EI_{Beverage}$), food (EI_{Food}) and beverage plus

283   food (EI_{Total}); nutrient intake; urine output; and water retention were performed using one-way repeated measures

284   analysis of variance (ANOVA). The remaining variables were examined using a two-way (Treatment × Time)

285   repeated-measures ANOVA. Pairwise comparisons were performed where significant main effects were present

11

286 (Bonferroni). One-way ANOVA (Bonferroni) were used to conduct post hoc comparisons where significant

287 interaction effects were present. Each of the 18 items on the Three-Factor Eating Questionnaire was given a score

288 between 1 and 4 and item scores were summated into raw scores for cognitive restraint, uncontrolled eating, and

289 emotional eating. Raw scale scores were then transformed to a 0–100 scale [((raw score − lowest possible raw

290 score)/possible raw score range) × 100]. Higher scores in the respective scales are indicative of greater cognitive

291 restraint, uncontrolled, or emotional eating (de Lauzon et al. 2004). Effect sizes are reported as partial eta squared

292 (η_p^2). Significant differences were accepted as $p<0.05$. Data are Mean±SD, unless otherwise indicated.

293

294 **3.0 Results**

295 **3.1 Standardization Procedures**

296 All 8 participants verbally acknowledged compliance to the pre-experimental procedures on arrival at the

297 laboratory. Participants' pre-trial records indicated similar energy, $F_{(3,21)}=1.78$, $p=0.182$; and water,

298 $F_{(3,21)}=0.555$, $p=0.651$; intakes 24 h prior to each experimental trial (Water: 9.2±1.8 MJ, 4.5±0.7 L; Sports Drink:

299 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

300 for BM, U_{SG} and P_{OSM} were also similar across treatments (Table 1).

301

302 **3.2 Exercise-Induced Dehydration**

303 All participants successfully replicated the same exercise protocol at each experimental trial. For three

304 individuals, the total exercise duration was 70 min; the remainder cycled 60 min to achieve the target BM loss. Gas

305 exchange data indicate that participants exercised at an intensity corresponding to 76±5% VO_{2max}. Neither BM loss

306 nor eEE differed significantly by treatment (Table 1) or by trial order, $F_{(3,21)}=0.279$, $p=0.840$; $F_{(3,21)}=0.806$,

307 $p=0.504$, respectively. 4 (Treatment) × 6 (Time) analyses of RPE and HR identified a significant main effect of time

308 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

309 treatment was also observed on HR, $F_{(3,12)}=3.21$, $p=0.044$; however, pairwise comparisons did not detect any

310 differences across trials (p's>0.05). No main effect of treatment was observed on RPE, $F_{(3,21)}=2.07$, $p=0.134$.

311

312 **3.3 Water Intake from Food and Beverages**

313   Water and beverage intakes are displayed in Table 2; beverage intake for individual participants is provided

314   in Supplementary Table S2. Beverage intake did not differ significantly by treatment (Table 2) or by trial order,

315     $F(1.8,12.3)=0.569$, $p=0.558$. However, $WI_{Beverage}$ was significantly lower with LS-MILK and HP-MILK compared to

316   Sports Drink ($p=0.040$) and Water ($p=0.022$), respectively. Whilst WI_{Total} also differed significantly across

317   treatments, pairwise comparisons only indicated a trend for a difference in WI_{Total} between HP-MILK and Water

318   ($p=0.080$); no other differences were observed (p's>0.05). A 4 (Treatment) × 4 (Time) analysis of mean hourly

319   WI_{Total} identified a significant main effect of time, $F(3,21)=62.4$, $p<0.001$, $\eta_p^2=0.90$; such that WI_{Total} was greater in

320   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

321   (315±42 g), 3rd (307±119 g) and 4th (191±140 g) hours of recovery (p's>0.05). No significant treatment × time

322   interaction was observed, $F(9,63)=1.66$, $p=0.118$, $\eta_p^2=0.19$.

323

324   **3.4 Urine Output and Water Retention**

325   Total urine output differed significantly across treatments (Water: 556±314 g; Sports Drink: 459±290 g; LS-

326   MILK: 220±53 g; HP-MILK: 230±117 g; $F(2.0,14.3)=6.57$, $p=0.009$, $\eta_p^2=0.48$). Pairwise comparisons revealed that

327   urine output was elevated with Water compared to HP-MILK ($p=0.048$) and tended to be elevated compared to LS-

328   MILK ($p=0.073$); urine output was similar between all other treatments (p's>0.05). A 4 (Treatment) × 4 (Time)

329   analysis of mean hourly urine outputs (Figure 2) indicated a main effect of time, $F(3,21)=4.544$, $p=0.013$, $\eta_p^2=0.48$;

330   such that mean urine output was greater during the 4th hour of recovery than the 1st hour ($p=0.027$); but comparable

331   across all other time points (p's>0.05). No treatment × time interaction was observed, $F(9,63)=1.25$, $p=0.281$,

332     $\eta_p^2=0.15$. A 4 (Treatment) × 4 (Time) analysis of mean hourly U_{SG} (Figure 2) values identified significant main

333   effects of treatment, $F(3,21)=17.7$, $p<0.001$, $\eta_p^2=0.72$; and time, $F(3,21)=5.62$, $p=0.005$, $\eta_p^2=0.45$; and a significant

334   treatment × time interaction, $F(9,63)=5.70$, $p<0.001$, $\eta_p^2=0.45$. Post hoc comparisons revealed that Water decreased

335   U_{SG} compared to LS-MILK and HP-MILK between the 2nd and 4th hours of recovery (p's<0.05); Sports Drink also

336   decreased U_{SG} compared to LS-MILK ($p=0.031$) and HP-MILK ($p=0.032$) during the 3rd hour of recovery, and

337   tended to decrease U_{SG} compared to LS-MILK ($p=0.084$) and HP-MILK ($p=0.054$) during the 3rd hour of recovery,

338   although this was not at a level of statistical significance. The proportion (%) of WI_{Total} retained differed

339   significantly across treatments (Water: 70.2±13.6%; Sports Drink: 74.2±18.1%; LS-MILK: 84.1±83.7%; HP-MILK:

340   83.7±9.5%; $F(3,21)=5.09$, $p=0.008$, $\eta_p^2=0.42$). Pairwise comparisons revealed that water retention increased with

341   LS-MILK compared to Water (p=0.043), but similar across all other treatments (p's>0.05). The overall quantity (g)

342   of WI_{Total} retained at the conclusion of the experimental protocol did not differ significantly by treatment (Water:

343   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,

344   η_p^2=0.0.7)

345

346   **3.5 Body Mass Changes**

347   Net BM changes are displayed in Figure 3. All trials concluded with participants in a state of negative net

348   BM relative to pre-exercise values (Water: -91±430 g; SD: -93±470 g; LS-MILK: -260±450 g; HP-MILK: -179±419

349   g). A 4 (Treatment) × 6 (Time) analysis of BM changes identified a significant main effect of time, F(1.4,

350   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,

351   η_p^2=0.19. However, post hoc comparisons failed to detect a difference between treatments at any time points

352   (p's>0.05).

353

354   **3.6 Plasma Osmolality**

355   A 4 (Treatment) × 4 (Time) analysis of P_{OSM} values identified significant main effects of treatment,

356   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

357   interaction, F(9,54)=15.5, p<0.001, η_p^2=0.72. Pairwise comparisons indicated that P_{OSM} increased following the

358   exercise-dehydration protocol (287±5 vs. 297±5 mOsm·kg^{-1}, p<0.001). Post hoc comparisons suggested that Water

359   elicited lower P_{OSM} values than LS-MILK (p=0.001) and HP-MILK (p=0.008) after the 1st hour of recovery; Sports

360   Drink also reduced P_{OSM} compared to LS-MILK (p=0.012) at this time (Water: 287±5 mOsm·kg^{-1}; Sports Drink:

361   291±8 mOsm·kg^{-1}; LS-MILK: 298±7 mOsm·kg^{-1}; HP-MILK: 296±4 mOsm·kg^{-1}). After the 4th hour of recovery,

362   Water again elicited lower P_{OSM} values than LS-MILK (p=0.013) and HP-MILK (p=0.004); Sports Drink also

363   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

364   time (Water: 288±5 mOsm·kg^{-1}; Sports Drink: 288±5 mOsm·kg^{-1}; LS-MILK: 295±5 mOsm·kg^{-1}; HP-MILK: 299±4

365   mOsm·kg^{-1}).

366

367   **3.7 Food and Nutrient Intakes**

14

368   Nutrient intakes during the 4 h recovery period and across the entire trial day (trial intake *plus* post-trial diet

369   record) are displayed in Table 2; total energy consumed by individual participants is included in Supplementary

370   Table S2. Mean energy intake (food, beverage and total) differed significantly across treatments during the 4 h

371   recovery period. Pairwise comparisons revealed that EI_{Food} was significantly lower with HP-MILK compared to

372   Water (p=0.005) and Sports Drink (p=0.006); EI_{Food} was also lower with LS-MILK compared to Water (p=0.033)

373   and tended to suppress intake compared to Sports Drink (p=0.086). EI_{Food} did not differ significantly between Water

374   and Sports Drink (p>0.05). Although not statistically significant, EI_{Total} tended to be increased with HP-MILK

375   compared to Water (p=0.071) and Sports Drink (p=0.085). Total CHO and protein intakes also differed significantly

376   across treatments during the 4 h recovery period. Pairwise comparisons revealed that Sports Drink (p=0.004), LS-

377   MILK (p=0.026) and HP-MILK (p=0.014) increased total CHO intake compared to Water; CHO intake was not

378   different between the other beverages (p's>0.05). LS-MILK and HP-MILK also increased total protein intake

379   compared to Water and Sports Drink (p's<0.05); protein intake was also higher with HP-MILK compared to LS-

380   MILK (p=0.006). Participants' post-trial intake of energy, water, CHO, fat and sodium did not differ significantly by

381   treatment (p's>0.05); only dietary protein intake was influenced by the beverage consumed post-exercise. Pairwise

382   comparisons revealed a trend for decreased protein ingestion post-trial with HP-MILK compared to Sports Drink

383   (p=0.065). Nonetheless, 24 h protein intake with HP-MILK was higher than with all other beverages (p's<0.05). 24

384   h energy, CHO and sodium intakes differed significantly by treatment (p's<0.05). Although pairwise comparisons

385   did not detect differences in total energy intake between trials (p's>0.05), LS-MILK and HP-MILK appeared to

386   increase intake in comparison to Water and Sports Drink. Sports Drink (p=0.076), LS-MILK (p=0.022) and HP-

387   MILK (p=0.087) all tended to increase 24 h CHO intake compared to Water.

388

389   **3.8 Gastrointestinal Tolerance**

390   A 4 (Treatment) × 6 (Time) analysis of hunger ratings identified a significant main effect of time,

391    $F(5,35)$=11.5, p<0.001, η_p^2=0.62; and a significant treatment × time interaction, $F(15,105)$=2.27, p=0.008, η_p^2=0.25.

392   Post hoc comparisons revealed that LS-MILK and HP-MILK decreased subjective hunger compared to Water and

393   Sports Drink during the 1st hour of recovery (p's<0.05). Hunger ratings were not significantly different at any other

394   point in time (p's>0.05). 4 (Treatment) × 6 (Time) analyses revealed significant main effects of treatment on thirst,

395    $F(1.4,9.7)$=34.4, p<0.001, η_p^2=0.83; and fullness ratings, $F(3,21)$=3.81, p=0.025, η_p^2=0.35; significant main effects

396   of time on thirst, $F_{(5,35)}=22.1$, $p<0.001$, $\eta_p^2=0.76$; and fullness ratings, $F_{(5,35)}=27.9$, $p<0.001$, $\eta_p^2=0.80$; and

397   significant treatment × time interactions on thirst, $F_{(15,105)}=10.4$, $p<0.001$, $\eta_p^2=0.60$; and fullness ratings,

398    $F_{(15,105)}=2.12$, $p=0.014$, $\eta_p^2=0.23$. Post hoc comparisons demonstrated that LS-MILK and HP-MILK increased

399   subjective fullness compared to Water during the 1st hour of recovery (p's<0.05). Fullness ratings were not

400   significantly different between treatments at any other point in time (p's>0.05). Ingestion of LS-MILK and HP-

401   MILK increased thirst ratings compared to Water and Sports Drink at all stages of recovery (p's<0.05).

402

403   **3.9 Beverage Palatability**

404   A 4 (Treatment) × 2 (Time) analysis of beverage pleasantness ratings failed to indicate a significant main

405   effect of beverage, $F_{(1.5,10.6)}=1.97$, $p=0.150$, $\eta_p^2=0.22$; although, pleasantness ratings were generally increased

406   with Water (79 ± 30 mm) and Sports Drink (70 ± 33 mm) compared to LS-MILK (50 ± 16 mm) and HP-MILK (56

407   ± 15 mm). The analysis identified a significant main effect of time, $F_{(3,7)}=10.4$, $p=0.015$, $\eta_p^2=0.60$; such that

408   pleasantness decreased between the onset and conclusion of the drinking period (67 ± 9 mm vs. 60 ± 10 mm). Total

409   beverage intake also differed by palatability, $F_{(3,21)}=10.6$, $p<0.001$, $\eta_p^2=0.60$; such that the participants consumed a

410   significantly greater quantity of their most preferred beverage than their least- ($p=0.007$) and second-least ($p=0.004$)

411   preferred beverages (1st: 2057 ± 498 g; 2nd: 1662 ± 370 g; 3rd: 1471 ± 389 g; 4th: 1515 ± 496 g).. Average ratings for

412   the 1st, 2nd, 3rd and 4th most palatable beverages were 95±5 mm, 72±19 mm, 52±14 mm and 34±12 mm, respectively.

413

414   **3.10 Post-Study Survey**

415   All 8 participants indicated that the purpose of the study was to investigate the effect of consuming different

416   beverages on recovery of cognitive function. Of these, 7 indicated they were either *absolutely* or *very confident* in

417   this response; one subject was *somewhat confident*. Mean±SD (Range) scores for Uncontrolled Eating, Cognitive

418   Restraint and Emotional Eating on the R18 Three-Factor Eating Questionnaire were: 33±11% (19–53%), 23±18%

419   (0–50%), and 25±26% (0–75%), respectively. No participant exceeded clinical thresholds for any of these

420   characteristics.

421

422

423

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

452   consumption by ~30–42% compared to water (Maughan and Leiper 1994; Brouns et al. 1998; Park et al. 2012;

453   Campagnolo et al. 2017) and by >50% compared to milk-based beverages post-exercise (Baguley et al. 2016;

454   Campagnolo et al. 2017). Each of the different test beverages in the present study were consumed in roughly similar

455   volumes. The inconsistency in findings between the current and previous reports may reflect gender differences.

456   That is, the former studies have predominantly been conducted using male participants and some evidence (albeit in

457   older individuals and/or during exercise) suggests sex differences exist in voluntary fluid consumption for different

458   beverages (Baker et al. 2005). Indeed, Baker et al. (2005) observed that females consumed more water but not CES

459   than males relative to BM. Furthermore, males consumed significantly more CES than water, but intakes between

460   the two beverages for females were not statistically different. Whilst this study examined fluid intake during rest

461   periods interspersed throughout an exercise protocol (and is therefore not directly comparable to the present study),

462   similar behaviors may apply post-exercise.

463   While beverage intakes were similar *on average* in this study, it is worthwhile noting that volumes varied

464   considerably at an individual-level (Supplementary Table S2). This may be due to participants having different taste

465   preferences. On examining the data, we can see that participants who indicated Sports Drink was "more pleasant"

466   than Water (*n*=2) did in fact, consume ~40% more Sports Drink; whilst those who perceived Sports Drink as "more

467   pleasant" than LS-MILK (*n*=5) and HP-MILK (*n*=5) also consumed ~40% more of the preferred beverage. The

468   influence of palatability is further demonstrated by the fact that participants consumed a greater amount of their

469   most preferred beverage than their least- and second-least preferred beverages. These data indicate that palatability

470   is an important determinant of fluid intake and that taste preferences can vary greatly amongst individuals. The

471   importance of thirst and beverage palatability as factors influencing fluid intake post-exercise is further supported by

472   results of the current study, where HP-MILK and LS-MILK were consumed in similar volumes. These two

473   beverages had similar sensory characteristics (flavor, mouth-feel, appearance, aroma), yet contrasting nutrient

474   profiles. Clearly, physiological/psychological cues provided when consuming similar tasting beverages with

475   different nutrition are too subtle or participants are unable to detect them to moderate drinking behavior. Thus,

476   individuals likely revert to consuming the beverage to relieve thirst and/or on the basis that they find it

477   palatable/pleasant, which influences intake volume.

478   Findings from this study indicate that food plays an important role in mediating fluid recovery following

479   exercise when beverages with basic nutrient profiles are consumed. Although the present investigation did not

480   incorporate a "beverage only" trial for direct comparisons, the available evidence suggests that if food is *not*

481   consumed, just ~30–56% of water (Maughan and Leiper 1995; Shirreffs and Maughan 1998; Shirreffs et al. 2007a;

482   Shirreffs et al. 2007b; Merson et al. 2008; Wong and Chen 2011; James et al. 2014; Stasiule et al. 2014; Tai et al.

483   2014; Wong et al. 2014; Seery and Jakeman 2016) and ~38–64% of sports drink (Wong et al. 2000; Shirreffs et al.

484   2007a; Shirreffs et al. 2007b; Watson et al. 2008; Evans et al. 2009b; James et al. 2011; Wong and Chen 2011;

485   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

486   et al. 2015; Seery and Jakeman 2016) is typically retained post-ingestion (1.50 L·kg BM lost^{-1}). Values indicated in

487   the current investigation are noticeably higher (Water: 70.2±13.6%; Sports Drink: 74.2±18.1%). This observation is

488   consistent with results from previous experiments suggesting that the consumption of food (providing energy and

489   nutrients) enhances fluid retention (Maughan et al. 1996; Pryor et al. 2015) by delaying gastric emptying and

490   attenuating osmotic diuresis (Nose et al. 1988). It is important to note that the male subjects in Campagnolo et al.

491   (2017) retained a *very similar* proportion of ingested water (Trial #1: 72±8%; Trial #2: 73±11%) and Powerade[®]

492   (74±17%) as the female participants in the current study, even though females derived roughly half the amount of

493   energy, CHO, protein and sodium (relative to BM) from food across on all beverage treatments. The fact that

494   individuals retained a similar proportion of Water and Sports Drink is also interesting, as it suggests that water may,

495   in fact (contrary to popular belief), be an appropriate rehydration solution when co-ingested with food; particularly,

496   if the calories delivered in sports beverages are not desired. Collectively, these data suggest that consuming food *ad*

497   *libitum* after exercise is likely to enhance fluid retention similarly in males and females, despite differences in their

498   dietary behavior.

499   Results from the present study indicate that the choice of recovery beverage can have a profound effect on

500   overall dietary intake. Total energy intake during the 4 h recovery period increased proportionately to the energy-

501   density of the experimental beverage (even despite an opposing step-wise reduction in energy consumed from food).

502   An analysis of the participants' post-trial diet records revealed that individuals did not modify their dietary behavior

503   over the remainder of the day to offset this difference in energy consumption. While the caloric beverages increased

504   CHO intake post-exercise (Water: 0.4±0.2 g CHO ·kg^{-1}·h^{-1}; all other treatments: 0.8±0.2 g·kg^{-1}·h^{-1}), it is worth noting

505   that ad libitum intake of food and any beverage included in this study failed to meet recommended CHO intakes for

506   "rapid refueling" after exercise; though total daily intakes were within the recommended range (~3.0–5.0 g CHO·kg^{-1}·d^{-1}

507   ^{1}·d^{-1}) (Thomas et al. 2016). Protein consumption during the first 2 h after exercise was in excess of recommendations

508   (0.25–0.30 g·kg^{-1}); particularly, when the milk-based beverages were consumed (Water: 0.47±0.17 g·kg^{-1}; Sports

509   Drink: 0.39±0.09 g·kg^{-1}; LS-MILK: 0.81±0.28 g·kg^{-1}; HP-MILK: 1.49±0.41 g·kg^{-1}) (Thomas et al. 2016). Total daily

510   protein intakes were generally appropriate (i.e. ~1.2–2.0 g·kg^{-1}·d^{-1}), but exceeded recommended levels on the HP-

511   MILK (2.6±0.8 g·kg^{-1}·d^{-1}) (Thomas et al. 2016). Hence, the type of beverage consumed may influence aspects of

512   post-exercise recovery and the suitability of certain beverages for individuals with specific dietary goals). For

513   instance, caloric beverages may facilitate rehydration, substrate repletion and positive energy balance in situations

514   where weight gain or large nutritional intakes are required. Whereas, the consumption of water (with food) should

515   be encouraged to facilitate rehydration without excessive caloric intake in circumstances where weight loss or

516   maintenance is desirable.

517

518   This investigation (and results from Campagnolo et al. (2017)) provides evidence that different commercial

519   beverages promote similar levels of fluid recovery after exercise. However, it is important to consider that "rapid

520   rehydration" is typically utilized to facilitate recovery *ahead of a subsequent exercise session*. Under these

521   circumstances, individuals may restrict their intake of food/fluid to avoid GI discomfort during exercise; potentially

522   affecting fluid and nutrient recovery. Additional research is required to determine the behaviors of athletes given

523   access to *ad libitum* food and different beverages when they are required to perform a subsequent exercise session;

524   and impact of these behaviors on post-exercise recovery and subsequent exercise performance.

525

526   In summary, this study demonstrates that different beverages are similarly effective at replenishing exercise-

527   induced sweat loss, but result in different energy/nutrient intakes, when consumed *ad libitum* with food. An athlete's

528   acute nutritional requirements to support recovery, broader dietary goals, taste preferences and access to food should

529   therefore inform selection of the most appropriate recovery beverage.

530

531   **5.0 Acknowledgements**

534

535

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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™; LS-MILK: Up & Go Reduced Sugar™. 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.
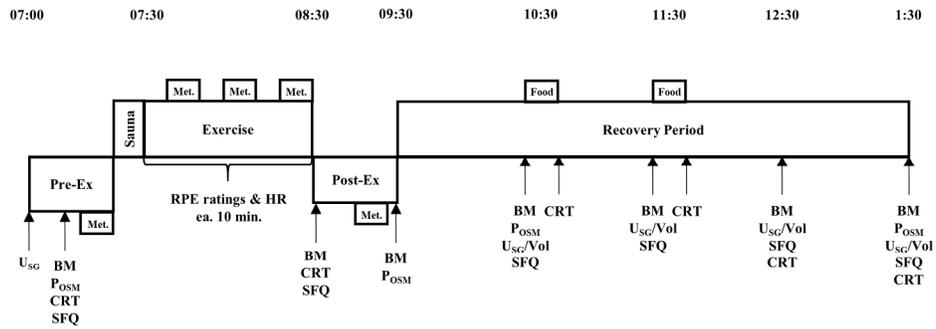
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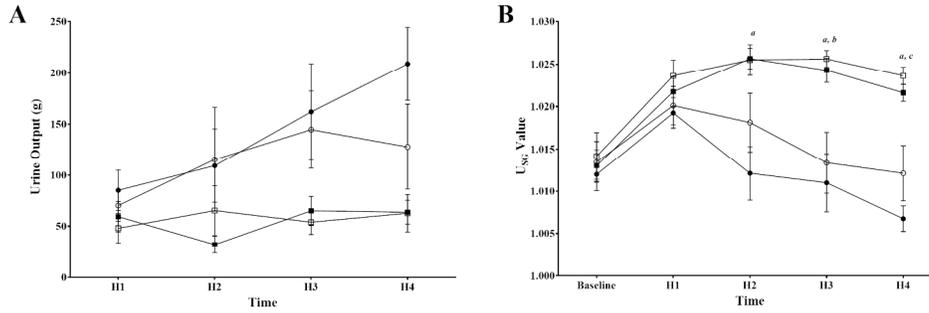
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Figure 2. Hourly urine output (A) and U_{SG} values (B) under each of the experimental treatments. Values are Mean±SEM for Water (●); Sports Drink (○); LS-MILK (■); HP-MILK (□). *a*, Water significantly different to LS-MILK and HP-MILK; *b*, Sports 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.
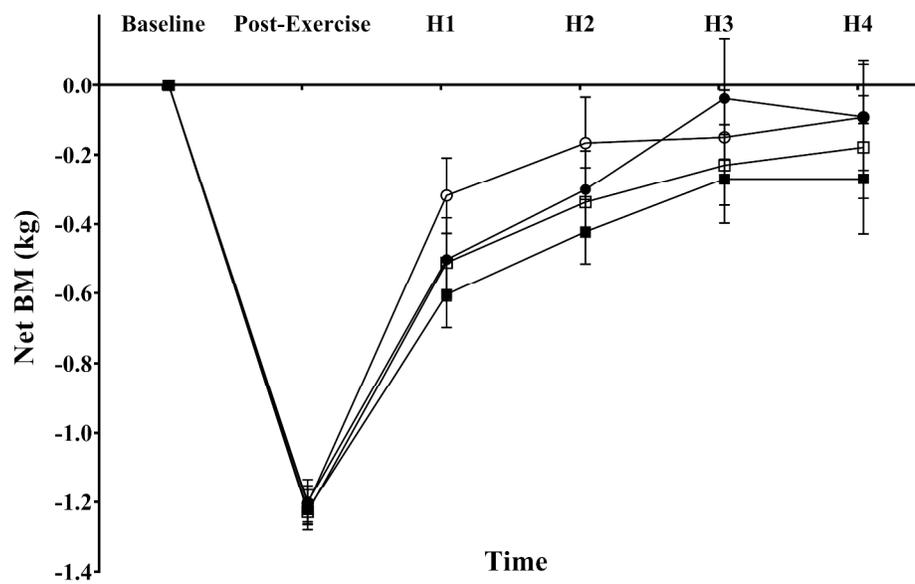
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Figure 3. Net BM responses under each of the experimental treatments. Values are Mean±SEM for Water (●); Sports Drink (○); LS-MILK (■); HP-MILK (□). H1–4: Hours 1 to 4 of the recovery period.

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