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The Effect of Different Post-Exercise Beverages with Food on *Ad Libitum* Fluid Recovery, Nutrient Provision, and Subsequent Athletic Performance

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Abstract:

This study investigated the effect of consuming either water or a carbohydrate (CHO)-electrolyte sports beverage ('Sports Drink') *ad libitum* with food during a 4 h post-exercise recovery period on fluid restoration, nutrient provision and subsequent endurance cycling performance. On two occasions, 16 endurance-trained cyclists; 8 male [M] (age: 31±9 y; VO_{2max}: 54±6 mL·kg^{-1}·min^{-1}) and 8 female [F] (age: 33±8 y; VO_{2max}: 50±7 mL·kg^{-1}·min^{-1}); lost 2.3±0.3% and 1.6±0.3% of their body mass (BM), respectively during 1 h of fixed-intensity cycling. Participants then had *ad libitum* access to either Water or Sports Drink and food for the first 195 min of a 4 h recovery period. At the conclusion of the recovery period, participants completed a cycling performance test consisting of a 45 min fixed-intensity pre-load and an incremental test to volitional exhaustion (peak power output, PPO). Beverage intake; total water/nutrient intake; and indicators of fluid recovery (BM, urine output, plasma osmolality [P_{OSM}]) were assessed periodically throughout trials. Participants returned to a similar state of net positive fluid balance prior to recommencing exercise, regardless of the beverage provided (Water: +0.4±0.5 L; Sports Drink: +0.3±0.3 L, p=0.529). While Sports Drink increased post-exercise energy (M: +1.8±1.0 MJ; F: +1.3±0.5 MJ) and CHO (M: +114±31 g; F: +84±25 g) intake (i.e. total from food and beverage) (p's<0.001), this did not improve subsequent endurance cycling performance (Water: 337±40 W [M] and 252±50 W [F]; Sports Drink: 340±40 W [M] and 258±47 W [F], p=0.242). Recovery beverage recommendations should consider the post-exercise environment (i.e. the availability of food), an individual's tolerance for food and fluid pre-/post-exercise, the immediate requirements for refueling (i.e. CHO demands of the activity) and the athlete's overall dietary goals.

Key words: Exercise Nutrition; Exercise Recovery; Eating Behavior; Hydration; Carbohydrate

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1.0 Introduction

The body's fluid and substrate stores (e.g. muscle/liver glycogen) are progressively depleted during prolonged exercise [1,2]. Endurance athletes may be required to complete consecutive exercise sessions with short periods of rest between bouts. In these situations, individuals have a limited opportunity to recover lost nutrients and are at risk of carrying residual carbohydrate (CHO) and/or fluid deficits from one activity to the next. To rapidly restore losses, individuals are encouraged to consume 1.25–1.50 L $H_2O \cdot kg\ lost^{-1}$ and 1.0–1.2 g $CHO \cdot kg^{-1} \cdot h^{-1}$ for 4 h beginning ≤30 min post-exercise [1,2]. These recommendations exist as dehydration [3] and low CHO availability [4] can impair endurance performance. Given their ability to deliver both fluid and nutrients, beverages may assist athletes to rehydrate and refuel simultaneously after exercise [5,6].

Numerous studies have investigated the ability of different beverages to influence acute recovery from exercise (i.e. restore fluid/substrate losses) and improve subsequent performance. Collectively, the available evidence suggests: (1) beverages with "complex" nutritional profiles (e.g. milk/milk-based formulations) are more effective rehydration agents than beverages with "simple" nutritional profiles (e.g. water and CHO-electrolyte sports beverages) [7-10]; and that (2) the consumption of CHO-containing beverages in the post-exercise period improves muscle glycogen resynthesis [11] and subsequent endurance performance [6,12]. However, these studies typically "prescribe" drinking (i.e. fluid volume and rate) and deny participants access to food. Studies that have allowed participants to eat during experiments generally indicate that the co-ingestion of food and fluid increases retention of "simple" rehydration beverages [13-15]. Still, most of these investigations have prescribed a small number of food items which may not reflect participants' usual dietary behaviour. Given that individuals usually control the volume of fluid they consume, and often have access to food during the post-exercise period, personal and/or contextual factors may alter fluid/nutrient recovery and influence subsequent performance.

Two recent studies conducted in our laboratory have investigated how the provision of different beverages influences post-exercise fluid/nutrient recovery when consumed voluntarily and with access to food [16,17]. These studies, involving endurance-trained males (M; n=10) [16] and females (F; n=8) [17], gave participants *ad libitum* access to one type of beverage (water, a CHO-electrolyte sports beverage or several milk-based formulations) and a variety of foods during a 4 h recovery period. In both instances, the different beverages were similarly effective at replenishing fluid losses. This was attributed to: (1) the water and CHO-electrolyte sports beverage being ingested in larger volumes than the milk-based formulations, and (2) the co-ingested food improving retention of these "simple" fluids [13,14]. Importantly, however, the consumption of different beverages did influence energy and CHO intake [16,17]. Specifically, the administration of a CHO-electrolyte sports beverage increased energy (M: ~2.5 MJ, or ~32%; F: ~1.0 MJ, or ~25%) and CHO (M: ~186 g, or ~95%; F: ~73 g, or ~68%) intake, compared to water. The milk-based formulations also increased energy and nutrient provision (to a similar extent observed with the CHO-electrolyte sports beverage for males and to an even greater extent in females); though, these tended to increase ratings of gastrointestinal (GI) discomfort [16-18]. Given that in both previous investigations participants were free to leave the laboratory at the end of the recovery period, the extent to which anticipation of a subsequent exercise session influences food/fluid choices requires clarification. In addition, whether the nutrient differences associated with access to the different beverages influences subsequent performance remains unknown.

The aim of this study was to investigate the effect of consuming either a commercial CHO-electrolyte sports beverage or plain water *ad libitum* (with food) during a 4 h post-exercise recovery period on fluid restoration, nutrient provision and subsequent endurance cycling performance in trained individuals. We hypothesized both beverages would be effective at replenishing fluid losses. Furthermore, we anticipated that access to a CHO-electrolyte sports beverage would increase CHO ingestion and therefore improve subsequent endurance cycling performance.

2.0 Materials and Methods

2.1 Participant Characteristics

Competitive, endurance-trained cyclists/triathletes aged 18–45 y were eligible to take part in this investigation. Sample size was determined using power calculation software (G*Power Version 3.1.9.2, University Kiel Germany, 2014). Our previous studies investigating post-exercise *ad libitum* food and fluid consumption behavior have demonstrated significant beverage effects (i.e. Water vs. Sports Drink) on total CHO intake in males (Cohen's d_Z=2.7) [16] and females (d_Z=2.1) [17]. Using a power (1-β) of 0.95, an α=0.01 and a more conservative effect size (d_Z=2.0), we anticipated that 8 male and 8 female subjects would be required to create a significant difference in CHO ingestion (i.e. within each sub-group). Twenty-four participants were recruited to account for attrition. Seven withdrew after completing one or both of the familiarization sessions (2 were lost to follow-up and 5 withdrew due to unavailability); an eighth participant was lost to follow-up after their first experimental trial. Thus, 16 participants; 8 male (age: 31±9 y; VO_{2max}: 54±6 $mL \cdot kg^{-1} \cdot min^{-1}$; PPO: 384±22 W; cycling: 214±124 $km \cdot week^{-1}$) and 8 female (age: 33±8 y; VO_{2max}: 50±7 $mL \cdot kg^{-1} \cdot min^{-1}$; PPO: 248±52 W; cycling: 204±87 $km \cdot week^{-1}$), completed both trials. This investigation was approved by the University's Human Ethics Committee (GU 2017/969) 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. Participants attended the laboratory on 5 occasions to complete a preliminary screening, two familiarization sessions, and two repeated-measures experimental trials. Experimental trials were separated by 4–14 d and counterbalanced for order. Female participants completed both experimental trials during the same menstrual phase (i.e. either the follicular or the luteal) to reduce the confounding influence of hormonal changes on appetite [19] and substrate utilization [20]; those using hormonal contraceptives (n=3) completed testing while on the active medication. Each experimental trial involved an initial standardized exercise bout on a stationary cycle ergometer, followed by a 4 h recovery period and a cycling performance test. Participants had *ad libitum* access to one test beverage – either Water or Powerade® Isotonic (Coca Cola Ltd.) ('Sports Drink') – and food for the first 195 min of the recovery period; no further food or fluid was consumed from 45 min prior to the performance test.

2.3 Eligibility, Preliminary Screening and Familiarization

On arrival at the initial visit, individuals completed a medical screening questionnaire and the Eating Attitudes Test-26 (EAT-26) [21]. 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 the EAT-26 indicated possible disordered eating, as were volunteers who reported an allergy, intolerance or dislike toward multiple food items or either test beverage used in the investigation. A self-reported body mass (BM) history (~6 months) was then collected. To participate, individuals had to be weight stable and not followed an energy-restricted diet in the previous 6 months. Once eligibility was verified, participants Sports Drink flavor preferences (Mountain Blast, Lemon-Lime or Berry Blast) were recorded. Participants then completed a graded exercise test on an electronically-braked cycle ergometer (Lode Excalibur Sport; Lode BV, Groningen, Netherlands) for determination of maximal aerobic capacity (VO_{2max}) using previously described protocols for males [16] and females [17]. Participants' respiratory gases were sampled continuously by breathing into a calibrated gas-analysis system (Medgraphics Ultima, MGC Diagnostics and Medisoft, USA). Peak sustainable power output (PPO) was also calculated [22] and used to set the exercise intensity on all trials. Following the preliminary screening visit, all participants undertook two familiarization sessions where they practiced the cycling performance test, before completing the main experimental trials.

2.4 Pre-Trial Procedures

Prior to trials, participants were instructed to: (1) abstain from alcohol and moderate/strenuous exercise (>24 h); (2) avoid caffeine-containing products (>12 h); (3) keep a record of all food and beverages consumed (24 h); (4) consume a pre-packaged standardized evening meal (~60 $kJ \cdot kg^{-1}$) [16]; (5) fast overnight (~10 h); and (6) collect a first-morning urine sample and consume 200 mL of water on waking before arriving at the laboratory. Each participant received a copy of their 24 h diet record (after their initial trial) and was instructed to replicate their behavior ahead of the subsequent trial.

2.5 Experimental Procedures

2.5.1 Pre-Exercise Period

Participants arrived at the laboratory fasted (~5–7 AM) and verbally acknowledged compliance to the pre-trial procedures; females also reported the onset of menstruation to determine menstrual phase. First-morning urine samples were analysed to determine urine specific gravity (U_{SG}; Palette Digital Refractometer, ATAGO, USA). If U_{SG} was ≥1.024, indicating likely dehydration [23], a second sample was collected and U_{SG} was re-assessed (all samples had U_{SG}'s<1.024). Euhydrated participants provided a blood sample and completed the GI questionnaire, before voiding their bladders completely and taking a pre-exercise nude BM measurement (HW-PW200; A&D Company Ltd, Tokyo, Japan).

2.5.2 Initial Standardized Exercise

The initial standardized exercise consisted of 6 consecutive 10 min 'blocks' performed on a cycle ergometer (Lode Excalibur Sport; Lode BV, Groningen, Netherlands). Blocks involved 8 min *steady-state* cycling, 1 min *high-intensity* cycling, and a 1 min *recovery* cycling (M: 125 W; F: 75W) period. For males, the steady-state and high-intensity phases were completed at 55% (211±12 W) and 70% (269±15 W) of their PPO, respectively; while, females exercised at 50% (124±26 W) and 70% (173±37 W) of their PPO. Fluid consumption was not permitted during exercise. Heart rate (HR; Ambit3 Peak, Suunto®, Vantaa, Finland) and ratings of perceived exertion (RPE) on the Borg scale (Range: 6–20) [24] were recorded at the end of each steady-state and high-intensity phase. Following activity, participants collected an initial post-exercise nude BM measurement, completed the GI questionnaire and provided a blood sample.

2.5.3 Post-Exercise Recovery Period

The 4 h recovery period began ~10 min post-exercise. For the first 5 min (while continuing to sweat), participants were restricted to consuming their assigned beverage only, i.e. Water (sodium: 3 $mg \cdot L^1$) or Sports

Drink (Energy: 103 kJ·dL^{-1}; CHO: 5.8 g·dL^{-1}; Sodium: 28 mg·L^{1}; Water: 95.0 g·dL^{-1}); they then recorded a second post-exercise nude BM measurement. Exercise-induced fluid loss was calculated as the initial change in BM (i.e. pre- to post-exercise) plus the post-exercise change in BM (i.e. the initial post-exercise BM minus the second post-exercise BM, after accounting for the volume of beverage consumed). Participants were then taken to an observation room, where they were able to continue drinking the assigned beverage and given access to a variety of foods. The food items included muesli bars, fresh fruit, bread and condiments (Supplementary Table S1). Individuals were instructed to "*self-serve*" and to "*eat and drink as much as they liked"*, as more would be provided upon request. The "eating/drinking period" lasted 195 min; participants were informed that no food or fluid would be available in the final 45 min of the recovery period. The beverage vessels were opaque and did not have volume increments; all beverages were stored in personal refrigerators (4°C). After 1 h of recovery, participants completed the GI questionnaire, collected their urine output and provided a blood sample, before showering and returning to the observation room. Individuals repeated the GI questionnaire and urine collection at the end of the second, third and fourth hours of the recovery period; blood sampling was repeated at the end of the fourth hour.

2.5.4 Cycling Performance Test

The cycling performance test consisted of a 45 min pre-load culminating in an incremental test to volitional exhaustion (Lode Excalibur Sport; Lode BV, Groningen, Netherlands). Male and female participants cycled (in front of a fan) at 55% and 50% of PPO, respectively during the 45 min pre-load; HR and RPE were recorded at 15 min intervals throughout. The incremental test consisted of a 1 W increase every 6 s until volitional exhaustion; a similar protocol has previously demonstrated sensitivity to different CHO doses [25]. Exhaustion was determined when the participant voluntarily ceased exercise or when their pedal cadence dropped below a threshold level (M: 75 rpm; F: 70 rpm) for a third time (individuals received two initial "warnings"). Maximum HR attained and PPO were recorded at the conclusion of exercise. Participants did not receive any feedback on elapsed time or encouragement during the test; investigators stood quietly behind the participant (i.e. outside their line of view). A financial incentive was provided to encourage engagement in the performance test. Participants completed the GI questionnaire shortly after exercise ceased.

2.6 Study Completion Procedures

At the conclusion of the second trial, participants completed a short questionnaire evaluating their knowledge/beliefs regarding certain aspects of sports nutrition (e.g. post-exercise rehydration and CHO consumption) and food composition (i.e. the CHO content of the food items offered in this investigation); questions were based on those used in a previous questionnaire [26]. Participants indicated their expectations regarding the ability of different beverages to influence cycling performance, and whether (or not) they consciously altered their dietary behavior as a result of trial order or the type of beverage provided. Lastly, participants completed the R18 Three-Factor Eating Questionnaire [27] to assess cognitive, behavioral and emotional influencers of eating behavior.

2.7 Data Collection

2.7.1 Food and Fluid Intake Measures

Energy, macronutrient, sodium and water consumption during the recovery period was estimated by weighing all food and beverages to the nearest 1 g pre-ingestion, and then again 90 and 195 min into the eating/drinking period (i.e. approximately halfway and at the end). Individuals were aware that their dietary behavior was being monitored. Nutritional values for packaged foods were taken from the product nutrition information panel; values for fresh food items and product water content were obtained from FoodWorks® Version 8 dietary analysis software (Xyris Software Pty Ltd, Spring Hill, Australia).

2.7.2 Urine Sampling and Water Retention

Participants voided their bladder completely into an empty container at the end of each hour of the recovery period for measures of hourly and total urine loss. Individuals 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. Each hourly urine sample was also analyzed to determine U_{SG} (Palette Digital Refractometer, ATAGO, USA). The proportion of ingested water (i.e. from food and beverage) retained at the end of the 4 h recovery period was calculated using the following formula:

$$\text{Water Retained (\%)} = \frac{(\mathrm{WI_{Total}(g)} - \text{Urine Output (g)})}{\mathrm{WI_{Total}(g)}} \times 100$$

where WI_{Total} represents the total amount of water consumed via food and beverage during the recovery period. Net fluid balance was also estimated as follows:

$$\text{Net Fluid Balance (g)} = \text{Fluid Loss (g)} + (\mathrm{WI_{Total}}\ \text{(g)} - \text{Urine Output (g)})$$

2.7.3 Gastrointestinal (GI) and Beverage Palatability Questionnaires

Visual analog scales (VAS) were used to evaluate GI symptomology (hunger, thirst, fullness and nausea) pre- and post-exercise, at the end of each hour of the recovery period and immediately after the performance test. VAS were also used to assess palatability ('beverage pleasantness') at the onset of drinking. All measures were completed on a 100 mm scale, with 0 mm representing 'not at all' and 100 mm representing 'extremely' using a computerized modifiable software program (Adaptive Visual Analog Scale; Marsh-Richard*, et al.* [28]).

2.7.4 Blood Sampling

For collection of blood samples, participants rested in a supine position prior to a 5 mL blood sample being drawn from an antecubital vein. 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 at -80°C and later analysed in duplicate to determine plasma osmolality (P_{OSM}) on a calibrated (300 $mOsm \cdot kg^{-1}$) osmometer (Osmomat 030, Gonotec, Germany).

2.8 Statistical Analysis

Statistical analyses were completed using SPSS Statistics for Windows, Version 25.0 (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 BM loss; fluid retention and net balance; total water intake from beverage ($WI_{Beverage}$), food

(WI_{Food}), and WI_{Total}; total nutrient intake; total urine output; beverage palatability; and PPO and maximum HR attained on the incremental cycling test; were conducted using Treatment × Sex split-plot analyses of variance (ANOVAs). Treatment × Time × Sex split-plot ANOVAs were used to investigate HR and RPE values; hourly urine outputs and U_{SG} values; and subjective GI ratings. Pairwise comparisons (Bonferroni) were completed where significant main effects were present. Paired and independent *t* tests (i.e. for within and between-subject analyses) were used to conduct post hoc comparisons on significant interaction effects. Paired *t* tests were also used to compare temperature and relative humidity (RH) across experimental trials and test for trial order effects on select variables. Each of the 18 items on the Three-Factor Eating Questionnaire was given a score between 1 and 4 and item scores were summed 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 [27]. Effect sizes were calculated 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 16 participants verbally acknowledged compliance to the pre-trial procedures on arrival at the laboratory. Pre-exercise values for BM and P_{OSM} differed significantly by Sex (Table 1); however, no main effects of Treatment or Treatment × Sex interactions were observed (*p*'s>0.05); pre-exercise U_{SG} values did not differ by Treatment, by Sex, or indicate a Treatment × Sex interaction (*p*'s>0.05) (Table 1). Temperature, $t(15)=0.368$, $p=0.718$; and RH, $t(15)=1.11$, $p=0.287$; were also similar on each trial (Water: 25±1°C, 61±10%; Sports Drink: 25±1°C, 63±8%).

3.2 Initial Standardized Exercise

Neither HR nor RPE differed significantly by Treatment during either the *steady-state*, $F_{[1,14]}=0.091$, $p=0.767$; $F_{[1,14]}=3.29$, $p=0.096$, respectively; or *high-intensity*, $F_{[1,14]}=0.265$, $p=0.615$; $F_{[1,14]}=0.469$, $p=0.505$, respectively; exercise phases and no Treatment × Time interactions were observed (*p*'s>0.05). On average, males and females cycled at 80±6% HR_{max} (RPE: 13±1) and 75±6% HR_{max} (RPE: 12±1) in the *steady-state phase*; and 85±7% HR_{max} (RPE: 15±1) and 82±7% HR_{max} (RPE: 14±1) in the *high-intensity phase*, respectively. BM loss did not differ significantly by Treatment or indicate a Treatment × Sex interaction; though males lost a greater proportion of their pre-exercise BM than females (Table 1).

3.3 Water Intake, Output and Retention

3.3.1 Beverage Intake and Water Intake from Food and Beverages

Fluid consumption data are summarized in Table 2. Total beverage intake, $WI_{Beverage}$, WI_{Food} and WI_{Total} did not differ significantly by Treatment or indicate a Treatment × Sex interaction; beverage intake and $WI_{Beverage}$ were also similar by Sex, although male participants consumed a greater quantity of WI_{Food} and, subsequently, WI_{Total} than females (Nb., however, that total beverage intake, $t(15)=3.31$, $p=0.005$ [Trial #1: 1.8±0.5 L; #2: 2.1±0.6 L]; and WI_{Total}, $t(15)=3.16$, $p=0.006$ [Trial #1: 2.1±0.6 L; #2: 2.4±0.6 L]; indicated significant trial order effects). An analysis of fluid ingestion over time revealed that participants consumed a greater quantity of WI_{Total} during the first half of the eating/drinking period (Males: 1624±299 g; Females: 1157±299 g) than the second half

(Males: 992±275 g; Females: 810±275 g), $F_{[1,14]}$=32.4, p<0.001, η_p^2=0.70; no other differences were detected in this analysis (p's>0.05). Beverage pleasantness ratings did not differ by Treatment, $F_{[1,14]}$=3.16, p=0.097; by Sex, $F_{[1,14]}$=1.34, p=0.267; or indicate a Treatment × Sex interaction, $F_{[1,14]}$=3.51, p=0.082; participants indicated a relatively high degree of liking for both beverages (Water: 86±13 mm; Sports Drink: 74±27 mm).

3.3.2 Urine Output and Water Retention

Urine output and water retention data are summarized in Table 2. Total urine output did not differ significantly by Treatment, by Sex, or indicate a Treatment × Sex interaction. Hourly urine outputs indicated a main effect of Time, $F_{[1.8,24.7]}$=7.30, p=0.004, η_p^2=0.34; such that urine output tended to be greater during the final hour of recovery (207±136 g), than during the first (105±76 g, p=0.071) and second (96±52 g, p=0.009) hours. No other significant differences were detected in this analysis (p's>0.05); analysis of hourly U_{SG} values also failed to indicate any significant effects (p's>0.05). Neither the proportion (%) or quantity (g) of WI_{Total} retained at the end of the recovery period differed by Treatment, or indicated a Treatment × Sex interaction; though males typically retained a greater proportion and total quantity than females. Regardless of the beverage consumed, participants were in a similar state of net positive fluid balance at the conclusion of the recovery period.

3.3.3 Plasma Osmolality

P_{OSM} values indicated a significant main effect of Time, F(3,39)=57.1, p<0.001, η_p^2=0.82. Pairwise comparisons revealed that P_{OSM} increased from pre- to post-exercise (291±3 vs. 302±3 mOsm·kg^{-1}, p<0.001), and then decreased from post-exercise to the end of the first hour of recovery (298±3 mOsm·kg^{-1}, p=0.004), and from the end of the first to the end of the fourth hour of recovery (294±4 mOsm·kg^{-1}, p=0.005). Except for a main effect of Sex, F1,13)=21.1, p<0.001, η_p^2=0.62; indicating that, on average, females had a lower P_{OSM} than males (294±3 vs. 299±3 mOsm·kg^{-1}), no other significant differences were observed in this analysis (p's>0.05).

3.4 Energy and Nutrient Consumption

Energy and nutrient intakes during the 195 min eating/drinking period are summarized in Table 3. On average, males consumed 2.2±0.8 MJ, 125±42 g CHO and 0.6±0.2 g sodium via Sports Drink; while females consumed 1.9±0.4 MJ, 103±23 g CHO and 0.5±0.1 g sodium; these intakes did not differ significantly by Sex. While the quantity of CHO, protein, fat and sodium consumed via food was not significantly affected by the beverage provided; the accumulation of small reductions in macronutrient consumption resulted in a significant decrease in energy intake from food when Sports Drink was consumed. Overall, Sports Drink had a significant effect to increase total (i.e. from food and beverage) CHO consumption during the first half of the eating/drinking period and total CHO, energy and sodium intake across the entire recovery period. Total energy, t(15)=1.51, p=0.153 (Trial #1: 7.3±2.0 MJ; #2: 7.9±2.2 MJ); energy via food, t(15)=1.05, p=0.312 (Trial #1: 6.4±1.8 MJ; #2: 6.7±2.2 MJ); total CHO, t(15)=0.796, p=0.438 (Trial #1: 239±82 g; #2: 259±82 g); and CHO via food, t(15)<0.001, p=1.000 (Trial #1: 192±60; #2: 192±66 g) did not differ by order of trials.

3.5 Cycling Performance Test

PPO attained on the incremental test to exhaustion did not differ by Treatment, $F_{[1,14]}$=1.49, p=0.242; or indicate a significant Treatment × Sex interaction, $F_{[1,14]}$=0.24, p=0.630 (Figure 2). Overall, males attained a PPO of 337±40 W on Water and 340±40 W on Sports Drink; females achieved 252±50 W and 258±47 W on each respective treatment. Individuals elicited a maximum HR equal to 96±6% HR_{max} during the performance test; this value did not differ by Treatment, $F_{[1,14]}=1.871$, $p=0.193$; by Sex, $F_{[1,14]}=0.064$, $p=0.805$; or indicate a Treatment × Sex interaction, $F_{[1,14]}=0.043$, $p=0.838$. Neither PPO, $t(15)=1.60$, $p=0.131$ (Trial #1: 294±61 W; #2: 299±60 W); nor the maximum HR attained, $t(15)=0.324$, $p=0.751$ (Trial #1: 96±7% HR_{max}; #2: 96±6% HR_{max}) differed significantly by trial order. HR and RPE did not differ by Treatment, $F_{[1,14]}=0.897$, $p=0.360$; $F_{[1,14]}=0.860$, $p=0.370$, respectively; or indicate a Treatment × Time interaction, $F_{[2,28]}=0.135$, $p=0.874$; $F_{[2,28]}=1.48$, $p=0.245$, respectively; during the 45 min pre-load. On average, male and female participants cycled at 79±6% HR_{max} (RPE: 13±1) and 74±6% HR_{max} (RPE: 12±1) throughout the pre-load, respectively.

3.6 Gastrointestinal Tolerance

Subjective ratings of thirst, $F_{[2.6,36.3]}=54.9$, $p<0.001$, $\eta_p^2=0.78$; hunger, $F_{[2.2,31.1]}=24.3$, $p<0.001$, $\eta_p^2=0.63$; and fullness, $F_{[3.3,46.7]}=29.6$, $p<0.001$, $\eta_p^2=0.68$; differed significantly across Time; hunger also indicated a significant Time × Sex interaction, $F_{[6,84]}=2.40$, $p=0.037$, $\eta_p^2=0.14$. Pairwise comparisons revealed higher thirst ratings immediately after the initial standardized exercise (81±14 mm) and the cycling performance test (68±20 mm) than at all other time points (24±12 mm, *p*'s<0.001). Participants also reported lower levels of fullness and higher levels of hunger on arrival (hunger: 44±24 mm; fullness: 20±18 mm) and immediately after the initial standardized exercise (hunger: 54±28 mm; fullness: 14±13 mm) than at all subsequent time points (hunger: 17±12 mm; fullness: 50±16 mm, *p*'s<0.030). Males reported higher levels of hunger than females after the first (29±19 vs. 11±10 mm, $p=0.037$), second (25±15 vs. 10±9 mm, $p=0.030$) and third (26±13 vs. 8±8 mm, $p=0.004$) hours of the recovery period. No other significant differences were detected in these analyses (*p*'s>0.05). Subjective ratings of nausea also differed significantly across Time, $F_{[2.1,28.8]}=3.97$, $p=0.029$, $\eta_p^2=0.22$; however, pairwise comparisons failed to identify any significant differences between time points (*p*'s>0.05).

3.7 Post-Study Survey

3.7.1 Three-Factor Eating Questionnaire

Mean±SD (Range) transformed scores for Uncontrolled Eating, Cognitive Restraint, Emotional Eating were 55±14% (28–71%), 53±13% (29–79%) and 44±18% (25–75%), respectively; these did not differ significantly by Sex, $t(9.8)=0.683$, $p=0.511$; $t(14)=0.378$, $p=0.711$; $t(14)=1.28$, $p=0.222$. No participant exceeded clinical thresholds for any of these characteristics.

3.7.2 Sports Nutrition Knowledge and Beliefs

All 16 participants believed fluid consumption was important and that recommencing exercise in a dehydrated state could impair endurance performance. However, only 4 were aware of amounts they should consume in accordance with current fluid replacement guidelines (i.e. 1.25–1.50 $L\cdot kg\ BM\ loss^{-1}$); most believed a smaller volume (e.g. *n*=7, 1.0–1.25 $L\cdot kg\ BM\ loss^{-1}$) would be sufficient to rehydrate. The majority of participants believed CHO was the most important macronutrient to replace after endurance exercise (*n*=13) and that the optimum time to eat (i.e. to enhance recovery) was within 30 min of activity (*n*=12). However, only 3 knew that commercial sports beverages contained 4–8% CHO; most believed them to contain more (e.g. *n*=7, 20–25% CHO). The vast majority of participants believed that sports bars (*n*=15), muesli bars (*n*=14), bananas (*n*=15), raisin bread (*n*=15), bread (*n*=16) and crumpets (*n*=15) were "high CHO foods"; apples (*n*=10), sultanas (*n*=12), dried apricots (*n*=12), rice crackers (*n*=12), honey (*n*=11), jam (*n*=11) and orange juice (*n*=11) were usually (but less frequently) perceived as "high CHO foods". Participants typically indicated that cheese (*n*=13), peanut butter (*n*=11), yeast extract spread (*n*=9), margarine (*n*=12), cashew nuts (*n*=13) and fruit-flavored yoghurt (*n*=12) were "low CHO foods".

3.7.3 Participant Expectations

Four out of the 16 participants (all female) expected to "perform better" on the incremental cycling test after consuming Sports Drink; two of these individuals did. The remainder believed they would perform similarly on both experimental trials. One participant deliberately altered their dietary behavior during the second trial (Sports Drink) because of their previous experience; specifically, he reported making a conscious effort to consume more fluid. Another participant deliberately altered their dietary behavior based on the available beverage; specifically, she reported making "less of an effort" to select high CHO foods when Sports Drink was available. No other participants indicated a deliberate alteration in their food and/or beverage intake between trials.

4.0 Discussion

This study investigated the effect of consuming either Water or Sports Drink *ad libitum* with food during a 4 h post-exercise recovery period on fluid restoration, nutrient provision, and subsequent endurance cycling performance in trained males and females. In line with our hypothesis, results indicate that both beverages were effective at replenishing fluid losses between consecutive exercise (cycling) sessions, and that Sports Drink increased total energy and CHO intake during the recovery period (irrespective of Sex). However, in contrast to our hypothesis, this additional CHO did not translate to an improvement in subsequent cycling performance. Findings from this study suggest that, in a laboratory setting with readily available access to fluid and food, the consumption of a CHO-electrolyte sports beverage between consecutive exercise sessions influences nutritional intake, rather than acute measures of fluid recovery or exercise performance. Post-exercise beverage recommendations should consider the post-exercise environment (i.e. availability of food), an individual's tolerance for food and fluid pre-/post-exercise, the immediate requirements for refuelling (i.e. CHO demands of the activity) and the athlete's overall dietary goals.

Fluid Restoration. Previous research generally indicates that beverages with "simple" nutritional profiles (e.g. water and CHO-electrolyte sports beverages) are poorly retained post-ingestion, often leaving individuals with a residual fluid deficit [7-10]. However, these studies typically prescribe fluid consumption (i.e. fluid volume and rate) and deny participants access to food: an approach with limited ecological validity. In contrast, the current investigation provided access to one type of beverage and a variety of food items *ad libitum*. In this context, these "simple" beverages were effective at replenishing fluid losses, returning participants to net positive fluid balance prior to recommencing exercise (Water: +0.4±0.5 L; Sports Drink: +0.3±0.3 L). Two recent studies [16,17] employing comparable methodology demonstrated similar effects; specifically, that water and CHO-electrolyte sports beverages were as effective as "complex" fluids (i.e. milk-based formulations) at replenishing fluid losses after exercise. These observations may be explained by two factors; first, that individuals in these studies voluntarily consumed the "simple" beverages in relatively large quantities (i.e. >1.25 L· kg BM lost^{-1}); and second, that the co-ingested food enhanced fluid retention – indeed, findings from previous studies that have allowed participants to eat as part of the experiment generally suggest that co-ingesting food and fluid increases retention of "simple" rehydration beverages (i.e. by delaying gastric emptying and attenuating osmotic diuresis) [13-15].

Unlike the current investigation, however, neither of the aforementioned studies incorporated a subsequent exercise session; participants instead left the laboratory at the end of the recovery period. This distinction is important because the anticipation of subsequent activity might influence dietary behavior, and consequently rehydration. Indeed, it is possible that individuals could restrict their intake of food and/or fluid in this situation to avoid experiencing GI problems during the second bout of exercise [29]. While the current study did not incorporate a "no exercise" trial to determine exactly *how* or *if* the subsequent activity influenced dietary behavior, the present data suggest that individuals were willing to consume *enough* food and fluid to support rehydration. In fact, participants consumed relatively similar amounts of fluid and energy as individuals in the previous investigations [16,17]. Considering the large volumes of fluid ingested (i.e. ~1.4–2.2 L· kg BM lost^{-1}), it is possible that the subsequent exercise session actually motivated drinking behavior (particularly as the participant's nutrition knowledge questionnaires indicated a belief that dehydration could impair subsequent athletic performance). Thus, the present data improve our understanding of post-exercise fluid recovery, indicating that beverages with "simple" nutritional profiles are likely to be effective at replenishing fluid losses when consumed voluntarily and with food between consecutive cycling sessions.

Nutrient Provision and Timing. Results indicate that the choice of recovery beverage can influence post-exercise nutritional intake. In keeping with our hypothesis, the current investigation found that participants consumed 25±13% (Hedges' *g*=0.77) more energy, 54±24% (*g*=1.44) more CHO, and 41±33% (*g*=0.75) more sodium when Sports Drink was provided during the recovery period. The intakes of other nutrients were not affected by the beverage treatment. For instance, the quantity of protein consumed was consistent with recommendations for post-exercise recovery (i.e. ~0.25–0.30 g·kg^{-1} ≤2 h post-exercise [2]), regardless of the beverage provided (Water: 0.42±0.14 g·kg^{-1}; Sports Drink: 0.35±0.11g·kg^{-1}). The timing of nutrient consumption also differed between beverages. Specifically, Sports Drink increased intakes of energy, CHO and sodium to a greater extent during the second-half of the eating/drinking period (1st half (% increase compared to Water), Energy: +12±33%, *g*=0.13; CHO: +38±47%, *g*=0.72; Sodium: +9±42%, *g*=0.01; 2nd half, Energy: +99±141%, *g*=0.87; CHO: +166±237%, *g*=1.30; Sodium: +236±295%, *g*=0.73). This result possibly reflects a reduction in solid food intake (but continued drinking) over the latter half of the eating/drinking period. Consequently, it is possible that some of this additional CHO may not have been completely absorbed prior to recommencing exercise.

Subsequent Endurance Cycling Performance. Previous studies demonstrating that the consumption of CHO-containing beverages in the post-exercise period enhances subsequent endurance performance typically deny participants access to food; meaning that the control condition often receives no CHO [6]. While participants in the current study ingested significantly *more* CHO during the recovery period with Sports Drink, they still consumed some CHO on the Water trial. Under these circumstances, the type of beverage provided did not influence subsequent endurance cycling performance. One possible explanation for the lack of a performance effect is that CHO consumption was already close to recommended levels for "rapid refueling" (1.0–1.2 g CHO·kg^{-1}·h^{-1} [2,30,31]) on the Water trial. In other words, participants voluntarily consumed sufficient CHO from food alone to facilitate muscle glycogen re-synthesis in this laboratory environment (i.e. where it was readily available post-exercise). Indeed, males and females consumed 0.91±0.22 and 0.85±0.25 g CHO·kg^{-1}·h^{-1} during the 195 min eating/drinking period, respectively. Ivy*, et al.* [32] failed to demonstrate a difference between similarly "sub-optimal" (e.g. 0.75 g·kg^{-1}·h^{-1}) and "optimal" CHO doses in terms of their effect on muscle glycogen re-synthesis ~4 h post-exercise. There is also limited evidence to suggest that consuming >1.2 g $CHO \cdot kg^{-1} \cdot h^{-1}$, as was the case when Sports Drink was provided (M: 1.35±0.14; F 1.26±0.28 g $CHO \cdot kg^{-1} \cdot h^{-1}$), accelerates glycogen re-synthesis further [30,31]. Additionally, given that protein has the capacity to enhance muscle glycogen re-synthesis when CHO intakes are sub-optimal [30]; and that the additional CHO consumed via Sports Drink may not have been completely absorbed prior to the performance test (see *Nutrient Provision and Timing*) [33], the observed result is not unexpected based on the profile of the observed nutrient intakes.

While the current study did not detect a benefit of consuming Sports Drink on subsequent endurance cycling performance, it is important to consider this outcome in context. First, while we attempted to provide exercise tasks that utilized CHO, it is possible that the protocols employed lacked sufficient duration/intensity to seriously deplete substrate stores and elicit a CHO-mediated performance change. A shorter or longer recovery period (i.e. between exercise sessions) may also elicit different effects. In addition, participants in this study were given *ad libitum* access to a variety of foods (including many high-CHO options) during a dedicated 195 min eating/drinking period that began almost immediately (i.e. ~15 min) post-exercise. In actuality, a wide selection of foods are not always readily available following exercise and it is possible that a reduction or delay in the availability of food items could alter the outcome of this study. Furthermore, other factors (e.g. nutrition knowledge and beliefs, food preferences, food cost, social environment, time of day, etc.) and the likelihood of subsequent GI tolerance issues (e.g. running vs. cycling [34]) may influence an individual's food and fluid intake during recovery in a free-living environment [35]. The post-exercise environment, type of activity and an athlete's immediate requirements for refuelling (i.e. the duration/intensity of the initial and subsequent sessions [36,37] are important contextual features when interpreting the findings of this study.

The present data also suggest that an athlete's overall dietary goals (e.g. body composition aspirations) should be considered when recommending a suitable post-exercise recovery beverage. In practical terms, the additional energy delivered via Sports Drink (M: +1.8±1.0 MJ; F: +1.3±0.5 MJ) is likely to represent a meaningful proportion (i.e. ~5–15%) of a competitive cyclist/triathletes' "typical" daily energy intake (M: ~14.5–22.9 MJ [38,39]; F: ~12.0–14.9 MJ [40]). For some athletes, regular consumption of CHO-electrolyte sports beverages post-exercise may assist in the maintenance of energy balance, particularly when exercise loads are high. Conversely, frequent consumption of CHO-electrolyte sports beverages during periods of reduced physical activity or by individuals with lower training-demands (e.g. recreational athletes) may promote excess energy intakes and could be counterproductive to body composition aspirations. This is particularly important given that individuals do not usually modify their dietary behavior to compensate for additional energy consumed in caloric rehydration beverages [17,41].

This study does contain some limitations. First, a blinded experimental design was not employed, since artificially-sweetening and/or flavoring the Water (i.e. to create a realistic placebo beverage) could have altered drinking behavior and fluid recovery. Thus, expectancy effects may have influenced cycling performance. To reduce bias, all participants received the same overview, which intended to create uncertainty regarding the outcome of the investigation; specifically, they were told that "*CHO-electrolyte sports beverages have been demonstrated to improve endurance performance*" but that "*studies had not tested their effects in combination with food*". We must also acknowledge the challenges associated with measuring "subsequent" endurance performance. Indeed, research suggests that prior exercise can reduce the reliability of a performance measurement and increase the risk of Type II error [25]. To improve sensitivity, the current study employed an incremental test (rather than a time trial), thereby avoiding the need for participants to select an appropriate pacing strategy. Finally, the extent to which an individual's CHO stores are depleted or saturated could potentially influence their dietary behaviour (i.e. the amount of CHO they choose to ingest); yet, the current study did not measure muscle glycogen content at the onset of each trial or at the completion of the initial standardized exercise (i.e. to confirm these were similar across trials). That said, pre-trial conditions were standardized to ensure consistency, and our previous studies [16,17] suggest that participants utilize a similar amount of energy during exercise when the power output on the cycle ergometer is fixed.

5.0 Conclusion

This study demonstrated that: (1) beverages with "simple" nutritional profiles were effective at replenishing fluid losses, when consumed *ad libitum* and with food between consecutive bouts of cycling; and (2) that individuals in the laboratory environment voluntarily derived enough CHO from food alone to meet post-exercise refuelling recommendations; meaning that the additional nutrition consumed during the Sports Drink trial did not benefit subsequent endurance cycling performance. Findings from the current investigation suggest that before spontaneously providing a CHO-containing fluid during recovery, consideration of the post-exercise environment, an individual's tolerance for food/fluid, the immediate requirements for refuelling and the athlete's overall dietary goals is required.

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Figures and Tables:

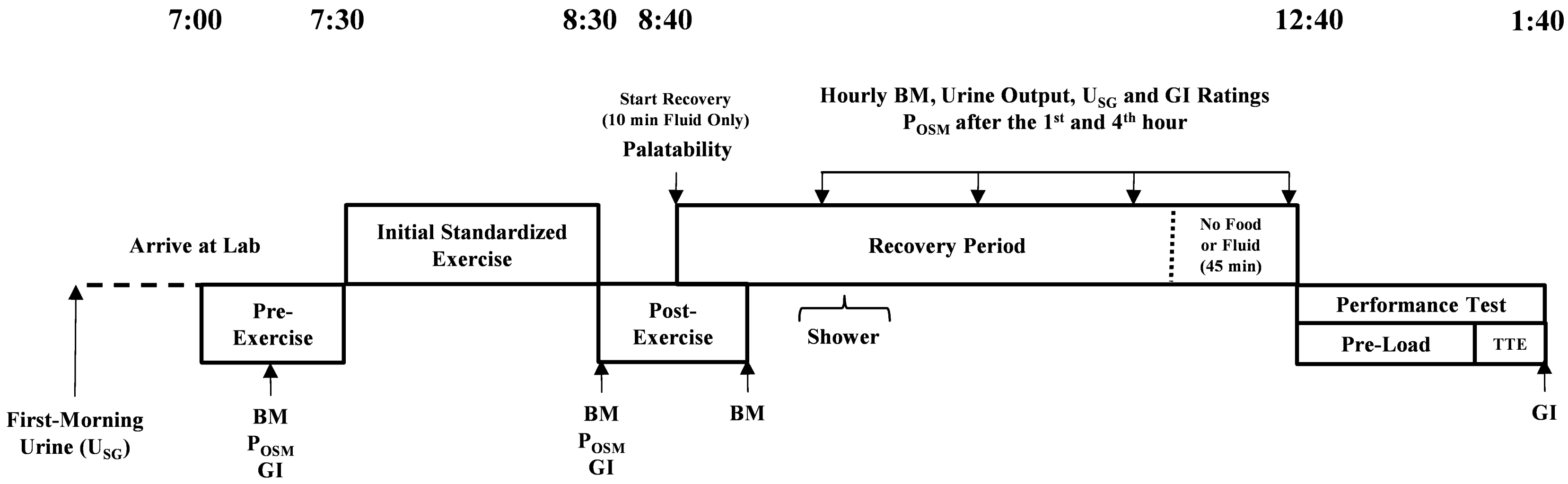

Figure 1. Schematic representation of the experimental procedures. BM: nude body mass; GI: gastrointestinal questionnaire; Palatability: beverage palatability questionnaire; P_{OSM}: blood collection for plasma osmolality analyses; U_{SG}: urine specific gravity; TTE: incremental cycling test to volitional exhaustion.

Table 1. Pre-trial conditions and exercise-induced dehydration (Mean±SD)

	Male Participants		Female Participants		Treatment Effect			Sex Effect		
	Water	**Sports Drink**	**Water**	**Sports Drink**	$F_{[1,14]}$	***p*-value**	η_p^2	$F_{[1,14]}$	***p*-value**	η_p^2
Pre-Exercise U_{SG}	1.016 ± 0.008	1.016 ± 0.006	1.014 ± 0.003	1.012 ± 0.004	0.61	0.448	0.04	1.45	0.249	0.05
Pre-Exercise P_{OSM}	294 ± 4	293 ± 4	290 ± 4	289 ± 4	0.907	0.358	0.07	7.76	**0.015**	0.37
Pre-Exercise BM	80.4 ± 6.9	80.2 ± 6.6	60.5 ± 8.0	60.7 ± 7.3	0.000	0.995	<0.01	29.8	**<0.001**	0.68
BM Loss (kg)	1.80 ± 0.15	1.79 ± 0.15	0.95 ± 0.21	0.96 ± 0.20	0.003	0.957	<0.01	112	**<0.001**	0.89
BM Loss (%)	2.25 ± 0.17	2.25 ± 0.35	1.57 ± 0.29	1.59 ± 0.32	0.032	0.860	<0.01	25.9	**<0.001**	0.91

BM: Body mass; P_{OSM}: Plasma osmolality (mOsm·kg^{-1}); U_{SG}: Urine specific gravity. P_{OSM} from *n*=8 male and *n*=7 female participants where blood sampling was successful. No significant Treatment × Sex interaction effects (*p*'s>0.05).

Table 2. Water intake, output and retention during the 4 h recovery period (Mean±SD)

	Male Participants		Female Participants		Treatment Effect			Sex Effect		
	Water	**Sports Drink**	**Water**	**Sports Drink**	$F_{[1,14]}$	***p*-value**	η_p^2	$F_{[1,14]}$	***p*-value**	η_p^2
Fluid Consumption										
Beverage Intake (g)	2306 ± 564	2150 ±716	1680 ± 620	1770 ± 400	0.074	0.790	0.01	3.89	0.069	0.22
$WI_{Beverage}$ (g)	2306 ± 564	2043 ± 680	1680 ± 620	1682 ± 380	1.25	0.283	0.08	3.95	0.067	0.22
WI_{Food} (g)	438 ± 55	448 ± 209	333 ± 106	239 ± 67	1.42	0.254	0.09	9.14	**0.009**	0.40
WI_{Total} (g)	2743 ± 571	2491 ± 389	2012 ± 539	1921 ± 389	2.12	0.168	0.13	8.00	**0.015**	0.36
BM Loss Replaced (%)	155 ± 42	139 ± 24	217 ± 57	206 ± 44	2.63	0.127	0.16	10.4	**0.006**	0.43
Fluid Output and Retention										
Urine Output (g)	543 ± 255	418 ± 307	709 ± 440	635 ± 311	1.66	0.219	0.11	1.66	0.218	0.01
Water Retention (%)	80 ± 9	84 ± 8	67 ± 15	68 ± 9	0.945	0.347	0.06	9.94	**0.007**	0.42
Water Retained (g)	2200 ± 530	2073 ± 360	1303 ± 342	1286 ± 144	587	0.456	0.04	28.0	**<0.001**	0.67
Net Fluid Balance (g)	+397 ± 616	+284 ± 278	+355 ± 259	+329 ±240	0.417	0.529	0.03	<0.001	0.993	<0.001

$WI_{Beverage}$: Water intake from beverage; WI_{Food}: Water intake from food; WI_{Total}: Water intake from food and beverage. No significant Treatment × Sex interaction effects (*p*'s>0.05).

Table 3. Energy and nutrients consumed via food and beverage during the 195 min eating/drinking period (Mean±SD)

	Male Participants		**Female Participants**		**Treatment Effect**			**Sex Effect**		
	Water	**Sports Drink**	**Water**	**Sports Drink**	$F_{[1,14]}$	***p*-value**	η_p^2	$F_{[1,14]}$	***p*-value**	η_p^2
Beverage Nutrient Intake										
Energy (kJ)	0 ± 0	2257 ± 752	0 ± 0	1859 ± 420	183	**<0.001**	0.93	183	0.212	0.11
CHO (g)	0 ± 0	125 ± 42	0 ± 0	103 ± 23	183	**<0.001**	0.93	1.71	0.212	0.11
Sodium (mg)	69 ± 17	602 ± 201	50 ± 16	496 ± 112	165	**<0.001**	0.92	2.08	0.171	0.13
Food Nutrient Intake										
Energy (kJ)	8105 ± 1761	7661 ± 1909	5515 ± 1053	4958 ± 874	5.01	**0.042**	0.26	14.3	**0.002**	0.51
CHO (g)	235 ± 53	225 ± 56	164 ± 47	145 ± 46	3.48	0.083	0.20	9.83	**0.007**	0.62
Protein (g)	58 ± 16	54 ± 17	39 ± 10	37 ± 6	1.62	0.224	0.10	8.83	**0.010**	0.39
Fat (g)	80 ± 38	75 ± 29	53 ± 11	48 ± 6	1.36	0.262	0.09	5.55	**0.034**	0.28
Sodium (mg)	1609 ± 693	1490 ± 778	1172 ± 411	1246 ± 417	0.112	0.743	0.13	1.37	0.262	0.09
Half-Time Nutrient Intake (Food + Beverage)										
Energy (kJ)	4920 ± 1964	5061 ± 1048	3705 ± 1410	3965 ± 993	0.254	0.622	0.02	4.61	**0.050**	0.25
CHO (g)	147 ± 33	192 ± 41	109 ± 51	135 ± 41	11.7	**0.004**	0.45	6.65	**0.022**	0.32
Protein (g)	35 ± 14	26 ± 10	26 ± 12	23 ± 6	3.09	0.100	0.18	1.80	0.201	0.11
Fat (g)	47 ± 33	32 ± 15	36 ± 17	31 ± 8	2.99	0.106	0.18	0.458	0.510	0.03
Sodium (mg)	979 ± 300	861 ± 321	850 ± 337	965 ± 290	<0.001	0.988	<0.01	0.011	0.920	<0.01
Full-Time Nutrient Intake (Food + Beverage)										
Energy (kJ)	8105 ± 1761	9918 ± 1376	5515 ± 1053	6817 ± 1078	59.8	**<0.001**	0.81	19.6	**0.001**	0.58
CHO (g)	235 ± 53	349 ± 30	164 ± 47	248 ± 58	201	**<0.001**	0.94	14.0	**0.002**	0.25
Protein (g)	58 ± 16	54 ± 17	39 ± 10	37 ± 6	1.63	0.222	0.10	8.84	**0.010**	0.39
Fat (g)	80 ± 38	75 ± 29	53 ± 11	48 ± 6	1.37	0.262	0.09	5.55	**0.034**	0.28
Sodium (mg)	1678 ± 696	2092 ± 741	1223 ± 419	1742 ± 444	39.7	**<0.001**	0.74	1.97	0.183	0.04

Half-Time: Total intake from food and beverage during the first 90 min of the eating/drinking period; Full-Time: Total intake from food and beverage during the 195 min eating/drinking period. No significant Treatment × Sex interaction effects (*p*'s>0.05).

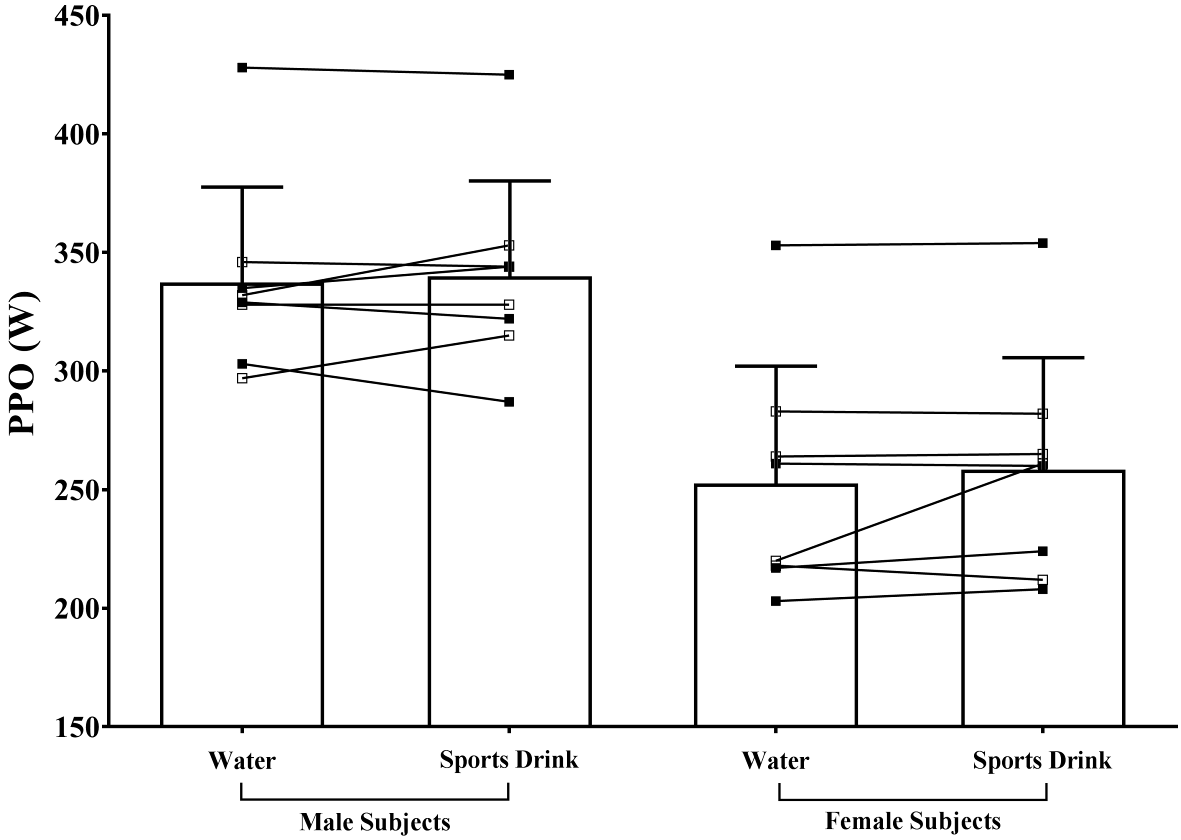

Figure 2. PPO attained on average (bars) and by individual participants (lines) on the incremental test to volitional exhaustion under each experimental treatment. Values are Mean±SD.

Supplementary Data

Table S1. Nutritional composition of the food items offered (per 100 g).

Food Item	Energy (kJ)	Protein (g)	Fat (g)	CHO (g)	Sodium (mg)	Water (g)
Sports Bar (Apple Berry Crumble), Winners	1,480	5.9	5.4	67.4	8	8.5
Sports Bar (Mountain Mix), Winners	1,630	7.3	11.6	62.0	8	8.5
Muesli Bar (Yoghurt & Strawberry), Uncle Toby's	1,630	7.1	11.1	59.9	19	8.2
Banana	385	1.4	0.3	19.6	0	76.2
Apple	247	0.3	0.4	11.9	0	83.9
Sultanas, Sunbeam®	1,290	3.1	0.1	69.0	10	16.3
Dried Apricots, Angas Park®	947	2.4	0.1	48.8	72	29.6
Raisin Toast, Tip Top®	1,150	8.7	2.2	52.9	196	36.0
Multigrain Bread, Woolworths Homebrand	1,080	9.3	2.5	47.0	400	37.1
Crumpets, Golden	750	5.7	0.9	35.5	600	51.8
Cheese, Coon™	1,690	25.8	33.3	1.0	700	34.0
Plain Rice Crackers, Sakata®	1,680	7.4	2.9	86.1	387	4.6
Crunchy Peanut Butter, Kraft	2,580	23.7	51.3	13.4	578	1.5
Honey, Woolworths Select	1,416	0.3	0.0	83.1	15	16.2
Jam, Fruits of the Forest, IXL®	1,110	0.4	0.1	64.1	17	30.7
Yeast Extract Spread, Vegemite	798	25.4	0.9	19.9	3,300	40.9
Margarine, Flora™	2,420	0.2	65.0	0.7	590	35.1
*Fruit-Flavoured Yoghurt, Yoplait®	375	4.7	1.9	13.2	50	77.4
*Orange Juice, Just Juice	170	0.6	<0.1	9.0	8	94.5
Salted Cashews, Woolworths Homebrand	2,560	21.3	48.5	22.1	220	1.9

*Participants were only given 200 g of these items to consume due to their high fluid content. Nutritional values for packaged foods were taken from the product nutrition information panel; values for fresh food items and product water content were taken from FoodWorks® Version 8 (Xyris Software Pty Ltd, Spring Hill, Australia).