Rehydration After Exercise-Induced Fluid Losses: Comparing Flavored Water, Coconut Water, and Carbohydrate-Electrolyte Sports Beverage

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Abstract

Bell, SK and Spriet, LL. Rehydration following exercise-induced fluid losses: comparing flavored water, coconut water, and carbohydrate-electrolyte sports beverage. *J Strength Cond Res* XX(X): 000–000, 2025—Effective fluid volume and electrolyte replacement after exercise is essential to rehydration and optimal athletic performance. Despite coconut water's (CW) inherently high electrolyte content, there is still limited supporting evidence on its use and rehydration efficacy. The following study investigated the rehydration efficacy and palatability of natural CW compared with flavored water (FW) and carbohydrate-electrolyte sports (CES) beverage, after exercise-induced dehydration. During this randomized, single-blind, cross-over study, 8 recreational athletes (7 men, 1 woman; 22.3 ± 0.4 years and 48.2 ± 2.2 ml min kg^{-1} $\dot{V}O_2max$), cycled at 70% $\dot{V}O_2max$ for 60 minutes until dehydrated by 1.36 ± 0.1% (1.07 ± 0.1 kg) of initial body mass (BM). During separate trials, subjects ingested 1 of 3 electrolyte beverages: FW, CW, or CES in volumes equivalent to 150% of BM lost. Hydration status was assessed with body mass measures and urine volume collections. Perceptual measures of beverage saltiness, thirst, and nausea were recorded using a 5-point Fluid Sensation Scale. After rehydration, FW produced statistically greater total urine output (530 ± 119.2 ml) compared with CW (170 ± 35.8 ml) and CES (170 ± 35.8 ml), $p < 0.05$. Subjects retained the greatest fluid volume with CW, but fluid status post rehydration was statistically insignificant between all beverages ($p > 0.05$). Perceived thirst was significantly greater for FW and CES at 0 minutes of rehydration ($p < 0.05$), while saltiness and nausea were insignificantly different between trials ($p > 0.05$). This study demonstrated that potassium-rich CW as a natural electrolyte rehydration alternative is equally effective in rehydration and palatability as the commercial CES drink, after moderate-to-high intensity exercise, despite having lower sodium concentrations.

Key Words: hydration status, exercise, urine volume, dehydration, oral rehydration solution

Introduction

Exercise capacity can be impaired by inadequate hydration after prolonged exercise, leading to a hypohydrated or dehydrated state. Athletes involved in regular exercise can be unaware of the clinical significance of proper rehydration—adequate fluid replacement after exercise assists in the maintenance of hydration status, thermoregulation, physiological health, as well as, enabling optimal cognitive and physical performance (4,10). Several studies and current position statements by the American College of Sports Medicine and National Athletic Trainer's Association encourage athletes to avoid fluid deficits during exercise, as decrements in body mass (BM) loss of only 1% can affect thermoregulatory responses during exercise, and 1.5–2% through sweat can result in dehydration, and may compromise cognitive function and aerobic performance (1,13,18,13,15,17,18). As the loss of bodily fluids coincides with the loss of electrolytes found in sweat to aid thermoregulation, sweat-induced water loss can be profound during moderate intensity exercise, ranging from 0.8 to 2.0 $L\cdot h^{-1}$ (12). A simple method to assess total body water volume lost, dehydration, and overall hydration status can be used through measuring acute changes in whole-body mass in exercising athletes. Hydration status can also be monitored by urine volume or gravity, plasma or urine osmolality, and thirst sensation, respectively. Individual fluid replacement volumes postexercise can be calculated as body weight changes reflect sweat losses during exercise (18).

Several studies report that the beverage volume consumed or replenished, composition, and palatability are all factors that can affect an athlete's rehydration status postexercise (12,18,25). Various research bodies, including consensus statements from the American College of Sports Medicine (ACSM), Sports Dietitians Australia, and International Olympic Committee, have reported that the fluid volume of a rehydration drink consumed postexercise should be between approximately 120 and 150% of body mass lost to achieve optimal rehydration and minimize urine losses (22,6,18,21,24,26,27). The addition of electrolytes to fluid assists in maintaining athletes' thirst and stimulates drinking; however, an excessive sodium content may be perceived as undesirable.

Although plain water is often consumed postexercise to temporarily restore fluid losses, it is absent of and does not replenish lost electrolytes, resulting in rapidly reduced plasma sodium concentrations and plasma osmolarity (23). As plain water lacks electrolytes, it increases diuresis while decreasing the sensation of thirst, before hydration is adequately achieved (5,20,23). In a hot environment, abnormally low plasma sodium due to prolonged exercise, followed by large volume consumption of plain water can result in hyponatremia (10). For this reason, it has been suggested that the inclusion of electrolyte salts in a rehydration beverage's composition may be advantageous, enhancing fluid retention, and re-establishing hydration, i.e., a euhydrated state.

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Numerous studies have found that rehydration with a carbohydrate-electrolyte sports beverage (CES), such as the leading commercial CES drink solutions, containing approximately 18.3 mmol·L^{-1} of sodium and 3.3 mmol·L^{-1} of potassium, can improve palatability and promote rehydration in athletes during and after exercise (5,7,10,11,20,21,24). Although sodium-enriched sports (SES) drinks containing greater than 50 mmol·L^{-1} of sodium have been proven optimal for rehydrating elite athletes, the higher sodium content often decreases the palatability of the drink for the average person, posing the problem of reduced consumption (21). Burke et al. (2) demonstrated that consumption of around 4–8% carbohydrates, often found in CES drinks, may be beneficial in endurance activities as they help replenish depleting glycogen stores. However, for shorter and less intense workouts, the overall ingestion and palatability of the fluids are the priority. Recent reports suggest that natural drinks, such as coconut water (CW), may be preferred and used by some athletes as a naturally effective CES drink alternative—preventing diuresis and promoting rehydration through CWs inherently high composition of potassium; in addition to, sodium, magnesium, calcium, and even vitamin C (10,20). Because CW contains less glucose than commercial CES drinks, it is also believed to prevent side effects such as nausea (21). O'Brien et al. (15) investigated coconut juice derivatives because of the high potassium content; however, the efficacy of these beverages during endurance exercise has been limited. Although CW contains less than one-third the concentration of sodium (6.59 mmol·L^{-1}) found in commercial CES drinks (18.3 mmol·L^{-1}), it has been shown equally effective in rehydrating recreationally active athletes after exercise, possibly by supporting intracellular water retention (19). This suggests that the high potassium content in CW (50.2 mmol·L^{-1}) compared with CES (3.3 mmol·L^{-1}) plays a larger role in rehydration, than is currently understood. Although the percentage of carbohydrates in CW (5%) is less than half that of CES (11%), CW still meets the recommended 4–8% carbohydrate energy requirements for exercising athletes.

Perceived aspects related to a drinks palatability may influence or deter an athlete from adequate rehydration in the setting of exercise, including: the taste or perceived "saltiness" of a drink, its association with nausea after consumption, and the sensation of thirst. Wilk et al. (28) found that ad libitum rehydration in young male athletes can be impaired by an athlete's perception of a sport drink's flavor or composition and its association with nausea. Studies have proven that the addition of electrolytes, such as sodium, assist in maintaining thirst and, thus, a "drive" to consume more fluids when exercising (21–25).

Despite CW's inherently high electrolyte content, there is still limited supporting evidence on its use or rehydration efficacy. Previous literature has investigated electrolyte rehydration in athletes after moderate intensity exercise to induce BM loss of 1.5–2%, followed by rehydration of 150% BM loss over a 2 to 4-hour rehydration period. The practical significance of the 150% BM rehydration over a 2 to 4-hour rehydration period is that it can easily be calculated by team trainers or physicians, and reasonably implemented by the athlete to consume this volume of fluid, which is critical to ensuring adequate rehydration between training sessions. In addition, this is a significantly greater beverage volume requirement from previously published guidelines of 100–120%, which may suggest previous recommendations for fluid replacement were insufficient to adequately rehydrate an individual. Although these studies (20,21) compared CW and carbohydrate-electrolyte beverages with plain water, subjects were not blinded from plain water's absent flavor, which may have resulted in confirmation bias. Based on previous research, using a similar dehydration and rehydration protocol with moderate-to-high intensity exercise, the primary aim of the following study was to investigate the effectiveness of flavored water (FW), natural CW, and a CES beverage, with varying electrolyte compositions, on achieving optimal fluid balance. A secondary aim was to assess the palatability of the drinks, after exercise-induced fluid losses.

Methods

Experimental Approach to the Problem

Subjects arrived at the laboratory on 5 separate occasions, with visits separated by at least 1 week. The initial 2 visits were preliminary trials to determine each subjects' $\dot{V}O_2$max through a 60-minute practice ride. Experimental trials took place during the morning or evening and were standardized by having the subjects fast 2 hours before each trial, with the exception of a 500 ml water allowance, with subjects asked to maintain similar diets in the 24-hour period before each visit, to ensure similar hydration status. Visits 3 to 5 were the experimental beverage (FW, CW, and CES) trials, completed in a randomized crossover design. Refer to Table 1 for the nutrient composition of experimental drinks.

Subjects

Eight healthy, recreational athletes (7 men, 1 woman) from a university population, volunteered to participate in the following study. Research took place at the University of Guelph Cardio-Respiratory Laboratory. The mean ± *SEM* age and body mass (BM) were: 22.3 ± 0.4 years and 81.1 ± 4.7 kg, measured using standard techniques. All subjects were physically active, participating in physical activity 2 to 3 times a week, and were not currently involved in any structured training programs. All subjects were informed of the experimental protocol, both orally and in writing, before written informed consent was obtained. The study was approved by the Research Ethics Board at the University of Guelph. An overview of subject characteristics is summarized in Table 2.

Procedures

Preliminary Trials

Before all experimental trials, subjects visited the laboratory on 2 separate occasions to perform 2 preliminary trials. On the initial visit, subjects performed a progressive test to volitional exhaustion ($\dot{V}O_2$ max) on a cycle ergometer, using a metabolic cart (AEI MOXUS II Metabolic System, Pittsburgh, PA), that lasted 8–12

Table 1

Nutritional composition of flavored water, coconut water, and carbohydrate-electrolyte sports beverage during each trial.*†

Variables	FW	CW	CES
Glucose (mmol·L^{-1})	0	0.22	0.34
Carbohydrate (grams)	0	45 (5%)	66 (11%)
Na^+ (mmol·L^{-1})	**0**	**6.59**	**18.3**
K^+ (mmol·L^{-1})	**0**	**50.2**	**3.33**
Cl^- (mmol·L^{-1})	**0**	**0**	**0**
Mg^{2+} (mmol·L^{-1})	**0**	**2.99**	**0**
Ca^{2+} (mmol·L^{-1})	**0**	**4.01**	**0**
P (mmol·L^{-1})	0	1.66	0
Vitamin C, $C_6H_8O_6$ (mmol·L^{-1})	0	0.79	0

*FW = flavored water; PW = plain water; CW = coconut water; CES = carbohydrate-electrolyte sports beverage.
†Bold shades of table represent electrolyte nutrients.

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Table 2

Physical characteristics of subjects included in this study (*n* = 8).

Characteristics	Mean ± *SEM*
Age (y)	22.3 ± 0.37
Height (cm)	180.9 ± 1.96
Body mass (kg)	81.1 ± 4.71
$\dot{V}O_2max$	3,889.6 ± 219.3
Relative $\dot{V}O_2$ (ml·kg^{-1}·min^{-1})	48.2 ± 219.3
70% $\dot{V}O_2max$ (W)	140.1 ± 9.3

minutes. This test was conducted as a means to determine an appropriate workload for each subject that would induce volume depletion of approximately 2% of their body mass. On the second visit, subjects performed a 60-minute practice ride to determine an exercise intensity corresponding to 70% $\dot{V}O_2max$ to ensure subjects maintained moderate-to-high intensity exercise.

Experimental Protocol

The same protocol was used for each beverage trial (FW, CW, CES), separated by a minimum of 7 days to allow adequate recovery. Each experimental trial consisted of 3 stages. The first stage began on arrival to the laboratory, where subjects urinated and were then weighed in their shorts to determine a pre-exercise weight. Followed by resting for 15 minutes before commencing each experimental trial. On completion of the 60-minute cycle, subjects were weighed again in shorts to determine postexercise weight. The difference between the pre and postexercise weight determined the total fluid volume lost during exercise. During the 3 experimental trials, 1 of 3 beverages was tested after 60 minutes of cycling: FW (bottle water, flavored with Crystal Light®), CW (VitaCoco® coconut water), and CES (Gatorade® carbohydrate-electrolyte sports drink).

Dehydration Protocol

The second stage was an exercise-induced dehydration (volume depletion) stage, in which subjects cycled for 60 minutes at 70% of $\dot{V}O_2max$, in a laboratory maintained at 19.8–21 degrees C, with a relative humidity of 23–26%, until they depleted approximately 1.5–2% BM. All subjects were required to cycle in sweatpants and a sweatshirt to ensure adequate body mass fluid loss occurred during the 60 minutes of moderate exercise.

Rehydration Protocol

After 60 minutes of moderate-to-high intensity exercise, subjects entered the final stage, a 2-hour volume repletion (rehydration) period (7). Immediately after exercise, subjects dried themselves off, with body mass reweighed in their underwear or shorts. During the 2-hour recovery period, individuals rested and ingested 1 of 3 experimental electrolyte beverages: FW (0 mmol·L^{-1} sodium [Na^+] and 0 mmol·L^{-1} potassium [K^+]), CES (18.3 mmol·L^{-1} Na^+ and 3.3 mmol·L^{-1} K^+), or CW (6.6 mmol·L^{-1} Na^+ and 52 mmol·L^{-1} K^+). Beverages were given in a random, blinded order to subjects, with drinks prepared and flavored (for the FW) in a separate room. All drinks were translucent, appearing visually similar, and were provided to the athletes in the original opaque dark green Gatorade sports bottles and opaque orange lids to further mask any visual differences. Rehydration beverage volume consumed was determined by total BM lost in the form of fluid (ml) during the exercise-induced dehydration protocol, using the following equation: 1,500 ml kg^{-1} × BM loss (kg) = amount of beverage consumed (ml). This provided subjects with a fluid volume replacement equivalent to 1.5 times or 150% of BM loss, similar to the ACSM position statement guidelines on fluid replacement and physical activity. Similar to previous rehydration studies but increased from the 120% BM loss protocol used by Ismail et al. (8), Perez-Idarraga et al. (20), and Saat et al. (21), beverages were given over 3 servings, equivalent to 150% BM lost during exercise. Subject feedback was collected after beverage consumption, at 0, 15, and 30 minutes postexercise. Study protocol is shown in Figure 1.

Outcome Measures

Mass loss (kg) and percent body mass loss (%), in the form of fluid volume losses (ml), were used to determine the appropriate fluid volume replacement (ml) equivalent to 150% rehydration. Variables used as outcome measures were the beverage volume of fluid provided (ml), urine volume output (ml), and fluid volume retained (ml), indicating net fluid balance (%/100) and overall hydration status, after the rehydration phase. After moderate-to-high intensity exercise (cycling) at 70% $\dot{V}O_2max$, subjective measures of beverage "saltiness, thirst, and nausea" were determined by providing a 5-point Fluid Sensation Scale assessment to subjects during the rehydration period at 0, 15, and 30 minutes. In a similar-sized rehydration study by Capitaná-Jimenéz and Aragón-Vargas (4), the test-retest reliability of the perceived thirst scale was proven reliable with a calculated an intraclass correlation coefficient (ICC) of r = 0.973 and $p < 0.0001$ between 2 post exercise thirst scores.

Cumulative Urine Output

Urine samples were collected before exercise, immediately postexercise at 0, 15, and 30 minutes, and as often as the subjects produced urine throughout the 2-hour rehydration period through volume-marked plastic graduated cylinders (21). A final urine collection and body mass were recorded at the end 120 minutes to ensure all urine was collected. At no point during the exercise period were subjects offered any hydration.

Net Fluid Balance and Percent Rehydration

The net fluid balance was determined by total percent body mass lost, and cumulative urine volume output, and experimental beverage volumes ingested (19–21). Percent body mass lost through exercise in each trial was calculated by the difference in pre-and-postexercise nude body mass, divided by nude pre-exercise mass, multiplied by 100. Fluid retention was calculated as the difference between volume of fluid consumed after exercise and the volume of urine collected by the end of each rehydration period. Percent rehydration was used as an index of whole-body rehydration based on the percent body mass lost that was regained from fluid volumes consumed. These calculations were based on the assumption that 1 milliliter of fluid was equivalent to 1 gram of body mass (8,19,20).

Fluid Sensation Measures

After exercising at 70% $\dot{V}O_2max$, subjects were required to complete a questionnaire at rest, rating sensations of thirst, saltiness, and nausea for each drink, during the rehydration period using a 5-point Fluid Sensation Scale (1 representing the lowest score; 5 representing the highest score) (20,21). Perceptual

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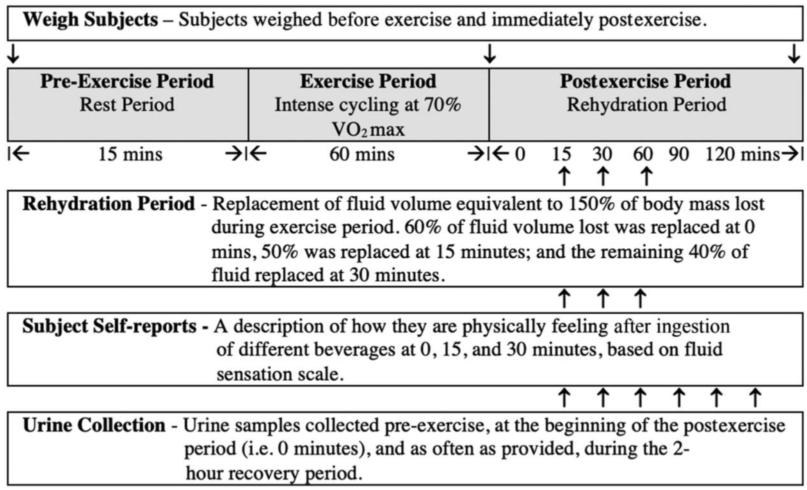

Figure 1. Experimental study protocol. Induced dehydration by exercising (cycling) at moderate-to-high intensity, 70% $\dot{V}O_2max$, followed by rehydration using flavored water (FW), coconut water (CW), or a carbohydrate-electrolyte sports beverage (CES).

measures were recorded after consumption of each beverage at 0, 15, and 30 minutes of rehydration.

Statistical Analyses

Statistical values were represented as mean ± *SEM* or 95% confidence interval (CI). A 1-way analysis of variance (ANOVA) was used to compare differences in experimental beverages. A 2-way repeated-measures ANOVA was applied to data collected over time. A 1-way repeated-measures ANOVA was used to determine fluid retention and cumulative urine volume. Intraclass correlation coefficients for test-retest reliability of perceived sensation scores was assessed by a repeated-measures 2-way analysis of variance. A paired Student's *t* test and Fisher's LSD *post hoc* test analysis program were used to identify significant differences between trials where appropriate. Statistical differences were considered significant at $p < 0.05$.

Results

Body Mass Loss and Fluid Volume Intake

The mean BM of subject's pre-exercise was the same across all 3 trials: FW (79.63 ± 4.5 kg), CW (79.23 ± 4.5 kg), and CES (79.56 ± 4.5 kg). The effect of 60 minutes of cycling at 70% $\dot{V}O_2max$ on BM was similar across all 3 trials, with subjects losing 1.13 ± 0.1 kg (FW), 1.06 ± 0.1 kg (CW), and 1.03 ± 0.1 kg (CES). Subjects lost a mean BM of 1.07 ± 0.1 kg and a mean percent body mass (%BM) loss of 1.36 ± 0.1%, which was similar across all beverage trials. During the rehydration period, subjects consumed similar mean fluid volumes for all 3 trials: FW (1,687.5 ± 171.8 ml), CW (1,593.8 ± 126.6 ml), and CES (1,537.5 ± 119.4 ml).

Cumulative Urine Output

During the rehydration period, the following cumulative urine volumes were produced: FW (530.63* ± 119.2 ml), CW (170.38 ± 35.8 ml), and CES (281.63 ± 54.4 ml), respectively. Total urine volume output was significantly greater for FW compared with CW ($p = 0.013$, $d = 1.17$, CI 95% [0.229, 2.06]) and CES ($p = 0.032$, $d = 0.941$, CI 95% [0.0747, 1.76]) by the end of the 2-hour rehydration period (Figure 2). There was no statistical difference in urine output between CW and CES beverages ($p = 0.151$, $d = -0.570$, CI 95% [−1.31, 0.199]) after rehydration.

Net Fluid Balance and Percent Rehydration

Net fluid balance was negative in all trials on completion of the 60-minute exercise-induced dehydration phase. After the 2-hour rehydration period, mean fluid volume retention was the greatest for CW (1,423.4 ± 132.7 ml), followed by CES (1,255.9 ± 129.4 ml) and FW (1,156.9 ± 198.7 ml). There was no statistical difference in fluid retention between the 3 experimental beverage trials, particularly when compared CW with CES ($p = 0.126$, $d = 0.613$, CI 95% [−0.166, 1.36]) (Figure 3). Percent rehydration status after the 2-hour rehydration period was nearest to a euhydrated state for CW (82.6 ± 1.0%), but there was no significant difference when compared with FW (61.9 ± 1.2%) or CES (75.0 ± 1.1%) trials. Subjects briefly achieved euhydration in all 3 beverage trials, but ultimately, resulted in a negative fluid balance and mildly hypohydrated state on completion of the rehydration period (Figure 4).

Fluid Sensation Measures

Perceived saltiness was greatest for CW compared with FW and CES, in all beverage trials, but there was no statistical difference between beverages at 0, 15, and 30 minutes of the rehydration period, $p > 0.05$. Perceived thirst for FW and CES were statistically greater than CW, at 0 minutes ($p < 0.05$), but not statistically significant at 15 or 30 minutes of rehydration ($p > 0.05$). Subject scores for perceived nausea were low with no statistical differences ($p > 0.05$) between beverages at all time-points of the 2-hour rehydration period (Table 3). The ICC for test-retest reliability of thirst sensation scores after exercise was an ICC = 0.414, 95% CI = 0.18–0.75.

Discussion

This study provides insights into the rehydration effectiveness and perceived sensation measures of CW in comparison with

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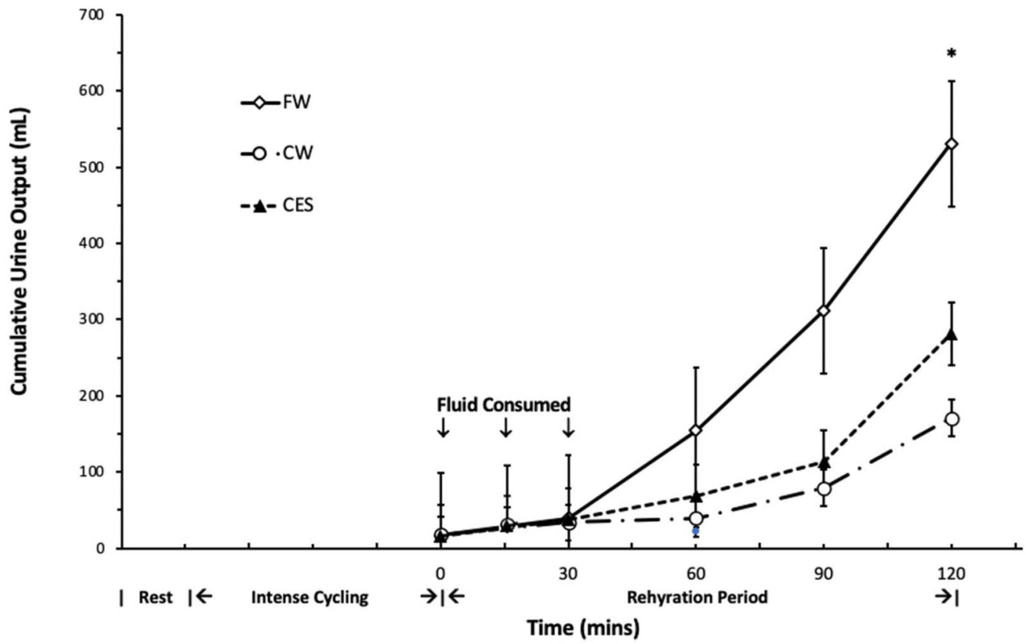

Figure 2. Cumulative urine volume output produced (ml) by FW (flavored water), CW (coconut water), and CES (carbohydrate-electrolyte sports) drinks, after each drink period (0, 15, and 30 minutes), during the 2-hour rehydration period. Data presented as mean ± *SEM* ($n = 8$). FW produced significantly greater cumulative urine volume output than CW and CES on completion of rehydration ($p = 0.013$ and $p = 0.032$, respectively).

a commercial carbohydrate-electrolyte sports beverage and FW on whole-body rehydration in healthy recreational athletes, when consumed after exercise-induced dehydration of approximately 2% body mass loss. Specifically, we measured percent rehydration and beverage palatability in response to moderate-to-high intensity exercise by cycling for 60 minutes at 70% $\dot{V}O_2max$. It was found that whole-body rehydration from CW was equivalent in rehydration effectiveness to the carbohydrate-electrolyte sports beverage and superior to FW. Despite CW and CES having a significantly higher sodium, potassium, and carbohydrate content than FW (absent of any electrolytes or nutrients), this study found no statistical significance between the 3 beverages on

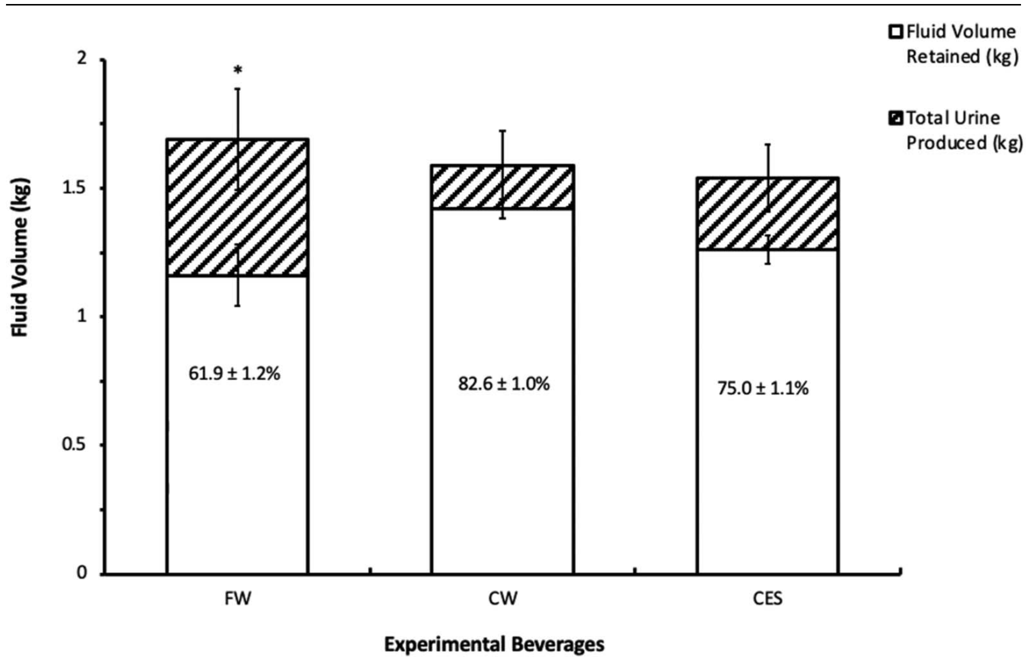

Figure 3. Distribution of total ingested fluid volume (kg) of flavored water (FW), coconut water (CW), and carbohydrate-electrolyte sports (CES) beverage. Fluid volume was retained (bottom portion of graph) or lost in the form of urine (top portion of graph). The percent body mass lost that was regained through retained fluid volume represented percent rehydration. Data presented as mean ± *SE* ($n = 8$). FW produced significantly greater urine than CW and CES by the end of 120 minutes rehydration ($p < 0.05$).

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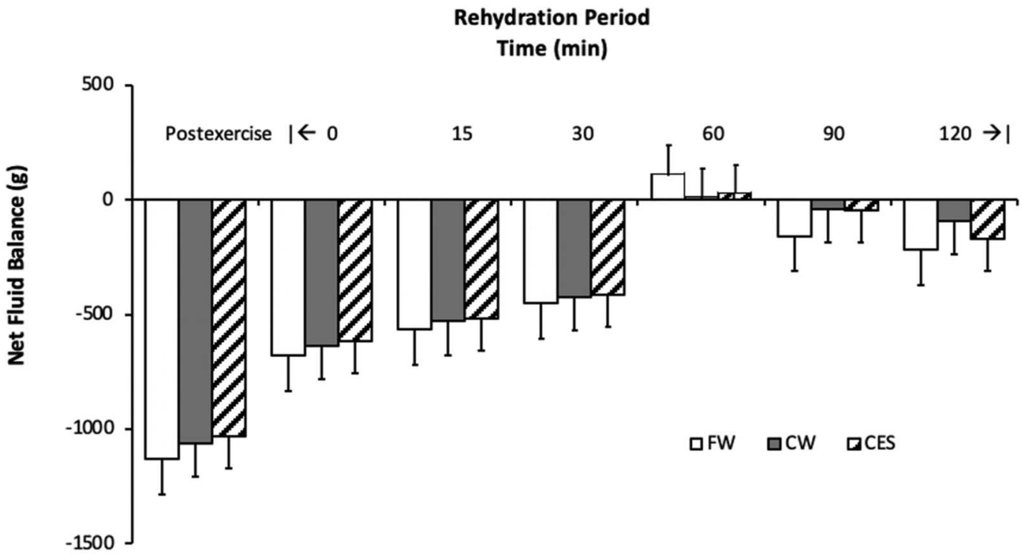

Figure 4. Comparison of net fluid balance for flavored water (FW), coconut water (CW), and carbohydrate-electrolyte sports (CES) beverages during the 2-hour rehydration period. Beverage replacement volumes of 60, 50, and 40% of 150% total BM lost were given at 0, 15, and 30 minutes during rehydration. Zero net fluid balance represents euhydration.

rehydration. All beverages were found to be palatable and well-tolerated, having a low association to nausea, including CES which had a high carbohydrate content of 11%. Flavored water was associated with the sensation of thirst despite containing no electrolytes.

Previous studies have assessed CW as rehydration beverage; however, to the best of our knowledge, none to date have blinded subjects in the plain water arm of the experiment by masking plain water with flavoring. Such studies have found CW as a natural rehydration beverage, superior to plain water, because of its innately high content of electrolytes and carbohydrates, as well as, being a preferable choice among athletes because of its improved palatability (8,20,21). In addition, researchers have found that regardless of a drink's composition, when subjects consumed a fluid volume equivalent to or less than bodily fluids lost during exercise, they could not achieve a euhydrated state (21). In previous CW studies, subjects were found mildly hypohydrated despite the rehydration protocols replenishing fluid volumes after exercise to 120% body mass lost. None of the studies blinded subjects from plain water's absent flavor. For this reason, in this study protocol, plain water was flavored with Crystal Light, the intensity of exercise was increased from 60–65% to 70% $\dot{V}O_2$max to encourage sufficient BM loss dehydration, the rehydration beverage volume was increased by from 120 to 150% of BM lost intending to compensate for insensible fluid losses, and the time of volume distribution intervals was shorted by 15 minutes to provide a longer rehydration evaluation period for each drink. When compared with the results Ismaiil et al. (8) and Pérez-Idárraga et al. (20) that applied the rehydration protocol of 120% BM loss, subjects of this study had a higher percent rehydration yet were still found mildly hypohydrated on completion of the rehydration period. This suggests that an increased rehydration beverage volume of 150% BM loss or greater is necessary after moderate-to-high intensity exercise and may compensate for some of the additional insensible fluid losses that would have occurred during exercises.

Although CW showed the greatest percent rehydration in this study, this was not found significantly different between FW and

Table 3

Subject feedback based on a fluid sensation scale: saltiness, thirst, and nausea.*†

	Time during 2-h rehydration (min)		
Experimental beverages	**0 min**	**15 min**	**30 min**
Saltiness (1 = not salty; 5 = extremely salty)			
FW	1.75 ± 0.31	1.19 ± 0.19	1.25 ± 0.16
CW	2.63 ± 0.56	2.25 ± 0.33	1.75 ± 0.41
CES	2.13 ± 0.30	1.63 ± 0.38	1.50 ± 0.27
Thirst (1 = not thirsty; 5 = extremely thirsty)			
FW	3.29 ± 0.56‡	1.81 ± 0.27	1.13 ± 0.13
CW	2.50 ± 0.45	1.88 ± 0.40	1.38 ± 0.38
CES	3.28 ± 0.46‡	1.98 ± 0.24	1.25 ± 0.13
Nausea (1 = no nausea; 5 = extremely nauseous)			
FW	1.66 ± 0.35	1.31 ± 0.21	1.13 ± 0.13
CW	1.75 ± 0.44	1.63 ± 0.38	1.75 ± 0.53
CES	1.69 ± 0.37	1.13 ± 0.13	1.06 ± 0.06

*FW = flavored water; CW = coconut water; CES = carbohydrate-electrolyte sports beverage.
†Data presented as mean ± *SE* (n = 8).
‡Thirst was significantly different for FW and CES at 0 minutes of the 2-hour rehydration period ($p < 0.05$).

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CES, similar to previous literature. The authors are aware that a urine specific gravity (USG), another indicator of hydration status was not performed, which may have identified inadequately hydrated, i.e., hypo/hyperhydrated subjects who were noncompliant with the fluid and dietary protocol before commencing the study.

The rationale for CW and the CES beverage trials conserving significantly more fluid than the FW is the result of both beverages containing carbohydrates and electrolytes—the latter known to reduce diuresis (12). Adequate plasma sodium concentration is required for the maintenance of proper antidiuretic hormone (ADH) to ensure water retention between vascular compartments, improving potential positive net fluid balance after exercise (9,23). The presence of circulating sodium will also sustain proper plasma osmolarity and stimulate one's "drive to drink," ensuring enough fluid is ingested to rehydrate the body (12). Studies conducted on triathletes have suggested that after exercise, an optimal rehydration beverage should contain a combination of carbohydrates and electrolytes, at concentrations of 4–8% and 50–60 $mmol{\cdot}L^{-1}$ of sodium, respectively (2). Although the optimal rehydration beverage recommended for an elite athlete is a combination of 4–8% carbohydrates and 50–60 $mmol{\cdot}L^{-1}$ concentration of sodium, research indicates that excess sodium concentrations are not necessary for individuals exercising at less intense levels of exercise and for shorter periods of time (2). For recreational athletes, the current held belief is that a fluid rehydration beverage should contain approximately 20–30 $mmol{\cdot}L^{-1}$, 2–5 $mmol{\cdot}L^{-1}$ potassium, and 5–10% carbohydrates (1). As per the American College of Sports and Exercise Medicine, variation in these requirements is dependent on the exercise task, i.e., intensity and duration, and weather conditions, the athlete is performing under.

Previous studies have reported both sodium and potassium are required to replace sweat electrolyte losses, as sodium stimulates thirst (22,23–25); and Maughan et al. (12) mentions potassium may be as effective as sodium in retaining body fluid. However, no study has been able to explain the specific role of potassium. Recent literature mentions potassium, as the major cation within the intracellular fluid, and its role as an effective rehydration solution in small quantities over short periods of time (21). Campbell-Falck et al. (3) also found CW to be a beneficial rehydration tool as a result of its naturally high potassium concentration, enhancing water retention within the intracellular space. The CW beverage used in this study contained one-third the sodium concentration (3 $mmol{\cdot}L^{-1}$), and a 15-fold potassium concentration (52 $mmol{\cdot}L^{-1}$), compared with present leading sports electrolyte drinks (sodium 20 $mmol{\cdot}L^{-1}$ and potassium 3.3 $mmol{\cdot}L^{-1}$). after exercise, CW retained an equivalent and greater fluid volume than CES. As CW contained a sodium concentration below the current recommendation of 20 $mmol{\cdot}L^{-1}$, and potassium could not be isolated from the CW beverage, the results could show a slight bias to CW, with additional nutrients (calcium and magnesium) not found in CES, potentially leading to an increase in plasma osmolarity and fluid retention.

The evidence pertaining to what specific component of a drink improves its palatability also remains uncertain. Meyer et al. (14) reported that regardless of flavor preference or cultural background among people, the degree of "sweetness" is the main contributor after the "pleasantness" of a drink. Other studies have found CW was a preferable choice because of its improved palatability, as it was associated less nausea and stomach upset compared with a carbohydrate-electrolyte sports drink and plain water (20,21). Ismail et al. (8), suggested CW could cause less nausea compared with a commercial sports drinks that may be associated with increased stomach upset, due to the large concentration of sugars present in commercial sports drinks. Passe et al. (17) found that the improved flavor and palatability of a drink is due to its sodium content, and potentially the reason sports electrolytes drinks are more popular. In our study, all 3 beverages, including the electrolyte-rich (CW and CES) and electrolyte-absent (FW) had a low association with nausea and stomach upset, and all were perceived as "salty." This was most notable for the FW, suggesting that water being masked by flavoring does improve a beverage's palatability. Adequately blinding subjects from FW's true composition and absence of electrolytes is important for future research. In addition, no statistical difference was found for the sensation of nausea between FW, CW, or CES drinks, indicating that the higher concentration of sugar found in CES did not cause stomach upset after exercise as some studies have suggested. While the reliability of perceived thirst sensation score ICC calculations from this study was moderately reliable, similar-sized rehydration studies have found good reliability for perceived "thirst" for rehydration beverages tested between 2 time points after exercise (4). This suggests using the sensation of thirst as an approximation of hydration status is acceptable when technical instrumentation is unavailable.

Notable limitations of this study were the limited sample size and environmental conditions not being perfectly matched between trials, which may have contributed to the greater fluid retention results for CW compared with CES. Similar to other rehydration studies, another limitation and uncontrolled factor potentially contributing to incomplete rehydration in this study was additional body water loss through insensible fluid losses, i.e., respiration and perspiration, and substrate metabolism during the recovery period. Future studies should ensure subjects are calorie-matched during each trial, with more rigorous hydration-status indicators measurements, such as USG, to ensure subjects remain compliant with pretrial protocols and prevent result bias. In addition, more extensive studies on a larger subject population with rehydration protocols lasting longer than 120 minutes, while also assessing sweat-rate variability, would be valuable to determine whether CW is a superior rehydration agent when the athlete has longer recovery periods between sport. Further research is also needed to determine whether sodium-enhanced CW in comparison with current carbohydrate-electrolyte drinks containing greater than 20 $mmol{\cdot}L^{-1}$ of sodium provides not only rehydration but also an ergogenic effect in athletes.

In conclusion, rehydration after moderate-to-high intensity exercise with a natural potassium-rich CW beverage showed improved rehydration compared with FW, despite having a sodium concentration approximately one-third of the leading commercial CES beverage. Fluid volume retention and subsequent whole-body rehydration for CW was as effective and comparable with a leading commercial carbohydrate sports beverage and greater than FW. While CW did not show increased palatability over CES as was hypothesized, this study did find CW was perceived as equally palatable when compared with CES. Finally, this study provided clinically relevant information for sports clinicians and athletes, highlighting the effectiveness of CW and the widely accepted carbohydrate electrolyte drink as a rehydration beverage after moderate-to-high intensity exercise—both reducing diuresis and improving fluid retention, but only CW providing athletes with the additional benefit of a healthy beverage alternative depending on an athlete's palate preference.

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Practical Applications

Rehydration beverage volume, electrolyte composition, and palatability are important factors that can affect an athlete's hydration status after exercise. Body mass is an invaluable measurement an athlete or trainer can easily use to monitor hydration status between sporting events, ensuring adequate rehydration. In-keeping with the current consensus statement by the ACSM, one should aim to rehydrate with beverage volumes equivalent to at least 150% BM lost from exercise during the 2-hour period immediately after exercise and before the next event. It is important to note these values have increased from previous recommendations of 100–120% BM, which may result in insufficient rehydration. The optimal sodium to potassium electrolyte ratio remains unclear and is highly variable among athletes due to individual sweat rates, exercise intensity/duration, and environmental factors—ultimately, requiring further studies to be determined. Finally, the choice of rehydration beverage boils down to the athlete's specific taste preference; an important consideration as it can dictate beverage consumption, degree of rehydration, and athletic performance. As CW can effectively aid in rehydration and is financially feasible, it provides athletes with a viable healthy drink alternative to other commercial electrolyte drinks.

Note: S. Kristyn Bell is now a Sport and Exercise Physician Registrar of the Australian College of Sport and Exercise Physicians, and graduate of Human Kinetics at the University of Guelph. Lawrence L. Spriet is now University Professor Emeritus for the Department of Human Health and Nutritional Sciences at the University of Guelph.

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