POST-EXERCISE REHYDRATION: POTASSIUM-RICH DRINKS VS. WATER AND A SPORTS DRINK

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ABSTRACT

Fluid retention, thirst quenching, tolerance, and palatability of different drinks were assessed. On four different days, 12 healthy, physically active volunteers (24.4 ± 3.2 years old, 74.75 ± 11.36 kg body mass (mean ± S.D)), were dehydrated to 2.10 ± 0.24% BM by exercising in an environmental chamber (32.0 ± 0.4 ºC db, 53.8 ± 5.2% rh). Each day they drank one of four beverages, in random order: fresh coconut water (FCW), bottled water (W), sports drink (SD) or potassium-rich drink (NEW); volume was 120% of weight loss. Urine was collected and perceptions self-reported for three hours. Urine output was higher ($p < 0.05$) for W (894 ± 178 mL) than SD (605 ± 297 mL) and NEW (599 ± 254 mL). FCW (686 ± 250 mL) was not different from any other drink ($p > 0.05$). Fluid retention was higher for SD than W (68.2 ± 13.0% vs. 51.3 ± 12.6%, $p = 0.013$), but not for FCW and NEW (62.5 ± 15.4% and 65.9 ± 15.4%, $p > 0.05$). All beverages were palatable and well tolerated; none maintained a positive net fluid balance after three hours, but deficit was greater in W vs. SD ($p = 0.001$). FCW scored higher for sweetness ($p = 0.03$). Thirst increased immediately after exercise but returned to baseline after drinking a small volume ($p < 0.0005$). In conclusion, additional potassium in FCW and NEW did not result in additional rehydration benefits over those already found in a conventional sports drink with sodium.

Key words: coconut water, recovery, dehydration, exercise, urine output, palatability, tolerance

INTRODUCTION

A number of studies support the practice of hydration before, during, and after exercise to protect health and performance (Del Coso et al. 2008; Sawka et al. 2007). However, some athletes start their practice or competition already hypohydrated which, combined with low fluid intakes and high sweat rates during exercise (Osterberg et al. 2009; Volpe et al. 2009), may result in considerable dehydration at the end of exercise (Noakes and Martin 2002; Shirreffs et al. 2004). While food and drinks from the diet may be enough to replenish losses before the next exercise bout, recovery time may be short and aggressive rehydration necessary (Sawka et al. 2007).

Sports drinks are widely used to promote rapid fluid replacement because their electrolyte content (mainly sodium) helps keep the ingested water in the body (Passe et al. 2009; Shirreffs and Maughan 1998; Shirreffs et al. 2007) while their flavor characteristics and sodium content promote voluntary intake (Sun et al. 2008; Wilmore et al. 1998).

The role of sodium replacement, which is lost in sweat at an average concentration of 35 $mEq\cdot L^{-1}$, (range: 10 to 70 $mEq\cdot L^{-1}$) (Sawka et al. 2007) is well documented. Potassium, however, has a lower average sweat concentration of 5 $mEq\cdot L^{-1}$ (range: 3 to 45 $mEq\cdot L^{-1}$) (Sawka et al. 2007), and has not received as much attention (Maughan et al. 2005). Potassium replacement could play an important role during rehydration because it is the major intracellular cation, potentially helping restore, in a selective manner, intracellular fluid volume (Casa et al. 2005). In fact, Maughan et al. (1994) found that a beverage with potassium could be as effective as a sodium beverage, compared to drinks without electrolytes. It has been suggested that more studies should be performed with higher potassium beverages (Shirreffs 2001; Shirreffs et al. 2004).

Fresh coconut water has been widely used in the tropics for decades as a simple, palatable drink. Recent commercial interest in coconut water as a natural sports drink has provided some preliminary results on the rehydration benefits of potassium. Coconut water, naturally rich in potassium but low in sodium, has been found to be as effective as a conventional sports drink and better than pure water for post-exercise rehydration in some studies (Aragón-Vargas and Madriz-Dávila 2000; Ismail et al. 2007; Pérez-Idárraga and Aragón-Vargas 2010), but not different from either water or sports drink in another (Saat et al. 2002). Furthermore, the benefits of combining electrolytes at concentrations found in conventional sports drinks (sodium) and coconut water (potassium) have not been studied in depth, even though some attempts have been made (Ismail et al. 2007; Maughan et al. 1994).

While theoretically appealing, the presence of larger concentrations of sodium and potassium salts may result in the perception of the drink as too salty, an important beverage flaw which may reduce voluntary intake. Meanwhile, the right saltiness is believed to actually increase voluntary fluid intake (Murray and Stofan 2001; Passe 2001). This palatability issue should be assessed in the formulation of any new rehydration drink.

Therefore, the purpose of this study was to compare the fluid retention, thirst-quenching, and palatability properties of two high-potassium drinks (fresh coconut water and a specially formulated drink) with those of two conventional beverages: bottled water and a sports drink. In addition, we wished to assess tolerance to each of the drinks when a large volume was ingested.

MATERIALS AND METHODS

Participants. Twelve (10 males and 2 females) apparently healthy (height = 1.73 ± 0.06 m, weight = 74.75 ± 11.36 kg), physically active, young (24.4 ± 3.2 years of age) volunteers were recruited for the study after they signed an informed consent and completed a health questionnaire; both the study and the informed consent procedure were approved by the University's committee on ethics and science.

Procedures. Participants were requested to complete a 24-hour dietary recall each day before testing and to try to follow the same diet each time. They were also encouraged to drink an extra five glasses of water, and requested to refrain from strenuous exercise, on the day before testing.

Each participant arrived in the laboratory early in the morning after an overnight fast of at least 10 hours, and submitted their first urine of the day for urine specific gravity (USG) analysis with a URC-NE Hand-Held refractometer (*ATAGO*®, Tokyo, Japan). He/she was considered euhydrated if USG ≤ 1.020 (Casa et al. 2005; Sawka et al. 2007). They proceeded to ingest a standardized breakfast, consisting of 775 kcal (73% carbohydrate, 17% fat, and 10% protein), 1300 mg Na^+, and 350 mL fluid. After a one-hour rest they were weighed nude to the nearest ten grams (pre-exercise body weight, BM_{pre}) on a *Ballar*® scale, Model DSB921 (Romanas Ballar®, San Jose, Costa Rica) and started their exercise in an environmental chamber at 32.0 ± 0.4ºC dry bulb, 53.8 ± 5.1 % relative humidity. The dehydration protocol has been published by others (Shirreffs et al. 2007); briefly, they exercised intermittently, alternating between a treadmill and a cycle ergometer for 20 minutes and resting for 5 min. Exercise intensity was verified with a *Polar*® heart rate monitor, model S120 (Polar Electro Oy, Kempere, Finland); participants aimed to stay between 80 and 85% of maximum heart rate, as obtained from HR_{max} = 207-(0.7 x age in years) (Gellish et al. 2007). Rest periods were used to obtain nude body weight, aiming for a dehydration equivalent to 2% body weight. After this target weight loss was achieved each participant took a cold shower, emptied his/her bladder, and was weighed once more in the nude (BM_{postex}).

Each participant repeated the procedure above on four separate occasions, one week apart, but then proceeded to drink one of the beverages: bottled water (Cristal®) (Florida Ice & Farm Co., San Jose, Costa Rica) (W), a lower carbohydrate, regular electrolyte sports drink (SD), fresh coconut water (FCW), or a specially formulated drink (NEW) (see Table 1). During the one-hour rehydration period, participants consumed a volume equivalent to 120% of body mass loss divided into four equal aliquots, one every 15 minutes; the order of administration of the four beverages was randomized. Room temperature was 26.3 ± 1.8ºC, with 53.1 ± 4.0% r.h.; drinks were presented at 9.0 ± 2.0°C.

Table 1. Beverage composition. Values are Mean±S.D.

Component	Bottled Water	Fresh Coconut Water	Sports Drink	Special Formula
Sodium ($mEq \cdot L^{-1}$)	0.5±0.0	4.8±1.3	17.9±0.2	17.5±0.2
Potassium ($mEq \cdot L^{-1}$)	0.2±0.0	71.1±22.5	4.0±0.0	50.2±0.2
Chloride ($mEq \cdot L^{-1}$)	0.5±0.0	31.1±5.6	22.5±0.2	32.4±0.2
Carbohydrate (%)	0.0	4.5±1.1	4.0±0.0	4.0±0.1
Reducing Sugars (%)*	Not detected	3.9±0.9	4.0±0.0	4.0±0.1
Sucrose (%)	Not detected	0.5±0.2	Not detected	Not detected
pH	7.0±0.0	4.7±0.5	2.7±0.1	4.04±0.21
Brix	0.0	5.9±0.5	4.3±0.0	4.95±0.01
Osmolality ($mOsm \cdot kgH_2O^{-1}$)	1.5±1.0	443.7±27.4	263.7**	311.6**

Notes: *Reducing sugars: fructose and glucose. Beverages were analyzed by flame photometry, AOAC 2005.
**Theoretical osmolalities calculated from beverage formulation.

Upon completion of rehydration, and once every 30 minutes for three hours, urine samples were obtained from each participant, who emptied his/her bladder as completely as possible. Urine volumes were calculated to the nearest mL by weighing with a *OHAUS*® food scale, model CS-2000 (capacity: 2 kg; precision: 1g) (OHAUS, Parsippany, NJ, USA). Nude body weight was measured at the end of rehydration (BM_{re}) and after the last urine sample was obtained (BM_{final}).

Subjective perceptions of thirst and tolerance (nausea, fullness, stomach ache, and urge to defecate) were assessed using a hybrid 100-mm visual analogue scale (Villanueva et al. 2005) before exercise, before rehydration, upon completing intake of each rehydration aliquot, and at the end of monitoring. A similar scale was used to evaluate beverage general acceptance, liking of saltiness, and liking of sweetness before exercise and after each rehydration aliquot. See Figure 1 for an overview of the protocol.

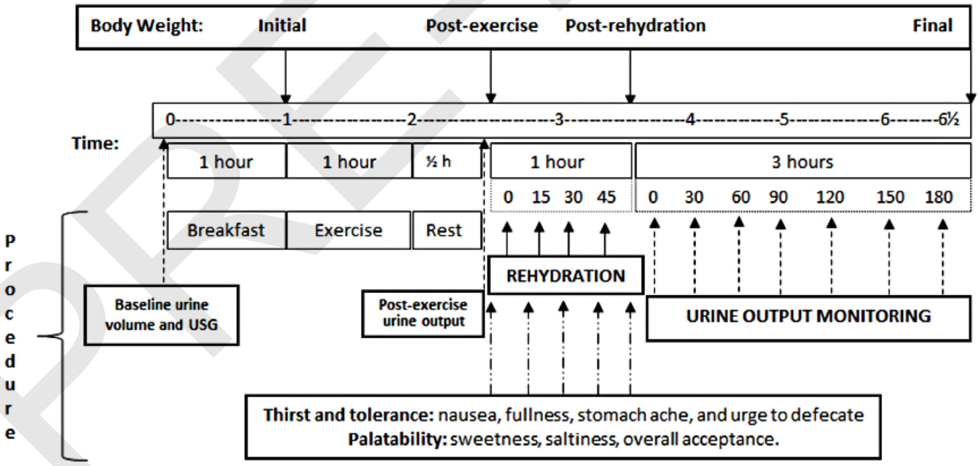

Figure 1. *Summary of protocol*

Fresh coconut water was obtained weekly from 25 to 30 immature coconuts without pulp or endosperm, mixed, bottled and refrigerated according to established good practices

(Rolle 2007). The powder mix for both SD and NEW (lemon-lime flavor) was prepared by the Gatorade Sport Science Institute® laboratory (Barrington, IL, USA) and reconstituted using bottled water.

Statistical analysis: Descriptive statistics (mean ± S.D.) were calculated to characterize the sample. After checking for data normality, a one-way analysis of variance (ANOVA) was performed across beverages for each of the following variables: baseline USG, BM_{pre}, exercise heart rate, exercise time, percent dehydration and fluid ingestion, to verify that conditions were the same before rehydration with each beverage. Next, a two-way, repeated-measures ANOVA was performed for urine output (4 beverages x 7 measures) and for net fluid balance (4 beverages x 4 measurements), followed by a one-way ANOVA across beverages for total urine output and fluid retention at the end of monitoring. Finally, a two-way, repeated-measures ANOVA was performed for each thirst-quenching, tolerance and palatability score: thirst, nausea, fullness, stomach ache, and urge to defecate (4 beverages x 7 measures), and sweetness, saltiness, and overall acceptance (4 beverages x 5 measurements). Post-hoc evaluation of significant main effects was performed with a Bonferroni test. Data are reported as mean ± S.D.; unless otherwise noted, we use S.E.M in figures for the sake of clarity.

RESULTS

Participants started the rehydration period under similar conditions for all beverages ($p > 0.05$) (see Table 2). They exercised in the heat for 52.6 ± 2.5 min to achieve a 1.57 ± 0.08 kg weight loss, equivalent to a dehydration of 2.10 ± 0.24% BM. Consequently, prescribed fluid intake (1881 ± 351 mL) was not statistically different among beverages (p = 0.469).

Table 2. Conditions prior to rehydration. Values are Mean±S.D.

Variable	**Bottled Water**	**Fresh Coconut Water**	**Sports Drink**	**Special Formula**	**p-value**
Baseline USG	1.016±0.007	1.016±0.006	1.015±0.007	1.016±0.007	.871
BM_{pre} (kg)	74.76±11.92	74.72±11.68	74.77±11.44	74.76±11.91	.982
Exercise HR (beats min^{-1})	156.6±5.0	157.4±6.8	157.4±6.0	157.8±6.9	.746
Exercise time (min)	50.8±10.0	55.0±10.0	52.9±8.9	51.7±10.1	.185
Dehydration (%BM)	2.12±0.28	2.13±0.19	2.10±0.19	2.03±0.22	.548
Prescribed fluid intake (mL)	1906±399	1919±360	1884±361	1816±315	.469

Urine output changed significantly over time, but the changes were different depending on the beverage (Figure 2). Urine output for the W trial was significantly higher than the SD at both 30 and 90 minutes of follow up ($p < 0.05$). FCW and NEW were lower than W at 60 minutes ($p < 0.001$), but SD was not ($p > 0.05$). When total post-rehydration urine output was calculated, there was a significant difference among beverages (p = 0.007); both SD (605 ± 297 mL, p = 0.028) and NEW (599 ± 254 mL, p = 0.010) were lower than W (894 ± 178 mL), but FCW (687 ± 250 mL) was not different (p = 0.147) (see Figure 3).

Fluid retention was obtained by subtracting total urine output from fluid intake, and expressed both as an absolute volume and as a percentage of intake (see Figure 3). Fluid retention was higher for SD (68.3 ± 13.1%) than W (51.3 ± 12.6%, p = 0.013), an absolute volume difference of ~260 mL. Neither FCW (62.5 ± 15.4%, p = 0.190) nor NEW (65.9 ± 15.4%, p = 0.058) was different from water.

Net fluid balance was calculated relative to pre-exercise body weight, which was established as zero. The following three points were from post-exercise, post-rehydration (0 min), and final (180) body weight; these take into account sweat loss, beverage intake, and urine production (Figure 4). By the end of monitoring, none of the beverages was able to maintain euhydration. Net fluid balance for the sport drink (-600 ± 286 g) was better than the water trial (-915 ± 186 g) only at the final data point ($p = 0.001$). No other significant differences were observed among beverages.

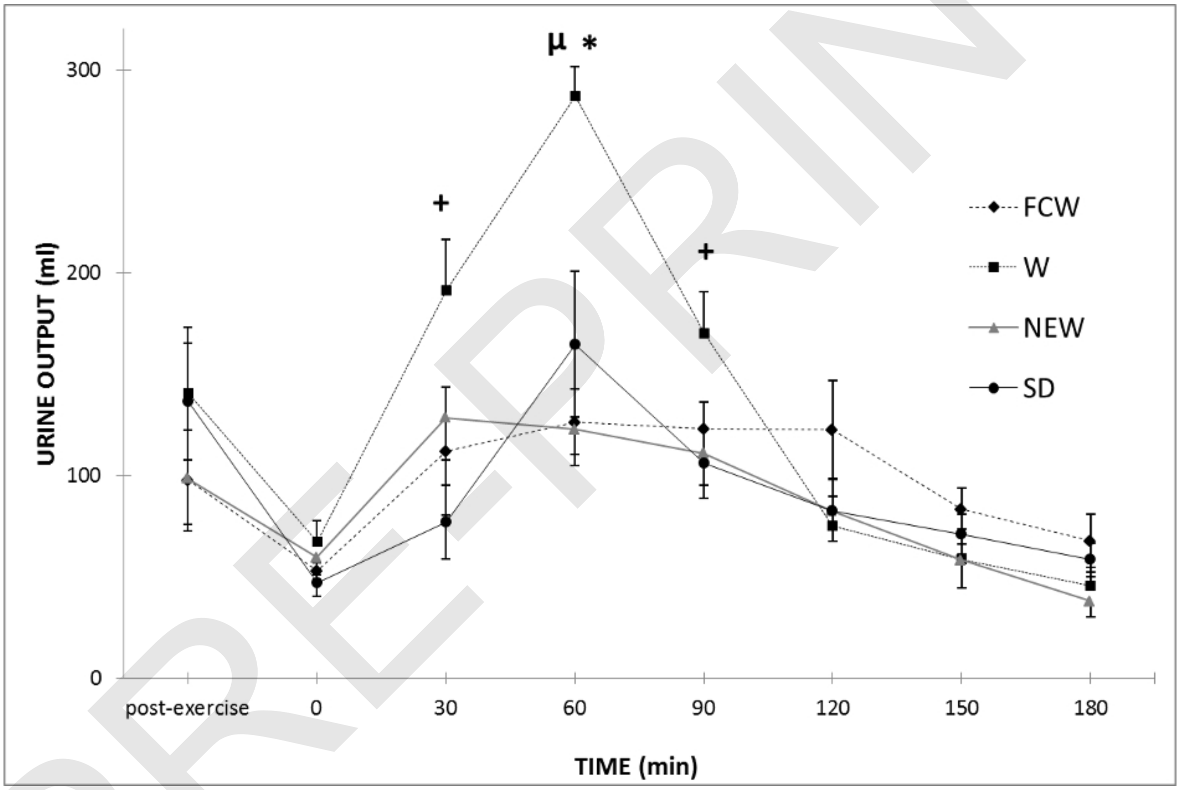

Figure 2. *Urine output over the course of the experiment.*

Points are mean values; error bars are standard errors of measurement. Interaction F=4.129, p=0.001. Beverage main effect F=3.458, p=.007. Measurement (time) main effect F=36.502, p < .0005.

(*) Urine output at this time is different from all others.

(+) W different from SD at that time (p < .05)

(µ) W different from NEW and FCW at that time (p < .05).

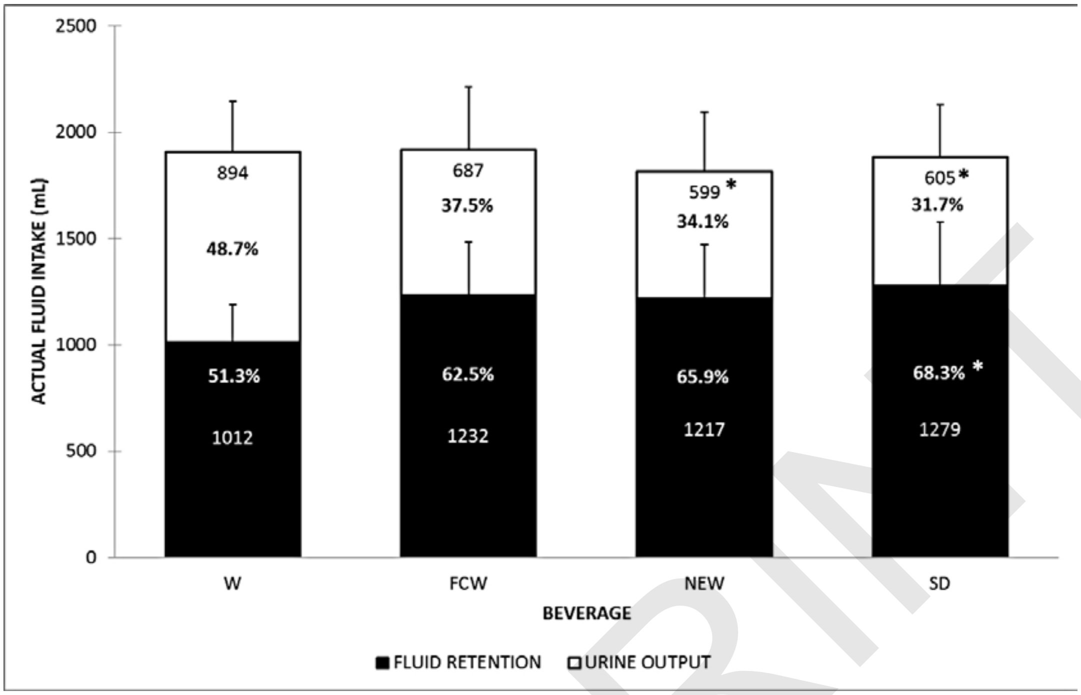

Figure 3. *Fate of ingested volume after three hours of follow-up*

Total bar height represents actual fluid intake, p=.469; bars are split by absolute volume. Error bars represent standard deviation of the mean. When fluid retention is expressed as a percent of intake, F=4.549, p=.009.
(*) *denotes a significant difference vs. water (p < .05)*

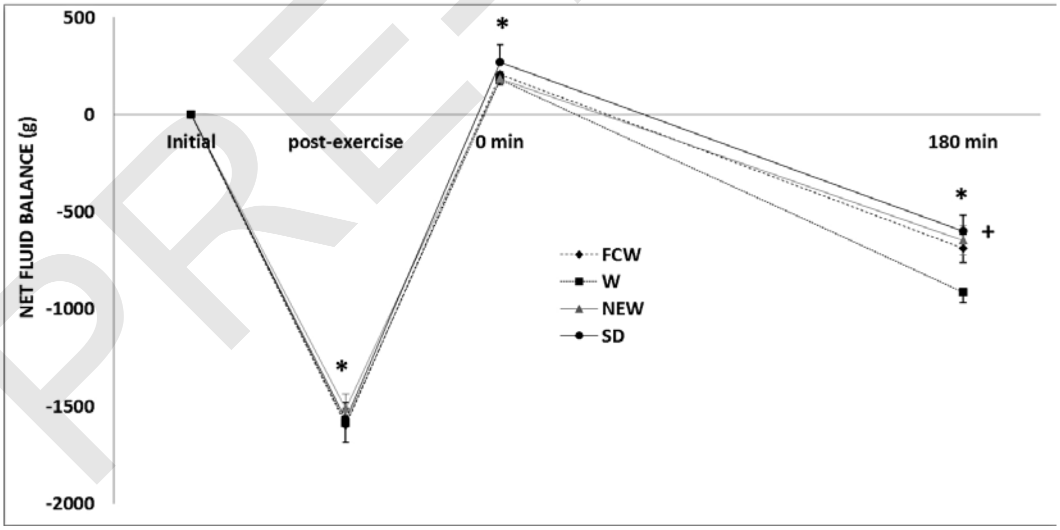

Figure 4. *Net Fluid Balance*

Points are mean values; error bars are standard errors of measurement. Interaction F=2.455, p = .014. Beverage main effect F = 7.474, p = .001. Measurement (time) main effect F = 264.35, p < .0005.
(*) The average at these points is different from preexercise, p < .05.
(+) SD significantly different from W, p = .001

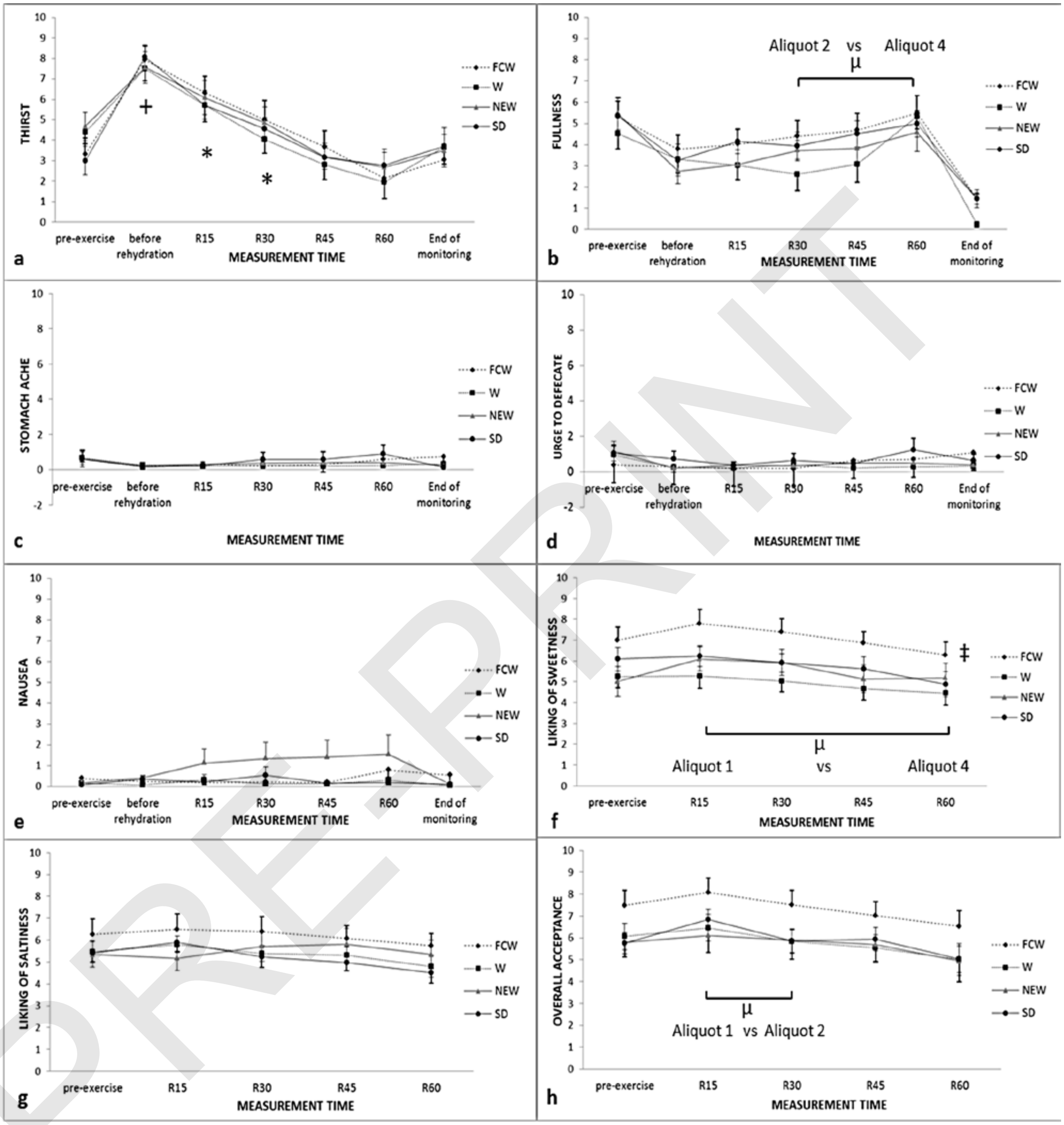

Figure 5. *Thirst, tolerance, and palatability scores before and during rehydration, and at the end of monitoring.*

Points are mean values; error bars are standard errors of measurement. There were no interactions between beverage and time of measurement for any of the reported perceptions.

(**‡**) Different from all other beverages *(p < .05)*.

(**+**) *Different from all other measurement times (p < .05).*

(*****) Different from all other measurement times except pre-exercise (p < .05).

(**µ**) *Significant pairwise differences between measurement times (p < .05).*

***Zero (0)** = absence of sensation or extreme dislike; **ten (10) =** extreme sensation or liking.*

Figure 5 shows the detailed results for thirst-quenching, palatability, and tolerance scores. There was no significant interaction between beverages and measurement (time) in any case (all $p > 0.05$). The time main effects showed an increased thirst before rehydration ($p < 0.0005$), a decrease in fullness at the end of monitoring ($p = 0.022$), a lower liking of sweetness after ingesting aliquot 4 when compared to aliquot 1 ($p = 0.010$), and a lower overall acceptance after aliquot 2 when compared to aliquot 1 ($p = 0.006$). There was only one significant main effect of beverages on liking of sweetness: coconut water was rated higher than the rest ($p = 0.032$) (see Figure 6).

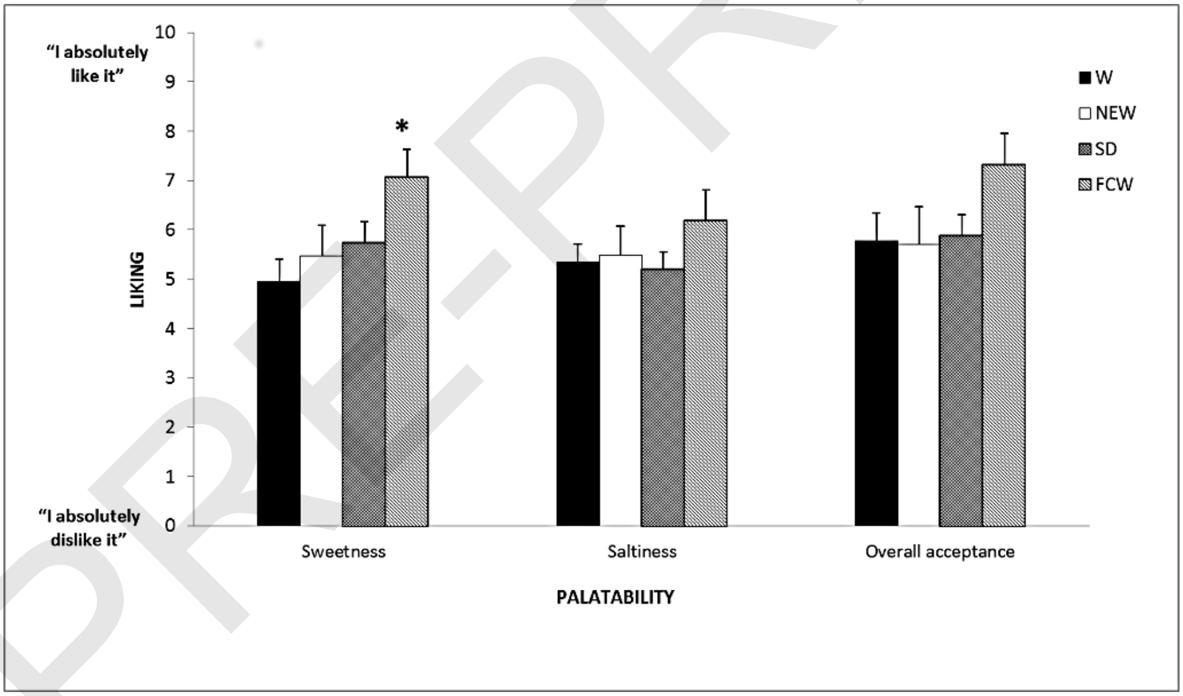

Figure 6. *Palatability for each different beverage*
Bar height is the mean score for each beverage. Error bars represent standard errors of measurement (*) FCW better than the rest, (p = .032)

DISCUSSION

The main finding of this study was that when humans are dehydrated by exercising in the heat to about 2% BM and then rehydrated with 120% of sweat loss, the natural presence of potassium in fresh coconut water, or its addition to a conventional sports drink with sodium (NEW), resulted in no additional fluid retention benefits when compared to a conventional sports drink with a normal sodium but a low potassium concentration. SD achieved better fluid retention scores than W, but it was not different from FCW or NEW. In addition, all the drinks were well tolerated and showed similar thirst-quenching ability, liking of saltiness, and overall acceptance; FCW, however, achieved better scores for liking of sweetness.

Most previous studies show that fresh coconut water provides better fluid retention than water. The first one of these was carried out at sea level in the tropics of Costa Rica: nineteen males, 11-15 years old, were dehydrated to 2.3%BM by running intermittently in the outdoor heat, and then rehydrated with 125% of their sweat loss using water, fresh coconut water, or a sports drink. At the end of three hours of monitoring while they rested at ambient heat, sweating and producing urine, hypohydration was worse for water (1.98 ± 0.28%BM) than for both coconut water (1.52 ± 0.22%BM) and the sports drink (1.46 ± 0.21%BM) ($p < 0.05$), a difference of about 300 g (Aragón-Vargas and Madriz-Dávila, 2000). More recently, Ismail et al. (2007) found that rehydration with coconut water resulted in better fluid retention than water after a 3% BM dehydration (65.1 ± 1.7% vs. 58.9 ± 9%, $p < 0.05$). Pérez-Idárraga and Aragón-Vargas (2010) also obtained better fluid retention with FCW (71.0 ± 7.9%) than water (55.9 ± 13.5%) ($p < 0.05$). However, Saat et al. (2002) found no significant differences in fluid retention between water and coconut water, and neither did we. There are no consistent study design differences between these two groups of studies to justify the discrepancy. For instance, while Saat et al. had a rather small sample (n=8), suggestive of a statistical power issue, the present study had 12 subjects and power was enough to detect many other differences among beverages. A recent study by Kalman et al. (2012), using coconut water from concentrate, and bottled, commercially available coconut water, does little to clarify this discrepancy, as Kalman et al. present internally conflicting results while providing no information on actual beverage composition. We are unable to explain why there was no difference in fluid retention between W and FCW in the present study.

A study by Shirreffs et al. (2007) looked at the fluid retention qualities of a different potassium-rich beverage, Apfelschörle, a combination of apple juice and mineral water. The drink used in the study had 8 mEq·L^{-1} Na^{+} and 30 mEq·L^{-1} K^{+}; net fluid balance was no better with Apfelschörle than bottled water, but it was with a conventional sports drink. It is possible that the presence of potassium in a drink is really not effective as a means to improve fluid retention. Alternatively, maybe the concentration needs to be higher than 30 mEq·L^{-1}, as in fresh coconut water. In addition, rehydration volume must be high enough to maintain euhydration after three or four hours of monitoring. In the present study, where we replaced 120% of sweat loss, none of the beverages sustained euhydration after three hours, while Shirreffs et al. (2007) maintained euhydration with the sports drink after four (they used 150% of sweat loss). The disadvantage of using larger volumes is a greater fluid waste, which may be too much of a luxury under some circumstances.

The manipulation of beverage electrolyte concentrations towards both higher sodium and potassium has been attempted before, with rather consistent results: neither a sodium-enriched (20 mEq·L^{-1} Na$^+$, 50 mEq·L^{-1} K$^+$) coconut water (Ismail et al. 2007) nor a special combination of high sodium and moderate potassium (60 mEq·L^{-1} NaCl and 25 mEq·L^{-1} KCl, Maughan et al. 1994) achieved better fluid retention than the regular sodium versions of the drinks. We hypothesized that NEW would be able to strike the right combination of carbohydrate, sodium and potassium to provide better fluid retention than SD or coconut water; all three were expected to be better than bottled water. We obtained, however, the same result as others: our higher-electrolyte combination drink (NEW) was not different from SD or FCW; however, in our case, NEW was only marginally better than water: urine output was lower, but net fluid balance was not significantly better ($p = 0.051$). Therefore, even at high potassium concentrations, the present study confirms the finding of Maughan et al. (1994) that using potassium in addition to sodium is not warranted, as drinks with enough sodium and very little potassium help maintain or restore plasma volume and retain more fluid than water (Mitchell et al. 2000; Shirreffs et al. 1996).

One difficulty when working with natural rehydration beverages is how they vary in composition, because other substances apart from electrolytes may influence results. Carbohydrate content, particularly the bioavailable sugars, could influence fluid retention (Kamijo et al. 2012; Osterberg et al. 2010). NEW was formulated with the same sodium concentration as a conventional sports drink (~18 mEq·L^{-1}), while potassium concentration was targeted at 50 mEq·L^{-1}, the average concentration previously found when analyzing fresh coconut water (Ismail et al. 2007; Pérez-Idárraga and Aragón-Vargas 2010; Saat et al. 2002). We also designed our SD and NEW to have ~4% carbohydrate (half glucose, half fructose) to match previously analyzed fresh coconut water. This was a strength of the present study, even though, in the end, FCW was considerably higher in potassium (70

$mEq \cdot L^{-1}$) and slightly higher in CHO (0.5% of sucrose by volume) than expected. This illustrates the limitations of working with a natural drink, as both the carbohydrate content and electrolyte concentrations will fluctuate by region, coconut species, and maturity, something that has been well documented for coconut water (Child and Nathanael 1950; Kuberski et al. 1979; Vigliar et al. 2006). Nevertheless, these differences in potassium and CHO content, together with a higher osmolality (444 $mOsm \cdot kgH_2O^{-1}$), did not induce large enough changes in the rate of fluid absorption (not measured) to delay urine output (see Figure 2).

Thirst perception was above zero before exercise, but this should not be interpreted as a sign of hypohydration, as average baseline USG was 1.016 for all beverage conditions and thirst has been shown to be slightly elevated in euhydrated humans (Obika et al. 2009). We found thirst perception to increase significantly after exercise, but it quickly returned to baseline values after drinking the first aliquot, a volume equivalent to only 30% of weight loss. The same result was obtained with all beverages (see Figure 5a), a finding that contradicts the general belief that only water, because of its greater dilution potential, can turn off thirst before complete rehydration is achieved (Costill and Sparks 1973). It is well established that the act of drinking activates oropharyngeal receptors and decreases thirst independently of plasma dilution (Figaro and Mack 1997), which may explain our findings. Furthermore, thirst remained low at the end of the session, a point when participants were again dehydrated. If rapid rehydration is to be achieved after exercise, thirst alone is likely not enough of a stimulus; how humans perceive the need to correct intra- or extracellular water and salt deficits is not fully understood (Obika et al. 2009), particularly after dehydration from exercising in the heat. It is possible that the thirst mechanism is intended to facilitate slow rehydration with a minimum waste of fluid in the form of additional urine production.

We found reasonably good tolerance to the large volumes ingested of all these beverages. Perception of fullness was slightly elevated from the beginning of testing (one hour after breakfast) and remained constant around 5 (somewhat full) on a scale from 0 to 10 after drinking 1881 ± 351 mL in one hour, with no difference among drinks. Nausea, urge to defecate, and stomach ache remained constant at very low values (below 2), again with no difference among drinks. These results support the use of NEW and FCW for post-exercise rehydration, even though they don't show the advantage obtained by Ismail et al. (2007) and Saat et al. (2002), who found a better tolerance for coconut water when compared to a sports drink and water. Any possible differences might be explained by the ingestion of a higher volume in their studies, or by a greater habituation of their subjects to coconut water.

Palatability was rated highly in our study, with only one small difference among drinks, in spite of clear electrolyte concentration differences: fresh coconut water was rated higher than all others for liking of sweetness ($p = 0.032$, see Figure 6). The presence of sucrose (0.5% by volume) in coconut water, together with a possibly higher fructose-to-glucose ratio than expected, may have given it a sweeter taste. The wording of the scale (*liking of sweetness, liking of saltiness* as opposed to plainly *sweetness* or *saltiness*) may have introduced some bias, but overall acceptance was not different ($p = 0.096$) and fluid temperature (~9°C) was the same for all drinks. We hypothesize that the flavor used in the formulation of SD and NEW could have masked the differences in electrolyte and carbohydrate content. This is noteworthy as the formulation of high-potassium drinks is not easy: we used potassium chloride, which normally tends to make the drink too salty; the alternative, using potassium monophosphate (as in some sports drinks), causes diarrhea in humans at the required concentration (unpublished observation).

A limitation of the present study is the presence of both men and women in the sample. We found no interaction between gender and beverage (p = 0.249) and no main effect of gender (p = 0.146) on fluid retention, but the small number of women (2) in the sample limits our power for this type of comparison. Nevertheless, previously shown differences in fluid retention between males and females (Claybaugh et al. 2000), which could have introduced undesirable variability in this study, are addressed by the repeated-measures study design used. A related concern is the possibility that our females may have retained fluid differently with each beverage because they were at different phases of their menstrual cycle. We are unable to verify this using our data, but it might explain some discrepancies between the present study and the results obtained by Pérez-Idárraga and Aragón-Vargas (2010). On the other hand, Stachenfeld (2008) concludes from her literature review that while sex hormones do have important effects on body fluid and sodium regulation, they have only a small effect on overall body water and sodium retention in healthy young women, confirming what had previously been shown by Maughan et al. (1996): there seems to be no menstrual cycle effect on acute fluid retention after post-exercise rehydration.

IN CONCLUSION, the combination of potassium and sodium in a single beverage (NEW) to match the typical concentration of potassium in fresh coconut water and sodium in a conventional sports drink, provides no additional rehydration benefit compared to the reference beverages, when they are ingested in a volume equivalent to 120% BM loss.

While NEW resulted in a lower urine output compared to bottled water, net fluid balance was not different by the end of the study. Meanwhile, the SD used resulted in lower urine output, better fluid retention, and a better net fluid balance than bottled water.

All four drinks showed similar thirst quenching, tolerance, and palatability characteristics, with a slightly higher rating of sweetness for FCW. We were unable to confirm better rehydration with fresh coconut water, as found in other studies. This natural drink remains, however, a reasonable option due to its good palatability, tolerance, and thirst quenching.

Finally, since all beverages quickly turned off thirst after drinking a volume equivalent to only 30% of weight loss, it is recommended that people who exercise in the heat do not rely on thirst alone to guide post-exercise rehydration.

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