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# The Effect of Fluid Replacement on Endurance Performance

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**ABSTRACT**

The purpose of this study was to examine the effects of fluid replacement on power output (PO), rating of perceived exertion (RPE), heart rate (HR), body weight (BW), urine osmolarity ($U_{osm}$), and urine electrolyte concentrations ($[U_{Na^+}]$, $[U_{K^+}]$, $[U_{Cl^-}]$) in physically active men ($n = 4$) and women ($n = 7$). The participants were asked to generate their highest possible PO during 60 minutes of cycling under 3 randomized conditions: ingestion of (a) no fluid (trial 1); (b) 1200 ml of distilled water (trial 2); and (c) 1200 ml of Gatorade (trial 3). BW and urine volume ($V_u$) were measured before and after the ride to determine sweat rate $[(SR = \Delta BW + V_{fluid\ intake} + V_u)/time]$. The results indicated that there were no significant differences between trials for PO (123–127 W), RPE (14), HR (140–142 b·min$^{-1}$), and SR (11.9–12.4 ml·min$^{-1}$). However, $[U_{Na^+}]$ was significantly ($p < 0.05$) lower postexercise for all 3 trials, and $[U_{Cl^-}]$ was significantly reduced following trials 2 and 3. There was a significant increase ($p < 0.001$) in BW postexercise for trials 2 and 3 when compared with the no-fluid trial; however, the effects of water and Gatorade were similar. These results suggest that fluid replacement during 1 hour of moderately intense cycling does not enhance performance in physically active men and women who are normally hydrated.

***Key Words:*** cycling, electrolytes, hydration, sweat rate, urine osmolarity

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## Introduction

Commercial sports drinks such as Gatorade, Powerade, and Allsport appeal to competitive and recreational athletes because the manufacturers of many of these products suggest that they enhance endurance performance and help maintain fluid-electrolyte balance during exercise. Indeed, the physiological benefits of being well hydrated prior to training and competition are widely accepted. It is also generally agreed that carbohydrates (CHO) and electrolytes added to fluid replacement (FR) beverages are beneficial during long-term exercise (>2 hours) because they increase the palatability, replace electrolytes lost to sweat, drive the thirst mechanism, prevent a fall in plasma volume, and possibly delay the onset of fatigue (3, 5, 12, 14). Current recommendations for exercise lasting longer than 1 hour suggest ingesting 600–1,200 ml·h$^{-1}$ of solutions containing 4–8% CHO and 0.5–0.7 g of sodium per liter of water to replace that lost to sweat (2, 15).

Although the effect of FR drinks on long-term endurance exercise has been well studied (3, 6, 7, 18), only recently have studies begun to focus more on the effect of CHO ingestion and fluid-electrolyte replacement on performance during short duration (≤1 hour), high-intensity exercise (3, 15, 18, 19, 26). Below et al. (3) found that both FR and CHO ingestion equally improved high-intensity cycling performance at exercise intensities greater than 80% of maximal oxygen consumption ($\dot{V}O_2max$) in 8 endurance-trained men, and their effects were additive. In contrast, other authors (19, 23, 26) have reported that the ingestion of water or FR drinks containing glucose and/or electrolytes has little effect on heart rate (HR), core temperature, sweat rate (SR), plasma sodium concentration ($[Na^+]$), or endurance performance during intense exercise (80–85% $\dot{V}O_2max$) for 1 hour in a mild environment (20–22° C) in trained subjects.

To our knowledge, no studies have examined the effects of FR on endurance performance using subjects who are physically active but not highly trained. Therefore, the purpose of the present study was to examine the effects of CHO ingestion and FR on endur-

**Table 1.** Characteristics of subjects prior to the first ride ($n = 10$).

| Age (y) | Height (cm) | Weight (kg) | Percent body fat (%) |
|---|---|---|---|
| 45 M | 179.6 | 101.36 | 30.5 |
| 24 M | 179.6 | 86.82 | 13.9 |
| 21 F | 166.9 | 60.23 | 19.5 |
| 23 F | 161.9 | 56.82 | 17.4 |
| 30 M | 179.6 | 76.59 | 15.4 |
| 38 F | 164.5 | 58.86 | 24.7 |
| 28 F | 172.0 | 65.00 | 22.1 |
| 22 F | 156.8 | 56.59 | 26.6 |
| 27 M | 172.0 | 75.68 | 12.1 |
| 32 F | 164.5 | 69.77 | 27.1 |
| Mean ± *SEM* | | | |
| 29 | 169.7 | 67.38 | 20.8 |
| 2 | 2.6 | 4.64 | 2.0 |

* M = men (male); F = women (female).

ance performance, urine osmolarity ($U_{osm}$), urine electrolyte concentration, and SR in physically active men and women.

## Methods

### *Subjects*

Six women and 4 men volunteered to serve as subjects and gave informed written consent prior to inclusion in the study. At the time of testing, all subjects were physically active but were not involved in competitive cycling or any other competitive sport. Average cycling time per week was 2.5 hours, and many of the subjects participated in other endurance activities (running = 7; walking = 5; stair climbing = 4; rollerblading = 2; and soccer = 1) 3–5 times per week for an average of 30–60 minutes per session. The descriptive characteristics of the subjects ($X \pm SEM$) are presented in Table 1.

### *Experimental Procedures*

On the first day of testing, height was measured to the nearest 0.5 inch using a height stadiometer and converted to centimeters. Body density (Db) was estimated using the sum of 3 skinfold equations of Jackson and Pollock (16) and Jackson et al. (17) for the men and women, respectively. Percent body fat was calculated from Db using the formula of Siri (29).

The subjects reported to the lab at the same time of day on 3 separate occasions to perform a cycle ergometer test under 3 experimental conditions: trial 1, no fluid ingestion; trial 2, ingestion of 1,200 ml of distilled water; and trial 3, ingestion of 1,200 ml of a commercially available carbohydrate drink containing electrolytes (Gatorade; Quaker Oats, Inc., Chicago, IL). Testing order was randomized and each trial was separated by a minimum of 48 hours. The subjects were asked to maintain their normal diet and activity patterns throughout the study and to standardize their diet and activity patterns for the day prior to testing. In addition, the subjects were also instructed to refrain from exhaustive physical exercise, as well as caffeine and alcohol consumption for 24 hours prior to testing.

Following a 5-minute warm-up at 50 W on an electronically braked cycle ergometer (Corval 400; Quinton Instruments, Seattle, WA), subjects were instructed to generate their highest possible power output (PO) for 60 minutes. The subjects were allowed to vary the power loading at any time during the test, but were asked to keep the pedal cadence between 40 and 80 revolutions per minute (rpm). The protocol was a modification of a 1-hour endurance performance test developed by Coyle et al. (11) using trained male cyclists ($n = 15$). Coyle et al. (11) reported a validity coefficient of $-0.88$ ($p < 0.001$) when comparing the average absolute PO generated during a 1-hour ride to actual time trial performance for 40 km. Bishop (4) determined the reliability of the test using 20 trained female cyclists and reported an intraclass correlation coefficient (ICC) of 0.97 ($SEM = \pm 3.4$ W) for average PO across 2 trials. In addition, Bishop (4) and Coyle et al. (11) also reported that PO during the 1-hour test was not related to peak $\dot{V}O_2$ ($r = 0.01$, $p > 0.05$) or average $\dot{V}O_2$ ($r = -0.39$, $p > 0.05$), respectively, when expressed relative to body weight (BW) and, therefore, was independent of aerobic fitness.

A small room fan was placed approximately 1.5 m in front of the subjects, and videos were available for viewing while they exercised. The drinks were chilled on ice prior to exercise, and subjects consumed the entire volume ad libitum over the 60-minute ride. The rationale for ad libitum fluid administration was to replicate as closely as possible that which occurs in a recreational setting. The volume of 1,200 ml was chosen because it represented a fluid volume equivalent to the SR of most endurance athletes (8), was within normal physiological limits for gastric emptying (GE) and intestinal absorption (14), and was consistent with fluid volumes used in similar studies (3, 19, 23, 26). The environmental conditions in the laboratory remained relatively constant during the course of the study (15 days): ambient temperature was 20.6 ± 1.0° C (range = 19–21° C) and relative humidity was 72.1 ± 1.0% (range = 65–80%).

Heart rate (HR) was monitored with a Polar Heart Monitor (CIC; Instruments, Port Washington, NY) and was recorded at 1-minute intervals. Power output in Watts was also recorded each minute, whereas rating of perceived exertion (RPE) using the Borg scale (scale range 6–20) was recorded at 5-minute intervals. The subjects were continually supplied with visual feedback of pedaling cadence and elapsed time, but were unaware of their HR and PO.

Upon arrival to the laboratory, the subjects were asked to completely void their urine and collect a sample in a 1.0 ml aliquot. Following urine collection, BW was measured on a calibrated physicians scale to the nearest 0.25 lb and converted to kilograms. At the completion of each ride, BW was immediately recorded and the subjects were again asked to void their urine. Total urine volume ($V_u$) was measured to the nearest 1.0 ml with a graduated cylinder, and another 1.0-ml sample was collected.

Urine samples were tested for osmolarity and electrolyte concentrations and were stored for no more than 3 days at 4° C following testing. Osmolarity was measured using a Vapor pressure osmometer (Wescor, Logan, UT), $[U_{Na^+}]$ and $[U_{K^+}]$ were measured using an IL 443 Flame Photometer (Instrumentation Laboratory, Inc., Lexington, MA), and $[U_{Cl^-}]$ was measured using a chloridometer (Haake Buchler Instruments, Saddle Brook, NJ). The SR for each trial was determined from the change in BW, fluid intake ($V_{fluid\ intake}$), and $V_u$ using the following formula: $[SR = (\Delta BW + V_{fluid\ intake} + V_u)/time]$ (21).

### *Statistical Analyses*

Differences pre- and postexercise for $U_{osm}$, urine electrolyte concentrations, and BW between trials (no fluid, water, and Gatorade) were analyzed using a 2-way (trial by time) repeated-measures analysis of variance (ANOVA). When a significant interaction occurred between trial and time, Tukey post-hoc tests were used to locate the differences. Dependent *t*-tests were used to identify differences pre- and postexercise for those variables that did not show an interaction. Because of the limited sample size and the exploratory nature of this study, probability values, as well as *t*-values at 0.01, 0.05, and the adjusted family-wise alpha were reported (13).

Differences between trials (no fluid, water, and Gatorade) for RPE and SR were identified using separate 1-way repeated-measures ANOVA. The PO and HR data were analyzed using separate 2-way (trial by time point) mixed-factorial ANOVA in which mean PO and HR for each 5-minute time point interval between *t*1 and *t*60 were used for analysis. Follow-up analysis included Tukey post-hoc comparisons. An alpha of 0.05 was considered significant for all analyses.

## Results

### *Cycling Performance*

Figure 1 presents individual data for the 10 subjects for each trial. There were no significant differences in mean RPE ($F = 0.441$, $p = 0.654$) and SR ($F = 0.051$, $p = 0.9503$) between the 3 trials. Figure 2 presents the 5-minute time point interval data for PO and HR for each trial. For PO, the 2-way interaction (trial by time point) was not significant ($F = 0.911$, $p = 0.582$) and follow-up analyses indicated no effect of time when collapsed across trial. For HR, the 2-way interaction (trial by time point) was not significant ($F = 0.677$, $p = 0.861$). However, there were significant differences ($F = 19.95$, $p = 0.000$) between time points (collapsed across trial) where $t5 < t10$–$t60$ and $t10 < t15$–$t60$. This finding likely reflects the expected cardiovascular adjustments to increased PO during the initial stages of the 1-hour test.

Reliability of the 1-hour performance test was determined by having 9 of the subjects complete 2 additional rides under the no-fluid condition. High test-retest ICCs (Table 2) were found for PO ($r = 0.96$, *SEM* ± 2.5 W), HR ($r = 0.88$, *SEM* ± 3.0 b·min$^{-1}$), and SR ($r = 0.93$, *SEM* ± 0.6 ml·min$^{-1}$); however, RPE resulted in a low ICC of 0.59 (*SEM* ± 0.5). The ICC values for PO, HR, and RPE are similar to those reported by Bishop (4) for highly trained athletes (ICC ± *SEM* = 0.97 ± 3.4 W, 0.91 ± 2.8 b·min$^{-1}$, and 0.75 ± 0.6, respectively).

### *Urine and Electrolyte Balance and Body Weight*

With the exception of BW, there were no significant interactions between treatment and time for any of the variables tested. For BW, post hoc analyses revealed that there were no significant differences prior to exercise (trial 1 = 70.74 ± 4.64 kg; trial 2 = 70.52 ± 4.48 kg; and trial 3 = 70.80 ± 4.62 kg), indicating that the subjects began each trial in the same hydrated state (19, 26). Results for the Tukey tests showed that there were significant ($p < 0.05$) differences in BW postexercise for trials 2 (water; BW = 71.11 ± 4.63 kg) and 3 (Gatorade; BW = 71.38 ± 4.60) when compared with the no-fluid trial (BW = 70.02 ± 4.63). However, there was no significant difference in BW between Gatorade and water (mean difference = 0.01 kg).

Table 3 presents the results of the dependent *t*-tests for the variables that did not show an interaction ($U_{osm}$, $[U_{Na^+}]$, $[U_{K^+}]$, $[U_{Cl^-}]$). There were no significant changes in $U_{osm}$ between pre- and postexercise; however, there were significant changes in urine electrolyte concentrations. Sodium was significantly reduced following all 3 treatments (trial I, $p < 0.05$; trial 2, $p < 0.003$; trial 3, $p < 0.01$), whereas $[U_{Cl^-}]$ also significantly decreased following trials 2 (water) and 3 (Gatorade; $p < 0.05$). In addition, there was a significant ($p < 0.05$) increase in $[U_{K^+}]$ during the no-fluid trial.

## Discussion

Many recreational athletes purchase commercially available sports drinks with the belief that it will enhance athletic performance. However, the results of the present study indicated that the ingestion of Gatorade during 1 hour of moderately intense cycling exercise had no significant effect on PO, HR, RPE, SR, and urine electrolyte concentrations when compared with water or no fluid ingestion. These results are in agreement with other researchers (19, 23, 26) who reported

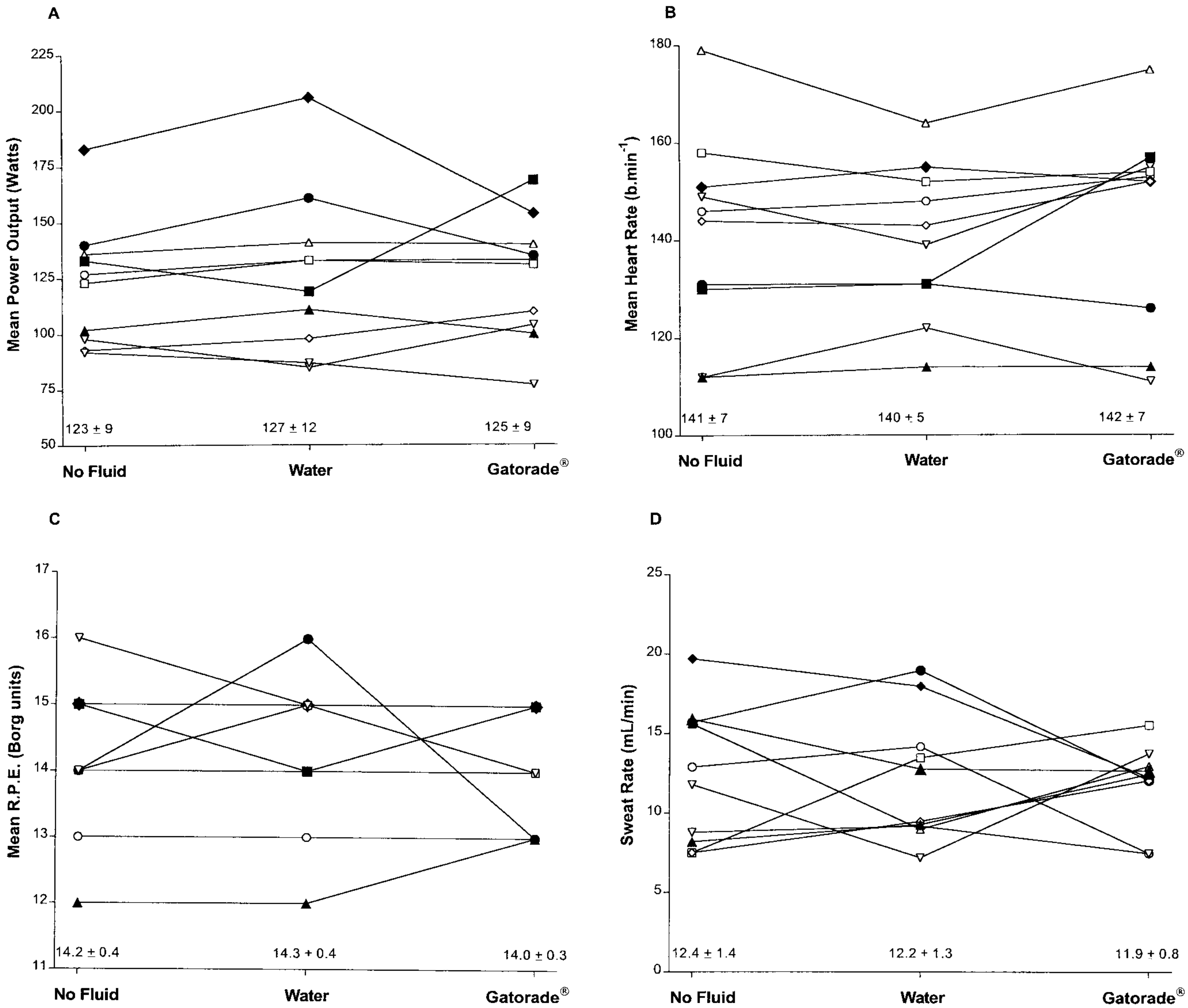


**Figure 1.** Individual means and group mean ± *SEM* for (A) PO, (B) HR, (C) RPE, and (D) SR for the 3 trials ($n = 10$). Closed symbols represent male subjects. Time points represent the mean for each 5-minute interval ($t5$–$t60$).

no significant improvement in 1-hour cycling performance with various FR beverages.

McConell et al. (19) reported that there is little benefit from ingesting water during intense 1-hour cycling exercise in mild environmental conditions (20.9° C) because it had no significant effect on HR, body temperature, plasma volume, plasma electrolytes, or performance. In their study, 8 well-trained men (26 ± 1 year; $\dot{V}O_2$peak = 5.05 ± 0.17 L·min$^{-1}$) cycled for 45 minutes at 80 ± 1% $\dot{V}O_2$peak followed by a 15-minute maximal performance ride while receiving no fluid, a volume of water that prevented BW loss (1.47 ± 0.05 L), or 50% of that volume (0.72 ± 0.03 L).

In agreement, Powers et al. (23) reported no significant ($p > 0.05$) differences in time to fatigue (35–40 minutes) in 9 trained male cyclists riding at 85% $\dot{V}O_2$max following ingestion of a nonelectrolyte placebo, a glucose polymer drink (7% CHO; Exceed; Ross Laboratories, Columbus, OH), or an electrolyte placebo drink without CHO. The authors also reported no significant differences in HR, RPE, and SR across trials, which is similar to the results of the present study. Powers et al. (23) suggested that the exercise duration and intensity was not high enough to deplete the liver or muscle glycogen stores or result in hypoglycemia, indicating that exogenous CHO supplementation is unwarranted for short-term, high-intensity exercise.

Robinson et al. (26) found that fluid ingestion actually decreased performance during a 1-hour time trial (85% $\dot{V}O_2$ peak) in a mild environment (20° C). In their study, subjects ingested an amount of fluid equal to the rate of fluid loss; however, it resulted in a feeling of abdominal fullness and reduced the distance covered in a 1-hour performance ride by 0.73 km ($p < 0.05$) when compared with a no-fluid trial (43.05 vs. 42.32 km). The subjects drank 629 ml of water at the

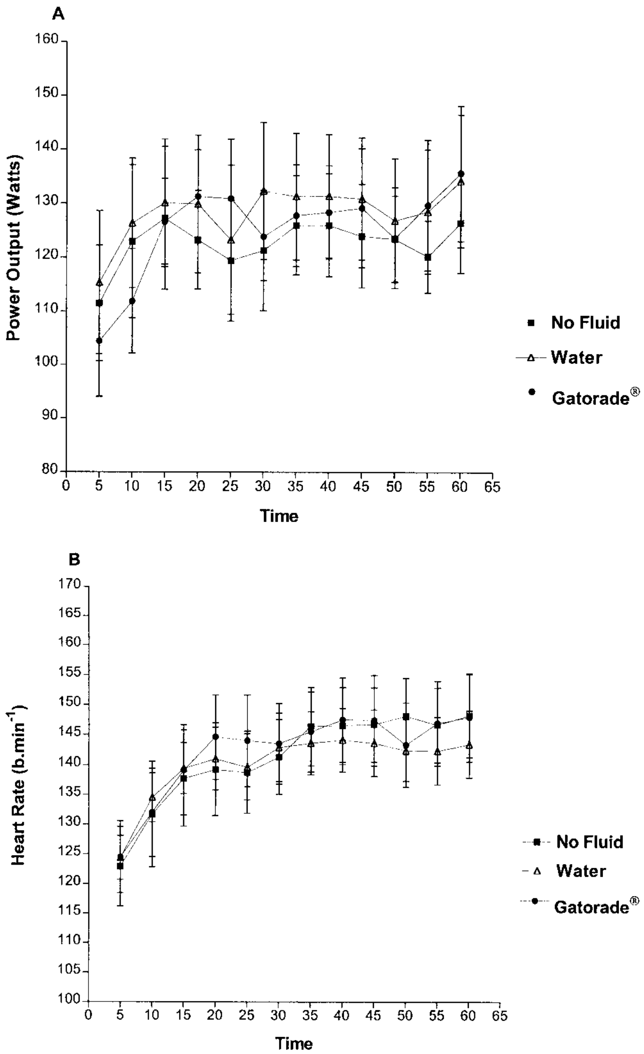


**Figure 2.** Mean ± *SEM* for (A) PO and (B) HR for the 3 trials during the 1-hour ride ($n$ = 10).

start of the warm-up (5 minutes) and then ingested approximately 1.5 L in equal aliquots at 0, 10, 20, 30, and 40 minutes of the 60-minute ride. Fluid ingestion decreased the mean average HR and reduced the final mean serum [$Na^+$] and osmolality, but did not significantly effect SR, rise in rectal temperature, RPE, or plasma volume when compared with the no-fluid trial.

**Table 3.** Changes in urine osmolarity and urine electrolytes for the 10 subjects (mean ± *SEM*) pre- and postexercise.

| Variable | Pretest $\bar{X}$ ± *SEM* | Post-test $\bar{X}$ ± *SEM* | $t$ | $p$ |
|---|---|---|---|---|
| Osmolarity (mOsm·kg$^{-1}$) | | | | |
| No fluid | 673 ± 90 | 676 ± 78 | −0.051 | 0.960 |
| Water | 594 ± 94 | 506 ± 89 | 1.399 | 0.190 |
| Gatorade | 657 ± 88 | 532 ± 86 | 1.202 | 0.260 |
| Sodium (mEq·L$^{-1}$) | | | | |
| No fluid | 94 ± 16 | 63 ± 10 | 2.785 | 0.020* |
| Water | 90 ± 20 | 47 ± 12 | 4.412 | 0.002** |
| Gatorade | 123 ± 18 | 69 ± 15 | 3.753 | 0.004*** |
| Potassium (mEq·L$^{-1}$) | | | | |
| No fluid | 77 ± 13 | 110 ± 15 | −2.805 | 0.020* |
| Water | 72 ± 21 | 70 ± 17 | 0.242 | 0.814 |
| Gatorade | 56 ± 8 | 93 ± 16 | −0.754 | 0.469 |
| Chloride (mEq·L$^{-1}$) | | | | |
| No fluid | 137 ± 21 | 135 ± 19 | 0.168 | 0.870 |
| Water | 113 ± 13 | 77 ± 15 | 2.997 | 0.015* |
| Gatorade | 147 ± 24 | 93 ± 16 | 2.603 | 0.029* |

* $t(9) \geq 2.26$, $p < 0.05$; ** $t(9) \geq 4.78$, $p < 0.003$; *** $t(9) \geq 3.25$, $p < 0.01$, alpha adjusted by Bonferroni.

In contrast to the previous studies, Below et al. (3) reported that both FR and CHO ingestion (with electrolyte levels held constant), independently improved performance during 1 hour of self-paced, high-intensity cycling exercise in 8 endurance-trained men ($\dot{V}O_2$ ± *SEM* = 62.3 ± 1.1 ml·kg·min$^{-1}$). In their study, subjects cycled continuously for 50 minutes followed by a 10-minute performance test at a predetermined work rate, which elicited a $\dot{V}O_2$ of 10% above their lactate threshold. During exercise, the subjects consumed either a large volume (1,330 ml) of a 6% CHO solution (Gatorade; F + C) or water and electrolytes (F), or a small volume (200 ml) of a 40% maltodextrin (79 ± 4 g) solution (C), or an electrolyte capsule washed down with water (placebo). When fluid or CHO were ingested individually (trials F and C), both improved performance by approximately 6% compared with the

**Table 2.** Trial means (±*SEM*), test-retest intraclass correlation coefficients (ICC), *SEM*, and coefficient of variation (CV) for absolute power output (PO), heart rate (HR), rating of perceived exertion (RPE), sweat rate (SR), and body weight (BW) ($n$ = 9).

| Variable | Trial 1 ± *SEM** | Trial 2 ± *SEM** | ICC | *SEM* | CV |
|---|---|---|---|---|---|
| PO | 122 ± 9 W | 119 ± 8 W | 0.96 | 2.5 W | 4.8% |
| HR | 143 ± 7 b·min$^{-1}$ | 138 ± 6 b·min$^{-1}$ | 0.88 | 3.0 b·min$^{-1}$ | 4.1% |
| RPE | 14 ± 0.3 | 14 ± 0.9 | 0.59 | 0.5 | 4.5% |
| SR | 11.6 ± 1.6 ml· min$^{-1}$ | 11.2 ± 1.5 ml·min$^{-1}$ | 0.93 | 0.6 ml·min$^{-1}$ | 12.1% |
| BW | 70.3 ± 5.1 kg | 70.1 ± 5.0 kg | 0.99 | 0.70 kg | 0.3% |

* Trials 1 and 2 were completed under the no-fluid condition.

placebo trial, and when both fluid and CHO were combined (Gatorade), performance was improved by 12% compared with the placebo. It was suggested that large FR improved performance by attenuating increases in core temperature and HR. The authors stated that the ability of CHO ingestion to improve performance during the 1-hour rides was somewhat surprising since blood glucose concentrations were nearly identical for the CHO and no-CHO trials (6.4 ± 0.6 vs. 6.3 ± 0.5 mM, respectively). Previous studies that have examined the effects of CHO supplementation on cycling at intensities between 70–74% of $\dot{V}O_2max$ have also reported that CHO ingestion does not increase blood glucose concentration or CHO oxidation during the first hour of exercise (6, 7).

To our knowledge, this is one of the first studies to examine the effects of FR on endurance performance using subjects who were physically active, but not highly trained. The mean PO (123–127 W) and HR (140–142 b·min$^{-1}$) values elicited by the subjects in the present study are representative of recreational fitness populations, but are considerably lower than values reported for trained subjects. For example, subjects in the studies by Powers et al. (23) and Below et al. (3) exhibited HR values that ranged from approximately 168 to 170 b·min$^{-1}$ and exercised at intensities that were equivalent to 85% of their peak $\dot{V}O_2$ or 10% above their lactate threshold, respectively. Following the warm-up, subjects in the present study were instructed to generate their highest possible PO for 1 hour. Although they exerted what may be considered a moderate intensity, it is possible that this was as hard as they perceived they could work for 1 hour. The mean RPE value for all 3 treatments was 14 (somewhat hard) and, although the validity of RPE for monitoring exercise intensity has been established, limited research has examined the reliability with which subjects can use RPE to monitor exercise intensity (4). In the present study, the test-retest ICC for RPE was low (0.59), indicating that it may not be a reliable method for monitoring exercise intensity. Although workloads that elicit a mean HR of 140–142 b·min$^{-1}$ may be considered relatively low when compared with trained athletes, the intensity was equivalent to approximately 74% of the subject's age-adjusted maximal HR and, therefore, would likely elicit a training effect (1).

The finding that ad libitum ingestion of 1,200 ml of Gatorade or water had no significant effect on PO, HR, SR, or RPE was likely a function of the intensity and duration of the exercise vs. the inability to absorb enough fluid to elicit an effect on performance. According to Gisolfi (14), gastric emptying (GE) can reach 30–40 ml·min$^{-1}$ or 1.8–2.4 L·h$^{-1}$, and the maximum absorptive capacity of the gut is approximately 1.4 L·h$^{-1}$. The most important factor influencing GE is the fluid volume in the stomach (2, 20, 22, 24), and when gastric fluid is maintained at 600 ml, most individuals can empty more than 1,000 ml·h$^{-1}$, particularly when fluids contain a 4–8% CHO concentration (such as Gatorade; 1, 12, 22).

One of the objectives of the current study was to replicate what occurs in the 'real world' (i.e., ad libitum fluid consumption) and, at the same time, maintain some degree of control by standardizing the volume of fluid consumed. A volume of 1,200 ml was chosen because it represented a fluid volume typically lost to sweat during endurance exercise (8, 27), was within normal physiological ranges for GE and intestinal absorption, and was similar to FR volumes used in related studies (3, 19, 23, 26). With the exception of 1 subject who tended to drink the majority of the fluid toward the end of the exercise, most subjects appeared to drink at regular intervals. Further, because the subjects were aware of the elapsed time, many attempted to consume at least half of the required volume (600 ml) during the first 30 minutes of the ride. In addition, there were no marked differences in the pattern of fluid intake between the 2 fluid trials. Data supporting these observations are unavailable and, thus, may be considered a limitation of the study. However, given the fact that the subjects were required to ingest the entire volume of fluid over the course of 1 hour suggests that there was adequate gastric volume to promote GE and intestinal absorption during the ride. In addition, it is not likely that the exercise intensity or training status of the subjects affected gastric function since mild to moderate exercise has been reported to have little or no effect on GE or intestinal absorption (28), and there appears to be no differences in GE or secretion between trained and untrained subjects (25).

The finding that there were no significant ($p > 0.05$) differences in $U_{osm}$ and BW prior to exercise across the 3 trials indicated that the subjects were normally hydrated upon arrival to the laboratory (Table 2). Normal $U_{osm}$ ranges from 400–800 mOsm·kg$^{-1}$, with lower values indicating greater levels of hydration. Although $U_{osm}$ decreased postexercise following trials 2 and 3 (506 and 532 mOsm·kg$^{-1}$, respectively), the values were not significantly different when compared with the no-fluid trial (676 mOsm·kg$^{-1}$). The fact that $U_{osm}$ remained within normal levels following 1 hour of cycling with no FR suggests that the duration and intensity of the exercise did not cause the subjects to become dehydrated. Costill et al. (9) also reported no significant changes in $U_{osm}$ immediately following 1 hour of treadmill exercise (~60% of $\dot{V}O_2max$) with no FR in 5 healthy men ($X$ age = 25 years), which is in agreement with the results of the present study. The results for the urine electrolyte concentrations also showed that there were significant decreases postexercise for [$U_{Na^+}$] for all 3 trials, as well as a significant decrease for [$U_{Cl^-}$] during the FR trials. Although [$U_{Cl^-}$] decreased during the no-fluid trial (−8 mEq·L$^{-1}$), the difference was small and not significant

($p > 0.05$). These results are somewhat expected given the fact that $Na^+$ and $Cl^-$ are the major ions lost to sweat and there is increased renal $Na^+$ reabsorption during exercise (9, 10).

The possibility that FR led to changes in plasma volume and electrolyte concentrations was not addressed in the present study. However, both Powers et al. (23) and McConell et al. (19) reported that fluid ingestion during short-term cycling (≤1 hour) at intensities ≥80% $\dot{V}O_2$ peak had little effect on plasma volume or plasma electrolyte concentrations. Therefore, it is not likely that subjects in the current study experienced any significant changes in these measures given the moderate intensity of the exercise. Future studies are warranted that examine the effects of FR on serum electrolyte concentrations and plasma volume in recreational fitness populations.

Fluid replacement during exercise that results in substantial losses in sweat is necessary to avoid dehydration, maintain BW, and possibly prevent a decrease in athletic performance (2). The SR of most athletes has been reported to range from 1.2 to 3.0 $L \cdot h^{-1}$, depending on the environmental conditions (8, 27). Sweat rates in the present study ranged from 0.71 $L \cdot h^{-1}$ (Gatorade) to 0.74 $L \cdot h^{-1}$ (no fluid) and, therefore, were well below values typically observed during intense exercise. In fact, the observation that the FR trials resulted in slight increases in BW postexercise (Table 3) suggests that subjects may have been overhydrated. However, subjects did not express feelings of discomfort or fullness as a result of FR, and there were no adverse effects on performance. The finding that there was a significant difference in BW postexercise when comparing the FR trials with no fluid ingestion suggests that the consumption of water or Gatorade may help maintain BW during 1 hour of moderately intense cycling exercise. However, because the effect of water and Gatorade on BW postexercise was similar, it appears that Gatorade is not superior to water for maintaining BW.

In conclusion, FR with or without CHO and electrolytes during 1 hour of moderately intense cycling exercise does not appear to enhance endurance performance in recreational athletes who are normally hydrated. It is likely that the exercise duration and intensity was not high enough to deplete liver or muscle glycogen stores or result in hypoglycemia. Therefore, exogenous C-E supplementation appears to be unwarranted for this type of exercise. However, when fluid ingestion is desired, water is recommended over C-E drinks such as Gatorade to replace fluid lost to sweat during exercise.

## Practical Applications

Commercially available sports drinks have a wide appeal to competitive and recreational athletes because the manufacturers of these products suggest that they enhance endurance performance and help replace water and electrolytes lost to sweat. However, the results of the present study suggest that FR during 1 hour of moderately intense exercise in physically active men and women did not produce any meaningful effects on PO, HR, SR, RPE, or urine electrolyte concentrations when compared with no fluid ingestion. Because water and Gatorade ingestion resulted in similar effects on performance and BW, water is recommended over Gatorade when fluid ingestion is desired. In addition, the test-retest reliability coefficients for PO, HR, SR, and RPE found in the present study were similar to those reported by Bishop (4), who used highly trained cyclists. These results suggest that a 1-hour cycling performance test may provide a practical and reliable technique for evaluating the effectiveness of different interventions on endurance performance in both competitive and recreational athletes. Future studies are warranted to replicate the findings of the present study using similar samples of recreational athletes.

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