

Electrolyte Hydration: Identifying the Most Refreshing Post-Workout Beverages

Sloane E. Partlan

The Rivers School, Weston, Massachusetts, United States, 01772

KEYWORDS. Gastrointestinal, Electrolyte, Hydration, Exercise, Sports Drink

BRIEF. This study compares the effects of water, electrolyte drinks, and fruit juice on post-exercise hydration, gastrointestinal symptoms, and subjective feelings of refreshment.

ABSTRACT. This study investigates the effects of three common post-workout beverages - flavored water (Propel), an electrolyte-rich sports drink (Powerade), and fruit juice (Welch's) - on hydration, gastrointestinal symptoms, and subjective feelings of refreshment. Electrolytes, such as sodium and potassium, are vital for maintaining fluid balance and muscle function during recovery, making drinks that contain these nutrients commonly recommended for post-exercise hydration. However, it remains unclear whether electrolyte drinks offer a distinct advantage over flavored water or fruit juice in promoting recovery. In this experiment, 14 healthy participants completed a 60-minute exercise session and were randomly assigned to one of the three beverage conditions. Hydration and gastrointestinal symptoms were assessed before and after exercise using subjective surveys, while objective measures of heart rate, weight, and temperature were recorded. Results showed that while electrolyte drinks had a higher taste preference, there were no significant differences in thirst levels, gastrointestinal discomfort, or physiological recovery between the three drinks. Flavored water, juice, and electrolyte drinks were equally effective in supporting recovery, suggesting that hydration needs can be met with flavored water, especially for those who prefer a more neutral taste. This study provides valuable insights for individuals seeking to optimize hydration and recovery strategies following exercise.

INTRODUCTION.

Physical exercise, particularly intense workouts, can lead to significant dehydration and an imbalance in electrolytes, which are critical for maintaining proper muscle function, hydration, and overall health [1]. Electrolytes, including sodium, potassium, and magnesium, play essential roles in maintaining fluid balance, nerve function, and muscle function during and after exercise [2]. As a result, proper rehydration is critical for recovery, and this has led to the development of various drinks designed to replace lost fluids and electrolytes. While flavored water or juice is a reliable choice for hydration, beverages containing both carbohydrates and electrolytes, such as sports drinks, are often considered superior for rehydration [3,4]. Some flavored waters, such as Propel, also contain added electrolytes, making them more comparable to sports drinks than to plain water.

The effectiveness of different types of sports drinks remains a subject of debate. Some drinks containing added sugars are widely used in athletic settings, while alternatives like flavored water are often consumed for hydration after exercise [5]. However, despite its popularity as a healthy, natural beverage, fruit juice is generally not recommended post-exercise due to its high carbohydrate content and low sodium levels, which may not effectively support hydration during recovery [6]. Research has shown that drinks containing high levels of electrolytes may improve hydration status and recovery more effectively than flavored water alone [7]. In particular, the impact of electrolyte-rich drinks on recovery is often examined through changes in hydration status, muscle soreness, and subjective feelings of refreshment. Some studies

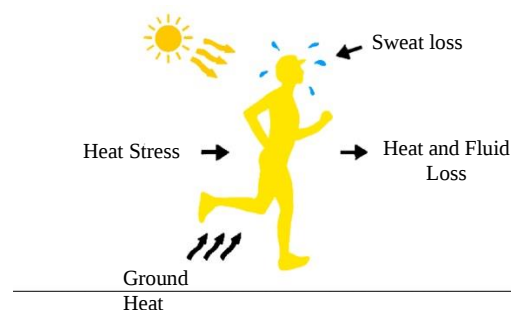


Figure 1. Illustration of fluid/heat generation and loss for a runner

suggest that drinks with electrolytes may provide a greater sense of rehydration and recovery than beverages without electrolytes, such as plain water or fruit juice [8]. However, there is still a lack of consensus regarding the most effective drink for post-workout recovery. Figure 1 illustrates heat generation and loss during exercise, emphasizing the importance of hydration in replacing lost fluids and maintaining performance.

This study aims to investigate how different types of post-workout beverages, specifically electrolyte drinks, juice, and flavored water, affect subjective feelings of hydration and refreshment after exercise. I hypothesize that the electrolyte drink, due to its higher electrolyte content, will provide participants with a more refreshed and hydrated feeling after exercise compared to juice or flavored water.

MATERIALS AND METHODS.

Preparation for blind-tested drinks.

To conduct the experiment, three different types of post-exercise drinks were selected for testing: an electrolyte-rich sports drink, fruit juice, and flavored water. These beverages were chosen based on their common use in athletic settings and their prevalence as post-exercise hydration options. The electrolyte drink was selected for its high electrolyte content, including sodium and potassium, while Welch's juice and Propel was chosen for comparison as a conveniently available drink. The electrolyte drink (Powerade) contains approximately 240 mg sodium and 80 mg potassium per serving, while Propel contains 230 mg sodium and 60 mg potassium and Welch's juice contains 10 mg sodium and 160 mg potassium per serving. To prevent bias, all drinks were poured into opaque water bottles with opaque straws, ensuring the participants could not see the color of the drink during the experiment.

Subjective measurements.

To assess participants' subjective feelings of hydration and refreshment, a custom questionnaire was developed based on previous research [9]. Three separate surveys were administered to participants: a gastrointestinal symptoms survey, a thirst level survey, and a palatability survey for the drink consumed. In the gastrointestinal symptoms survey, participants were asked to rate their symptoms using a scale from 0 to 9, with 0 indicating no symptoms and 9 indicating the most severe symptoms. Gastrointestinal symptoms included heartburn, bloating, nausea,

muscle cramps, and other common post-exercise discomforts. The thirst level survey asked participants to rate their thirst on a 9-point scale, where 1 indicated they were not thirsty at all and 9 indicated they were extremely thirsty. After consuming the provided beverage, participants completed the palatability survey and rated the drinks on a 9-point scale for taste, with 1 indicating they disliked it completely and 9 indicating they liked it extremely.

Objective measurements.

Objective physiological measures were taken before, immediately after, and one-hour post-exercise. These measurements included heart rate, body temperature, and body weight, which were recorded using a Garmin Forerunner 55 smartwatch, a Datram GK-128B infrared thermometer, and a Eufy Bodysense smart scale, respectively. To ensure accuracy, participants were instructed to wear the smartwatch throughout the experiment to monitor their heart rate. Body temperature was also recorded to assess the impact of exercise on thermoregulation.

Experimental protocol.

The experiment involves recruiting 14 healthy participants (five males, nine females). Prior to the exercise, participants were required to complete the GI questionnaire, and their body weight, heart rate, and temperature were all measures to ensure they were rehydrated. During the exercise phase, participants completed a 60-minute run. Heart rate and temperature were measured every 15 minutes throughout the exercise and participants consumed 1.5 mL/kg of plain water every 15 minutes to stay hydrated. Post-exercise, participants were randomly assigned to one of three beverage conditions: electrolyte-rich sports drink (Powerade), fruit juice (Welch’s juice), or flavored water (Propel). Each participant consumed 237 mL of the assigned beverage within 10 minutes. The drinks were prepared and dispensed by a single researcher, who was the only individual aware of which drink each participant received. After drinking the assigned beverage, participants filled out the thirst and palatability questionnaire. They were then allowed to drink as much plain water as desired, and the volume was carefully recorded. Objective measures of heart rate, body weight, and body temperature were taken again immediately after beverage consumption and one hour later to assess recovery. Statistical analysis will be performed to compare the subjective ratings (thirst, gastrointestinal symptoms, and palatability) and objective measures (heart rate, weight and temperature) between the three beverage groups.

RESULTS.

Participants.

The study involved 14 participants (19.56 ± 13.24 years) divided into three beverage groups: electrolytes (n=9), juice (n=9), and flavored water (n=9). 13 of the participants participated in 2 experiments, with drinks in different categories and flavors. Table 1 presents the demographic data, including weight, height, and BMI, with no significant differences observed between the groups. The mean weight was 149.70

Table 1. Participant Demographics and Characteristics

	Overall (n=27)	Electrolytes (n=9)	Juice (n=9)	Flavored water (n=9)
Age	19.56 ± 13.24	19.67 ± 12.52	19.56 ± 16.14	19.44 ± 11.85
Weight (lb)	149.70 ± 32.95	138.87 ± 27.94	154.19 ± 37.91	156.03 ± 33.35
Height (in)	67.80 ± 4.24	66.78 ± 4.09	67.33 ± 4.42	69.28 ± 4.44
BMI	22.39 ± 3.10	21.73 ± 3.21	22.88 ± 3.53	22.57 ± 2.77
Gender	9 males, 18 females	2 males, 7 females	3 males, 6 females	4 males, 5 females

± 32.95 lb for the overall group, with slight differences in the individual beverage groups: electrolytes (138.87 ± 27.94 lb), juice (154.19 ± 37.91 lb), and flavored water (156.03 ± 33.35 lb). Similarly, the mean height was 67.80 ± 4.24 inches, with the flavored water group slightly taller (69.28 ± 4.44 inches), though no significant differences were noted in height or BMI across the groups.

Cardiovascular Responses

In terms of cardiovascular responses, Table 2 shows the heart rate (HR) at different time points for all participants and by beverage group. The baseline HR before exercise was 75.85 ± 6.12 bpm for the overall group, and similar rates were observed across the three beverage groups (electrolytes: 77.11 ± 4.59 bpm, juice: 74.11 ± 6.72 bpm, flavored water: 76.33 ± 7.07 bpm). During exercise, HR increased progressively across all groups, with no significant differences in HR at any time point (15, 30, 45, or 60 minutes). Post-exercise HR dropped to 78.81 ± 6.86 bpm at one-hour post-workout, with similar trends across beverage groups, suggesting that all beverages supported recovery in terms of cardiovascular parameters.

Table 2. Heart Rate (HR) in bpm at Different Time Points

Timepoints	Overall (n=27)	Electrolytes (n=9)	Juice (n=9)	Flavored water (n=9)	P-value
Before exercise	75.85 ± 6.12	77.11 ± 4.59	74.11 ± 6.72	76.33 ± 7.07	0.5768
15 min. into exercise	158.85 ± 9.32	159.33 ± 10.81	157.67 ± 7.71	159.56 ± 10.19	0.9027
30 min. into exercise	160.37 ± 9.41	161 ± 10.83	159.67 ± 7.52	160.44 ± 10.62	0.9587
45 min. into exercise	161.89 ± 9.33	162.56 ± 10.51	161.44 ± 7.95	161.67 ± 10.40	0.9675
60 min. into exercise	163.37 ± 9.22	164.11 ± 10.55	163 ± 7.75	163 ± 10.19	0.9605
One hour post workout	78.81 ± 6.86	80.78 ± 6.24	78.78 ± 8.05	76.89 ± 6.39	0.5027

Body temperature (Temp) was measured at the same time points and is shown in Table 3. Prior to exercise, the overall group’s mean body temperature was 98.44 ± 0.17°F, and there were no significant differences in baseline temperature between groups (electrolytes: 98.41 ± 0.20°F, juice: 98.44 ± 0.16°F, flavored water: 98.48 ± 0.18°F). During exercise, body temperature peaked at 98.83 ± 0.14°F at 60 minutes across the overall group, with no significant differences between the beverage conditions. Post-exercise body temperature decreased to 98.56 ± 0.20°F at one-hour post-workout, with no notable differences across beverage groups. The statistical analysis of the relationship between HR and temperature across different time points, shown in the last table, demonstrates no significant correlations (p-values for all time points > 0.05).

Thirst Ratings.

Thirst ratings were assessed at three key time points: prior to exercise, immediately after exercise, and after recovery (Table S1). Prior to exercise, flavored water participants reported the highest thirst levels (8.67), followed by juice (7.33) and electrolytes (8.11). Immediately after exercise, all beverage groups showed a significant decrease in thirst levels, with flavored water reporting the lowest thirst score (3.11), followed by flavored water (3.22), and juice (4.56). After recovery, flavored water again had the lowest thirst rating (1.44), while electrolytes (2.56) and juice (1.22) showed moderate thirst reductions.

Table 3. Temperature Measurements at Different Time Points

	Overall (n=27)	Electrolytes (n=9)	Juice (n=9)	Flavored water (n=9)	P- value
Temp. before exercise	98.44 ± 0.17	98.41 ± 0.20	98.44 ± 0.16	98.48 ± 0.18	0.7342
Temp. 15 min. into exercise (°F)	98.56 ± 0.18	98.52 ± 0.19	98.55 ± 0.15	98.61 ± 0.20	0.5897
Temp. 30 min. into exercise (°F)	98.68 ± 0.17	98.66 ± 0.13	98.68 ± 0.18	98.71 ± 0.20	0.7944
Temp. 45 min. into exercise (°F)	98.76 ± 0.16	98.71 ± 0.16	98.76 ± 0.13	98.81 ± 0.18	0.4299
Temp. 60 min. into exercise (°F)	98.83 ± 0.14	98.81 ± 0.12	98.8 ± 0.14	98.88 ± 0.15	0.3312
Temp. One hour post workout (°F)	98.56 ± 0.20	98.52 ± 0.16	98.54 ± 0.26	98.6 ± 0.19	0.7193

Palatability Ratings.

Palatability ratings are provided in Figure S1. The overall beverage taste was rated as follows: juice (5.78), electrolytes (5.89), and flavored water (5.33). Juice received the highest ratings for flavor (6.44) and sweetness (7.00), while flavored water received the lowest ratings for both flavor (5.78) and sweetness (4.00). All beverages scored similarly for saltiness, with the ratings for all beverages falling between 1.11 and 1.22, indicating a low level of perceived saltiness. For tartness, juice scored the highest (4.11), followed by electrolytes (3.11), and flavored water (2.56).

Gastrointestinal Symptoms.

Gastrointestinal (GI) symptoms were assessed at three time points: prior to exercise, immediately after exercise, and one-hour post-exercise, across three beverage groups: juice, electrolytes, and flavored water. Overall, the GI symptoms exhibited some differences between the beverages, though many remained relatively consistent.

Reflux heartburn symptoms were minimal prior to exercise and showed similar levels in all groups immediately after exercise. Immediately post-exercise, reflux heartburn remained low across all groups (0.56 for juice and electrolytes, 0.11 for flavored water), with symptoms resolving entirely by one hour for juice and electrolytes (0.11), and no heartburn for flavored water (0). Belching was absent before exercise, but increased slightly after exercise for all groups, with juice (1.56) and electrolytes (1.67) showing slightly higher levels than flavored water (1.33). After one hour, belching decreased substantially for all groups, with the juice group reporting the lowest levels (0.11). Both heartburn and belching were generally mild, with no major difference between beverages, as shown in Figure S2 and S3.

Bloating symptoms were more noticeable prior to exercise in the flavored water group (3.56), compared to juice (2.78) and electrolytes (2.67). However, immediately post-exercise, bloating decreased across all groups, with juice and electrolytes showing a similar reduction (1.33 and 1.11, respectively), and flavored water (1) showing the greatest reduction. By one hour, bloating rebounded in the juice group (3), while electrolytes (2.78) and flavored water (2) remained at moderate levels.

This suggests that bloating was most pronounced before exercise in flavored water, but improved across all groups post-exercise, with juice showing a slight rebound (Figure S4).

Stomach pain/cramping was mild prior to exercise across all groups. After exercise, symptoms were more pronounced in the juice group (3.89) compared to electrolytes (3) and flavored water (3.22). One hour later, stomach pain decreased in all groups, with juice showing the greatest reduction (1.44), while electrolytes (2.11) and flavored water (1.22) showed moderate improvements (Figure S5).

Flatulence was mild prior to exercise, but increased after exercise, with juice (2.78) reporting the highest levels, followed by electrolytes (2.33) and flavored water (2.44). By one hour, the juice group reported the lowest flatulence levels (1.78), while electrolytes (2.67) and flavored water (1.33) showed more moderate reductions. Flatulence was a common post-exercise symptom, though it was more pronounced in the juice group immediately after exercise (Figure S9).

Dizziness and headache symptoms were relatively consistent across the groups, with slight increases immediately after exercise (juice = 1.67, electrolytes = 1.78, water = 1.67 for dizziness) and similar reductions after one hour, as shown in Figure S15 and Figure S14. For headaches, all groups reported a slight increase immediately post-exercise, with electrolytes showing the highest levels (2.89), followed by juice (1.89) and flavored water (2.89). By one hour, all groups showed a decrease in headache symptoms, with juice (0.56) and flavored water (1.67) showing greater improvement compared to electrolytes (2.67).

In terms of more severe GI symptoms, such as diarrhea, loose stool, and vomiting, there were only minor reports of these symptoms immediately post-exercise, with no significant differences between the beverage groups (Figure S7, Figure S12, Figure S13). All symptoms that increased slightly immediately post-exercise were resolved by one hour.

DISCUSSION.

The primary objective of this study was to investigate how different post-workout beverages, specifically an electrolyte-rich sports drink, fruit juice, and flavored water affect subjective feelings of hydration and refreshment after exercise. The results suggest that, while there were some minor differences in gastrointestinal symptoms, thirst levels, and palatability, the overall effect of the three beverages on rehydration and recovery was not significantly different, indicating that flavored water can be as effective as juice or electrolyte drinks for rehydration.

Participants reported higher thirst levels immediately post-exercise due to fluid loss through sweating [10]. Thirst ratings peaking after the exercise session, and participants reporting a decrease in thirst after consuming their respective beverages. This is consistent with the expected physiological response, where post-exercise thirst reflects the body's need to replenish lost fluids. As expected, the greatest thirst reduction was observed across all groups immediately after beverage consumption, with flavored water showing the lowest thirst scores at recovery. Although the thirst reduction was similar across beverage types, the fact that participants' thirst levels did not return to baseline after consuming any of the beverages suggests that additional fluid intake post-exercise (plain water) may still be necessary for full rehydration [11].

Gastrointestinal symptoms such as bloating, heartburn, and flatulence were assessed throughout the study. Overall, while all beverages caused mild GI discomfort, there were no significant differences between the drinks in terms of overall symptom severity. Heartburn and belching resolved after one hour, so it does not significantly impact overall recovery. Importantly, the minor differences in bloating and flatulence, with juice showing the highest levels immediately post-exercise, may be due to its higher sugar content, which could affect gut motility and digestion [12]. However, these symptoms were not severe enough to hinder recovery, consistent with research showing that minor GI discomforts from sugary drinks do not always impede rehydration [13].

The results from the palatability form showed that, in general, all three drinks were rated similarly for taste, with the electrolyte drink receiving slightly higher ratings than juice or flavored water. Juice received the highest ratings for sweetness, which could explain why participants found it more enjoyable. However, while taste preferences can influence beverage choice, the slight difference in palatability did not translate into significantly better hydration or recovery, indicating that participants might select electrolytes more for taste preferences than for superior rehydration benefits [14]. This suggests that, while flavored, sweetened beverages like the electrolyte drink may encourage higher fluid intake due to their taste, they do not necessarily provide a clear advantage over flavored water in terms of hydration [15].

When considering objective measures such as heart rate and bod temperature, no significant differences were observed across the three beverage types. These findings suggest that, at least within the parameters of this study, electrolytes, juice, and flavored water all effectively supported recovery, as evidenced by similar trends in heart rate normalization and body temperature regulation after exercise. Given that hydration status did not differ significantly between groups, it stands to reason that, while electrolyte drinks may provide additional nutrients, their effect on hydration may be largely equivalent to flavored water in typical post-exercise scenarios.

CONCLUSION.

The findings of this study suggest that while flavored drinks may appeal to some individuals due to their taste, they do not necessarily provide any substantial advantages over any water in terms of improving hydration, recovery, or gastrointestinal comfort.

ACKNOWLEDGMENTS.

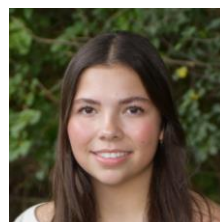
I would like to express my appreciation to my research advisor, Trinny Tat, for her guidance throughout the course of this project.

SUPPORTING INFORMATION.

The supporting information document contains bar graphs depicting the severity ratings of various gastrointestinal symptoms, thirst levels, palatability scores, and other physiological responses across different post-exercise beverage conditions.

REFERENCES.

1. B. McDermott, S. Anderson, L. Armstrong, D. Casa, S. N. Cheuvront, L. Cooper, W. L. Kenney, F. G. O'Connor, W. O. Roberts, National Athletic Trainers' Association Position Statement: Fluid Replacement for the Physically Active. *J. Athl. Train.* **52**, 877–895 (2017).
2. J. Yu-Yahiro, Electrolytes and their relationship to normal and abnormal muscle function. *Orthop. Nurs.* **13**, 38–40 (1994).
3. S. Shirreffs, L. Aragon-Vargas, M. Keil, T. Love, S. Phillips, Rehydration after exercise in the heat: A comparison of four commonly used drinks. *Int. J. Sport Nutr. Exerc. Metab.* **17**, 244–258 (2007).
4. M. Minehan, M. Riley, L. Burke, Effect of flavor and awareness of kilojoule content of drinks on preference and fluid balance in team sports. *Int. J. Sport Nutr. Exerc. Metab.* **12**, 81–92 (2002).
5. S. Wong, Y. Chen, Effect of a carbohydrate-electrolyte beverage, lemon tea, or water on rehydration during short-term recovery from exercise. *Int. J. Sport Nutr. Exerc. Metab.* **21**, 300–310 (2001).
6. G. Rajauria, B. Tiwari, "The Importance of a Juice" in *Fruit Juices* (Elsevier, 2018), pp. 3.
7. M. Millard-Stafford, T. Snow, M. Jones, H. Suh, The Beverage Hydration Index: Influence of electrolytes, carbohydrate, and protein. *Nutrients* **13**, 2145 (2021).
8. R. Murray, *Foods, Nutrients, and Food Ingredients with Authorized EU Health Claims* (Woodhead Publishing, 2014), pp. 349–372.
9. B. Pfeiffer, A. Cotterill, D. Grathwohl, T. Stellingwerff, A. Jeukendrup, The effect of carbohydrate gels on gastrointestinal tolerance during a 16-km run. *Int. J. Sport Nutr. Exerc. Metab.* **19**, 485–503 (2009).
10. L. Baker, Sweating rate and sweat sodium concentration in athletes: A review of methodology and intra/interindividual variability. *Sports Med.* **47**, 111–128 (2017).
11. L. Armstrong, Rehydration during endurance exercise: Challenges, research, options, methods. *Nutrients* **13**, 3456 (2021).
12. N. Muñoz-Urtubia, A. Vega-Muñoz, C. Estrada-Muñoz, G. Salazar-Sepúlveda, N. Contreras-Barraza, D. Castillo, Healthy behavior and sports drinks: A systematic review. *Nutrients* **15**, 6789 (2023).
13. E. O'Neal, S. Poulos, P. Bishop, Hydration profile and influence of beverage contents on fluid intake by women during outdoor recreational walking. *Eur. J. Appl. Physiol.* **112**, 3971–3982 (2012).
14. G. A. Galaz, "History of Sports Nutrition Beverages" in *Nutrition and Enhanced Sports Performance* (Academic Press, 2019), pp. 231–237.
15. D. Passe, M. Horn, R. Murray, Impact of beverage acceptability on fluid intake during exercise. *Appetite* **35**, 219–229 (2000).



Sloane Partlan is a student at The Rivers School in Weston, MA. She participated in a research internship through the Crimson Research Institute.