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Human Kinetics
BRIEF REPORT

Hydrogen-Rich Water Supplementation and Up-Hill Running Performance: Effect of Athlete Performance Level

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Purpose: Hydrogen-rich water (HRW) has been shown to have an antifatigue effect. This study assessed up-hill running performance, as well as physiological and perceptual responses after supplementation with 1680 mL HRW between 24 h and 40 min before running, in athletes of heterogeneous running ability. ***Methods:*** Sixteen males (mean [SD] age 31.6 [8.6] y, VO_2max 57.2 [8.9] mL·kg^{-1}·min^{-1}, body fat 13.4% [4.4%]) participated in this study. Using a randomized, double-blind, placebo-controlled crossover design, participants consumed either HRW or placebo prior to performing two 4.2-km up-hill races separated by a week. Race time (RT), average race heart rate, and immediately postrace rating of perceived exertion were assessed. ***Results:*** After analysis of data for all runners, HRW effect was unclear (−10 to 7 s, 90% confidence interval) for RT, likely trivial for heart rate (−2 to 3 beats·min^{-1}), and likely trivial for postrace rating of perceived exertion (−0.1 to 1.0). A possible negative correlation was found between RT differences and average RT (r = −.79 to −.15). HRW for the 4 slowest runners (RT = 1490 [91] s) likely improved the RT (−36 to −3 s), whereas for the 4 fastest runners (RT = 1069 [53] s) the performance effect of HRW was unclear (−10 to 26 s). ***Conclusions:*** HRW intake had an unclear antifatigue effect on performance in terms of mean group values. However, it appears that the magnitude of the antifatigue effect of HRW on performance depends on individual running ability.

Keywords: molecular hydrogen, antioxidant, antifatigue, exercise, field testing

During exercise, reactive oxygen species and reactive nitrogen species are produced by mitochondrial and nonmitochondrial sources, reflecting oxidative stress, that promote adaptation to exercise.[1] However, high levels of reactive oxygen species and reactive nitrogen species have been associated with mitochondrial dysfunction and cellular damage[2] that may contribute to fatigue and delayed recovery in athletes.[3] Molecular hydrogen (H_2) has been shown to be a strong and selective antioxidant with high scavenger affinity toward cytotoxic hydroxyl free radicals, thus aiding in maintaining cellular redox balance,[4] and has a stimulating effect on mitochondrial oxidative phosphorylation.[5] Supplementation with hydrogen-rich water (HRW) before exercise has been shown to improve lactate, ventilatory, and perceptual response[6] as well as have an antifatigue effect, particularly in endurance, strength, and repeated-sprint ability performance.[7–9] However, athletes display better immunological responses to exercise,[10] endogenous antioxidant capacity, more efficient mitochondrial function, and adenosine triphosphate (ATP) production compared with sedentary or less-active individuals.[11] These training-induced adaptations may potentially alter performance advantages of HRW supplementation in athletes with different abilities. Therefore, the primary aim of this study was to assess physiological, perceptual, and performance responses to an up-hill running race after administration of HRW in a heterogenous group of athletes.

Methods

Participants

A total of 16 male athletes (mean [SD]; age 31.6 [8.6] y, body mass 71.5 [8.8] kg, body height 177.0 [7.2] kg, body fat 13.4% [4.4%], VO_2max 57.2 [8.9] mL·kg^{-1}·min^{-1}) volunteered for this study. They followed instructions to avoid using dietary supplements (including sport drinks and coffee) and maintain the same individually prescribed training load from 1 week before the first run until completion of the second run, including during the washout period. Athletes performed 4 to 6 training sessions/week with training session duration ranging from 45 to 140 minutes. One day before each race, all runners trained; both session rating of perceived exertion (RPE; HRW: 11.9 [1.5], placebo: 11.8 [1.2], P = .55, Wilcoxon test) and duration (HRW: 47 [9] min, placebo: 48 [10] min, P = .47, Wilcoxon test) were not significantly different. Two days before each race, 5 runners trained with no difference in session RPE (HRW: 9.6 [1.7], placebo: 10.0 [1.4], P = .63) or duration (HRW: 44 [10] min, placebo: 43 [7] min, P = .69). Participants provided informed consent, and the study was approved by the ethics committee of Faculty of Physical Culture, Palacký University Olomouc.

Using a randomized, double-blind, placebo-controlled crossover design, participants consumed either HRW or placebo prior to performing two, 4.2-km up-hill races (same asphalt road, 215-m

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elevation, race start at 5:00 PM, and environmental temperature 20–24°C). A total volume of 1680 mL of HRW (Aquastamina HRW; Nutristamina s.r.o., Ostrava, Czech Republic) or placebo (Aquastamina H_2 free; Nutristamina s.r.o.) was administered in four, 420-mL doses at 24 hours, 3 hours, 2 hours, and 40 minutes before the races that were separated by a 1-week washout period.[7] Both drinks were served in visually identical plastic aluminum packages. Athletes could not distinguish between HRW and placebo, because H_2 is colorless, odorless, and tasteless. HRW/placebo characteristics were as follows: pH = 7.8/7.6 and dissolved H_2 = 0.9/0.0 ppm.

Athletes started each race separated by 2-minute intervals (order randomized), with race time (RT) measured manually using a digital timer (HS80; Casio, Shibuya, Japan). Average race heart rate (HR, V800; Polar Electro Oy, Kempele, Finland) and an immediately postrace RPE (6–20 points) were recorded.

Statistical Analysis

Data are expressed as mean (SD) unless otherwise stated. Differences between HRW and placebo values were checked for normality using the Kolmogorov–Smirnov test and changes in means were evaluated using a paired *t* test. Correlations between HRW and placebo differences and pooled values of RT, $(RT_{HRW} + RT_{Pla})/2$, were evaluated using Pearson correlation coefficient. Subgroups of the 4 slowest runners and 4 fastest runners were selected from the whole sample of 16 runners. The effect of HRW compared with placebo in each subgroup was evaluated again using the paired *t* test. The outcomes were interpreted using magnitude-based inference.[12] The smallest worthwhile change for RT and HR was set at 0.3 and 0.5, respectively, of the within-individual SD. The smallest worthwhile change for RPE was set to 1.0. Only a large (≥0.5) correlation coefficient was considered meaningful, so the smallest worthwhile change was set to 0.5.

Results

The data were normally distributed (RT: $P = .41$, HR: $P = .35$, RPE: $P = .28$). After analyzing the whole sample, HRW compared with placebo had an unclear effect on RT and a likely trivial effect on both HR and RPE (Table 1). However, a possible negative correlation was found between RT_{HRW} and RT_{Pla} differences and pooled RT (Figure 1). Correlation between HR_{HRW} and HR_{Pla} differences and pooled RT was possibly trivial ($r = .47$; 90% confidence interval, .05 to .75; $P = .07$; chances 44/56/0). Correlation between RPE_{HRW} and RPE_{Pla} differences and pooled RT was likely trivial ($r = -.14$; 90% confidence interval, −.53 to .31; $P = .61$, chances 1/92/7). Analysis of the subgroup of the 4 slowest runners (RT = 1490 [91] s) revealed that HRW likely improved RT, likely increased HR, and effect on RPE was likely trivial (Table 2). In the subgroup of the 4 fastest runners (RT = 1069 [53] s), the effect of HRW on both RT and HR was unclear and effect on RPE was likely trivial (Table 2).

Discussion

Although HRW has been associated with an antifatigue effect in various modes of exercise,[7–9] we found an unclear effect of preexercise HRW intake on performance in terms of mean group values. However, the analyses suggest that the performance enhancing (antifatigue) effect of HRW may depend on the performance ability of athletes, because a possible negative correlation ($r = -.54$) between RT differences and pooled RT was found. Specifically, prerace hydration with 1680-mL HRW compared with placebo likely improved endurance running performance by 1.3% in the slowest runners, whereas the effect of HRW on race performance in the fastest runners was unclear (deterioration by 0.8%). Furthermore, the increase in performance was accompanied by a likely increase in average race HR by 3.8% in the slowest runners, whereas in the fastest runners there was an unclear change (0.1%). HRW administration in the slowest runners had a likely trivial effect on postrace RPE, suggesting that increased race intensity was not accompanied by increased perceived effort. These findings are in line with a recently published study in which perceptual strain at an exercise intensity of $4\ W \cdot kg^{-1}$ for 8 minutes was lower after acute preexercise HRW administration compared with placebo.[6]

An antifatigue effect of HRW ingestion ($2\ L \cdot d^{-1}$ for 2-wk preexercise) during intermittent cycling was also reported by Da Ponte et al,[9] who showed a 7.4% attenuation in the decline of peak power output from the sixth to the ninth of 10 sprints. Similarly, Aoki et al[7] demonstrated an attenuated decrease (3.7%) in peak torque and postexercise lactate level after 20 isokinetic knee

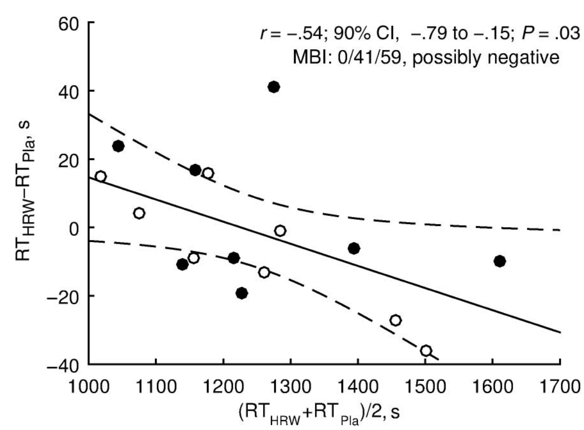

Figure 1 — Correlation analysis between RT differences and pooled RTs. CI indicates confidence interval; HRW, hydrogen-rich water; MBI, magnitude-based inference; RT, race time; RT_{HRW}, RT when HRW was administered; RT_{Pla}, RT when placebo was administered. Filled circles indicate runners who received HRW in the first race; open circles, runners who received HRW in the second race. Dashed lines denote 90% CI.

Table 1 Effect of HRW Compared With Placebo on Race Time, Heart Rate, and RPE in the Sample of 16 Runners

	HRW	Placebo	HRW–Placebo	90% CI	*P*	Chances[a] +/trivial/−	Inference
Race time, s	1249 (163)	1250 (173)	−1 (20)	−10 to 7	.77	8/73/19	Unclear
Heart rate, $beats \cdot min^{-1}$	178 (7)	178 (10)	0 (6)	−2 to 3	.80	5/93/2	Likely trivial
RPE, points	17.8 (1.2)	17.4 (1.3)	0.4 (1.3)	−0.1 to 1.0	.20	5/95/0	Likely trivial

Abbreviations: CI, confidence interval; HRW, hydrogen-rich water; RPE, rating of perceived exertion.
[a] Chances that the true value of HRW effect is substantially positive, trivial, or substantially negative.

Table 2 Effect of HRW Compared With Placebo on Race Time, Heart Rate, and RPE in the 4 Fastest Runners and the 4 Slowest Runners

	Group	HRW–Placebo	90% CI	RC (90% CI)	*P*	Chances[a] +/trivial/–	Inference
Race time, s	Fastest	8 (15)	–10 to 26	0.8 (–0.9 to 2.5)	.37	66/24/10	Unclear
	Slowest	–20 (14)	–36 to –3	–1.3 (–2.4 to –0.2)	.07	2/4/94	Likely negative
Heart rate, beats·min^{-1}	Fastest	0 (2)	–2 to 3	0.1 (–1.2 to 1.5)	.82	25/60/15	Unclear
	Slowest	6 (7)	–2 to 14	3.8 (–1.0 to 8.5)	.16	78/19/3	Likely positive
RPE, points	Fastest	0.3 (1.0)	–0.9 to 1.4	1.5 (–5.0 to 8.1)	.64	11/85/4	Likely trivial
	Slowest	0.0 (0.8)	–1.0 to 1.0	0.1 (–5.9 to 6.1)	>.99	5/90/5	Likely trivial

Abbreviations: CI, confidence interval; HRW, hydrogen-rich water; RC, relative change in percentage; RPE, rating of perceived exertion.
[a] Chances that the true value of HRW effect is substantially positive, trivial, or substantially negative.

extensions following HRW ingestion (1.5-L HRW within 8-h preexercise). Because of the reduced exercise-induced muscle fatigue and lactate lowering effects of H_2, HRW ingestion was suggested to be suitable and beneficial for athletes.[7] Unfortunately, there is still limited information about the dose–response as well as appropriate chemical characteristics of HRW, particularly of dissolved H_2 concentration and pH.

In an animal study, Ara et al,[8] who used a comparable technology for HRW preparation to the present study, found that ad libitum HRW intake over 4 weeks, in chronically forced exercise mice, led to a 2.7-fold increase in swimming time to exhaustion compared with the placebo group. The authors suggested that HRW exerted antifatigue effects, mediated via enhanced metabolic coordination and immune redox balance, specifically through increased liver glycogen storage; lactate dehydrogenase and glutathione peroxidase activity; and reduction of interleukin-6, interleukin-17, and tumor necrosis factor-α.[8] The present results suggest that the faster runners had reduced sensitivity to the performance-enhancing effects of HRW. We propose that faster runners compared with slower runners will probably exhibit lower or even negligible performance benefits from acute HRW administration, possibly due to existing training-induced upregulation of antioxidative,[11] metabolic,[11] and/or immune systems.[10]

Limitations of the study include that ventilatory and metabolic responses as well as changes in participant antioxidative capacity were not measured. These variables may have improved the understanding of mechanisms underlying our results. Other limitations are that the dose of H_2 was not adjusted for body mass and the low sample size.

Practical Applications

Athlete endurance ability determines the effectiveness of preperformance HRW supplementation and/or athlete individual sensitivity to H_2 exposure. Therefore, it is important to evaluate individual responsiveness. This finding should be considered when designing future studies assessing the HRW effect on athletes.

Conclusion

Preexercise HRW intake had an unclear antifatigue effect on performance in terms of mean group values. However, it appears that the magnitude of the effect of prerace HRW supplementation on up-hill running performance depended on individual running ability.

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