Updated report March 2025 based upon information from credible scientific studies, including those indexed on PubMed and research institutions.

Hydrogen-Rich Water (HRW) in Sports Performance: A Comprehensive Analysis

1. General Applications of HRW in Sport

Endurance Performance

Hydrogen-rich water has been investigated for its potential to boost endurance exercise capacity. Several studies indicate that HRW can delay fatigue during prolonged or high-intensity exercise. For example, supplementation with HRW has improved repeated-sprint ability and time to exhaustion, likely by reducing exercise-induced fatigue. Athletes who consumed HRW before endurance trials showed lower blood lactate accumulation and improved ventilatory efficiency at higher intensities. These findings suggest that HRW may help athletes sustain aerobic performance longer by mitigating metabolic stress during endurance exercise.

Strength and Power Output

There is evidence that HRW can enhance anaerobic performance and muscular power, especially in trained individuals. In a controlled trial, a 7-day intake of HRW significantly increased peak power output (from ~766 W to ~827 W) and mean power in a cycling sprint test for trained cyclists, while also lowering the fatigue index. Similarly, other research noted improved power-endurance metrics (e.g. more repetitions at a given weight) when athletes used HRW during resistance training. These improvements in strength and power output are attributed to HRW's anti-fatigue effects, allowing athletes to sustain higher forces for longer without performance drop-off.

Recovery and Muscle Fatigue

One of the touted benefits of HRW is faster recovery and reduced muscle soreness after intense exercise. Preliminary studies support this: athletes who hydrated with HRW experienced less decline in muscle function post-exercise and quicker recovery of performance. For instance, Aoki et al. found that pre-exercise HRW prevented the normal drop in peak muscle torque seen after exhaustive exercise, indicating reduced muscle fatigue. HRW also appears to decrease markers of muscle damage and soreness during recovery. In an elite swimmer trial, four days of HRW intake led to significantly lower creatine kinase levels (a muscle damage marker) and less perceived muscle soreness 12 hours after two exhaustive training sessions, compared to placebo. Athletes consuming HRW also regained better explosive performance (jump height) by the next day. These outcomes suggest HRW can aid post-exercise recovery by attenuating muscle micro-injury and fatigue, thereby helping athletes bounce back faster between training bouts or competitions.

Hydration and Metabolic Efficiency

As a form of water, HRW naturally contributes to hydration, but it may offer additional metabolic benefits beyond plain water. Adequate hydration alone is known to support performance and thermoregulation; HRW provides this while also delivering molecular hydrogen. Notably, HRW

may improve the body's acid–base balance during exercise. Research by Ostojic et al. showed that drinking ~2 liters of HRW daily for 14 days increased arterial blood pH both at rest and after exercise (e.g. post-exercise pH rose by ~0.07 units) and elevated bicarbonate levels, relative to placebo. This slight alkalinizing effect can combat exercise-induced metabolic acidosis, potentially delaying fatigue associated with lactic acid buildup. HRW is therefore considered an effective hydration strategy that not only replaces fluids but also helps buffer acidity. By improving hydration status and maintaining a more favorable metabolic environment, HRW could enhance endurance and efficiency during prolonged exercise.

2. Scientific Evidence and Mechanisms

Key Studies on Athletic Performance

A growing number of peer-reviewed studies have examined HRW's impact on various performance metrics. Overall, the literature reports mixed but largely positive effects. For example, one pilot study found that athletes who drank HRW had reduced blood lactate and less decline in muscle power after intense cycling, compared to those drinking placebo water. Another trial reported improved anaerobic cycling performance (higher sprint power output) after one week of HRW intake in trained athletes. In runners, acute pre-exercise hydrogen-water ingestion has been associated with improved exercise tolerance in some cases – Botek et al. noted slight improvements in uphill run times and lower heart rates in less elite runners using HRW. HRW has also shown benefits for repeated high-intensity efforts: in professional soccer players, molecular hydrogen supplementation mitigated performance decrements across repeated sprints, indicating an anti-fatigue effect in intermittent exercise scenarios. On the recovery side, Sládečková et al. (2024) demonstrated that athletes who supplemented with HRW around intense training had lower post-exercise muscle damage markers and soreness than those on placebo. While sample sizes in many of these studies are modest, the trend suggests HRW often outperforms plain water in supporting exercise performance and recovery.

It must be noted, however, that not all studies have found significant ergogenic effects. Some well-controlled trials report no meaningful performance difference between HRW and placebo. For instance, Valenta et al. (2022) observed that a one-time high dose of HRW before exercise did **not** improve treadmill running time to exhaustion or VO_2 max in trained runners versus normal water. Similarly, a few other acute studies failed to show benefits of HRW on endurance capacity in highly trained athletes, indicating that the effects of HRW can depend on the context and population. These discrepancies in results underline the importance of exercise mode, athlete fitness level, and supplementation protocol in determining HRW's efficacy. In summary, while a majority of studies support performance or recovery enhancements with hydrogen-rich water, a minority have reported null results. This suggests that HRW is not a guaranteed performance booster in every scenario, but it has considerable potential under the right conditions.

Mechanisms of Action: Oxidative Stress, Inflammation, and Mitochondria

The proposed mechanisms behind HRW's effects are grounded in molecular hydrogen's biological activity. Hydrogen gas (H_2) acts as a selective antioxidant and cell signaling modulator in the body. Unlike broad-spectrum antioxidants, H_2 selectively neutralizes the most harmful reactive oxygen species, such as the hydroxyl radical (•OH) and peroxynitrite, while sparing beneficial ROS that serve as signaling molecules. Intense exercise generates a surge of ROS and reactive nitrogen species that contribute to oxidative stress, muscle fatigue, and inflammation. By scavenging those damaging radicals, HRW can reduce exercise-induced oxidative stress and protect cells from damage. Indeed, research confirms that hydrogen-rich water intake leads to lower lipid peroxidation

and bolsters the body's antioxidant defenses. Athletes supplementing with HRW have shown increased activity of endogenous antioxidant enzymes (like superoxide dismutase) and higher total antioxidant capacity compared to controls.

HRW's antioxidant action has downstream benefits on inflammation and mitochondrial function. Exercise-induced oxidative stress is closely tied to inflammatory pathways and muscle damage. By mitigating excess ROS, HRW indirectly helps control inflammation – e.g. long-term HRW supplementation in athletes attenuated rises in pro-inflammatory cytokines (such as IL-6 and TNF-α) that normally occur with strenuous training. This anti-inflammatory effect can limit secondary muscle damage and soreness. Moreover, protecting cells from oxidative insult preserves mitochondrial integrity and function. Mitochondria are both producers and targets of ROS; molecular hydrogen may help maintain efficient energy production during stress by preventing mitochondrial dysfunction. There is also evidence that H_2 influences cell signaling and gene expression related to oxidative stress adaptation. In summary, HRW likely enhances performance and recovery through a combination of reducing oxidative stress, dampening exercise-induced inflammation, and supporting cellular energy systems. These mechanisms align with observed outcomes such as less fatigue, improved endurance, and faster recovery in athletes using HRW.

HRW vs. Placebo: Comparative Findings

Most of the cited studies on HRW utilize double-blind, placebo-controlled designs, comparing hydrogen-rich water to regular water (placebo). The comparative results often favor HRW, though with varying magnitudes. In endurance trials, athletes on HRW have shown slower accumulation of lactate and lower perceived exertion than their placebo counterparts. Performance metrics like sprint times, total work performed, or time to exhaustion have been modestly better with HRW in many cases. For instance, in a cycling study the HRW group's anaerobic work output increased, whereas no change was seen with placebo. In recovery studies, biochemical markers of stress (creatine kinase, inflammatory markers) were significantly lower after HRW than after placebo water, indicating superior recovery support. It's noteworthy that where HRW shows benefits, those benefits are observed in direct comparison to identical hydration with plain water, underscoring that the dissolved hydrogen gas—not just hydration—is responsible. On the other hand, when studies report no effect, the outcome measures for HRW and placebo are statistically indistinguishable. These null results suggest that in certain high-performing populations or short-term protocols, HRW provides similar hydration as water but no extra performance edge. Nonetheless, the balance of evidence leans toward HRW offering an advantage over standard water in at least some aspects of exercise performance and recovery. Future larger trials will further clarify the consistency and extent of HRW's benefits versus placebo under various conditions.

3. Effects of HRW on Marathon Running and Endurance

Aerobic Capacity and VO_2 Max

For marathon runners and other endurance athletes, a key question is whether HRW can improve maximal aerobic capacity or endurance performance. Current evidence indicates that HRW is not a magic bullet for VO_2 max itself. Controlled experiments have found no significant differences in VO_{2max} values or maximal oxygen uptake between HRW and placebo conditions. In an acute trial with trained runners, pre-exercise hydrogen-rich water did not raise VO_2 max or prolong time to exhaustion at maximal aerobic speed compared to plain water. Thus, HRW is unlikely to directly increase the upper ceiling of aerobic capacity. However, where HRW may aid marathon performance is by improving sub-maximal endurance and delaying the onset of fatigue. Some

studies report that HRW can enhance exercise efficiency and tolerance at intensities relevant to long-distance running. For example, hydrogen water ingestion has been associated with improved ventilatory thresholds and a reduction in lactate buildup during heavy aerobic exercise. By making a given pace feel easier (lower RPE) or by clearing lactate more effectively, HRW might help runners sustain a faster pace before fatigue sets in. In summary, while a marathoner's VO_2 max is largely unchanged by HRW, their ability to perform near their aerobic limits for longer could be modestly improved through hydrogen-rich hydration.

Oxidative Stress and Muscle Damage in Long-Distance Running

Marathon running places considerable oxidative and mechanical stress on the body, leading to muscle damage, inflammation, and lipid peroxidation. HRW's antioxidant and anti-inflammatory properties are particularly relevant in this context. Studies in endurance sports have shown that chronic intake of HRW can mitigate exercise-induced oxidative stress. In long-distance runners or endurance trainees, HRW supplementation attenuated the rise of markers like malondialdehyde (MDA) that indicate lipid peroxidation, compared to controls. Likewise, HRW users exhibited a more controlled inflammatory response post-exercise; for instance, levels of IL-6 and TNF-α (inflammatory cytokines that typically surge after ultra-endurance exertion) were significantly lower with HRW than with placebo over weeks of training. This suggests that hydrogen-rich water helps protect tissues from oxidative damage during prolonged exercise. Marathoners might experience less cumulative muscle damage when using HRW as part of their regimen. Indirect evidence comes from the previously mentioned swimming study, where athletes doing repeated intense sessions had 18% lower creatine kinase after HRW vs placebo. Applied to a marathon, this could translate to reduced muscle fiber breakdown. Additionally, many runners report severe delayed onset muscle soreness (DOMS) and inflammation post-marathon; HRW's anti-inflammatory effects may help ameliorate these issues, aiding quicker recovery. Overall, by blunting oxidative stress and muscle damage, HRW can be a tool to preserve muscle function and reduce recovery time in long-distance running events.

Endurance Performance and Biomarkers in Marathon Context

Marathon performance is influenced by endurance-related biomarkers such as lactate, blood pH, and heart rate under effort. Hydrogen-rich water has shown impacts on several of these variables. One important factor is lactate threshold – the point at which lactate begins accumulating rapidly. HRW appears to shift this threshold favorably. In exercise tests, athletes hydrating with hydrogen-rich water had lower blood lactate concentrations at the same workload than when they drank placebo. For marathoners, this could mean the ability to maintain a given pace with less metabolic acidosis. In fact, hydrogen's potential to buffer acidosis is supported by research: HRW intake over 1–2 weeks significantly increased blood bicarbonate and alkalinity in physically active men. This might help runners maintain a more stable pH during the latter stages of a marathon, delaying fatigue. Another relevant biomarker is exercise heart rate. Improved efficiency often reflects as a lower heart rate for a given pace. Some evidence suggests HRW can contribute here as well. In a field study of an uphill 4.2-km race, slower runners who preloaded with ~1.6 L of HRW saw a ~3–4% reduction in race heart rate along with a slight performance boost, whereas no improvement was seen in the fastest runners. This implies that less-trained endurance athletes might derive more performance benefit (relative to their baseline) from HRW than elite runners, possibly because they have more to gain from improved redox balance. In terms of actual race outcomes, any performance gains with HRW seem modest – on the order of 1% improvement in time in some cases – but even a 1% gain is meaningful over a marathon distance. Ultimately, HRW's effects on endurance performance are subtle and likely person-dependent. It may help optimize physiological variables (lactate, pH, heart

rate) during endurance exercise, which in aggregate can contribute to a better marathon performance or experience, especially for those prone to high oxidative stress or slower recovery.

4. Practical Applications for Athletes

HRW Supplementation Protocols: Timing and Dosage

To achieve the potential benefits of hydrogen-rich water, athletes should consider how and when to ingest it. Research protocols provide guidance on effective dosing strategies. Many studies that reported positive outcomes used relatively high volumes of HRW, often around 1–2 liters per day. For instance, endurance trials have used about 1.5 L of HRW spread throughout the day prior to an event, and some intervention studies supplied ~2 L daily over multiple days or weeks. A common approach is to start loading with HRW in the days leading up to competition: Sládečková et al. gave athletes ~1.26 L of HRW per day for 3 days before an event, then an additional 2.5 L on race day. For acute use, ingesting hydrogen water in the hours before exercise is typical. Doses of about 600 mL to 1 liter taken in the 30–120 minutes pre-workout have been tested for immediate performance effects. In one protocol, runners consumed four servings of HRW (total ~1260 mL) at 2 hours, 1 hour, 30 min, and 10 min before a treadmill run to exhaustion. Another field study had athletes drink ~1680 mL of HRW in the 24 hours before an uphill run, finishing the last portion ~40 minutes pre-start. During prolonged exercise like a marathon, athletes could also sip HRW at aid stations as part of their normal hydration, though keeping the hydrogen dissolved can be a challenge. It's important to note that hydrogen gas is volatile; to maximize intake, HRW should be consumed soon after opening or generating, in a sealed container to limit H_2 escape. In summary, an effective regimen might involve drinking hydrogen-rich water regularly (e.g. 1–2 L per day) during training, and then acutely before and possibly during a competition. Athletes should replace their normal water intake with HRW in those periods to ensure both hydration and hydrogen delivery.

Safety and Regulatory Status

From a safety standpoint, hydrogen-rich water is very well tolerated and is regarded as a natural, legal supplement for athletes. The body produces small amounts of hydrogen gas during normal metabolism (via gut bacteria), and H_2 has no known toxicity at the levels used for supplementation. Clinical studies have reported no adverse effects attributable to HRW, even at high intakes (2+ liters daily) for weeks. In one trial, no participants experienced any "vexatious side effects" or health issues while consuming 2 L/day of HRW for 14 days. This safety profile is a key advantage of HRW over many ergogenic aids. Hydrogen gas is neither a stimulant nor a controlled substance; it simply diffuses into the body's tissues and exerts antioxidant effects before being exhaled. Consequently, hydrogen-rich water is not on any doping list and is permitted by the World Anti-Doping Agency (WADA). In fact, given the strict banning of many performance-enhancing substances, HRW's status as a naturally occurring, non-toxic compound makes it an attractive alternative for athletes seeking gains without breaking rules. There is no restriction on HRW use in competition – it is essentially treated as water. Athletes should ensure the hydrogen source or generator they use is reliable and only produces H_2 (some cheap "hydrogen" products might also alkalize water or add minerals, but pure HRW is just H_2-infused water). As always, it's wise to source products from reputable companies if used in elite sports, but molecular hydrogen itself is not banned. Overall, hydrogen-rich water is a safe supplement with no known contraindications at common doses. Athletes can use HRW in training and competition without concern for safety or legality, making it a practical addition to their nutrition and hydration strategy, provided they manage the logistics of carrying and consuming the water to retain its hydrogen content.

References: Key sources include peer-reviewed studies and reviews on HRW's effects on exercise from *Metabolites*(Zhou et al., 2024), *Medicine & Science in Sports & Exercise* and *Frontiers in Physiology* (various trials on cyclists, runners, and swimmers), as well as systematic reviews analyzing HRW in sports medicine. These sources, among others, provide the scientific evidence and mechanistic understanding summarized above.