The Effects of Cold-Water Immersion, Hot-Water Immersion, and Contrast Bath Therapy on Next-Day Sprint Performance in Division I Collegiate Swimmers

Brief Review

JoAnn Adler[1]

[1]*University of Cincinnati, Cincinnati, Ohio/USA*

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Abstract.

Competitive Division I collegiate swimmers are routinely exposed to repeated high-intensity sprint efforts with limited recovery time, particularly during multi-day competitions involving preliminary and final races. These demands place substantial stress on neuromuscular, metabolic, and inflammatory systems, making effective recovery strategies essential for maintaining next-day sprint performance. Water immersion modalities such as cold-water immersion (CWI), hot-water immersion (HWI), and contrast bath therapy (CBT) are widely used in athletic settings; however, their effectiveness in enhancing subsequent sprint performance in collegiate swimmers remains unclear.

This review examines and compares the physiological, perceptual, and performance-related effects of CWI, HWI, and CBT on next-day recovery, with a specific focus on sprint-based performance outcomes relevant to Division I collegiate swimmers. Studies were evaluated with respect to participant characteristics, immersion protocols, and physiological and performance outcomes. Evidence indicates that CWI is the most consistently supported modality for attenuating muscle soreness, inflammation, and neuromuscular fatigue, particularly when applied immediately post-exercise at water temperatures between 10-15°C for durations of at least 14 minutes. CBT appears to offer reliable perceptual and physiological benefits, including reduced perceived fatigue and improved circulatory responses, though direct improvements in next-day sprint performance remain inconsistent across the literature. In contrast, HWI generally produces subjective comfort and acute vascular responses but demonstrates limited efficacy for enhancing performance-related recovery outcomes when used alone.

Overall, water immersion modalities may support short-term recovery within constrained timeframes, inconsistencies in protocols, populations, and outcome measures limit definitive conclusions regarding their impact on next-day sprint performance in Division I swimmers. Further swimmer-specific, standardized research is needed to establish optimal recovery strategies.

Key Words: post-exercise recovery modalities, hydrotherapy, athlete

Corresponding author: JoAnn Adler, adlerjo@mail.uc.edu

Introduction

Athletes in competitive swimming frequently engage in multiple high-intensity training sessions and competitions each week, often completing two practices per day and multi-day meets lasting several hours, with recovery windows sometimes limited to only a few hours between sessions[1]. These repeated training and competition demands are not only psychologically taxing but also place considerable physiological stress on the body, contributing to muscle fatigue, tissue damage, inflammation, and reductions in subsequent performance capacity [2].

Swimming events in collegiate competition range from short sprint to long distance races, each relying on different energy systems and presenting distinct recovery demands. Sprint events, typically lasting 19-55 seconds such as the 50-yard and 100-yard freestyle, depend heavily on anaerobic energy systems, resulting in high lactate production and substantial rapid neuromuscular fatigue[2]. Because anaerobic power takes considerable time to fully restore, sprint performance is particularly vulnerable to short recovery windows. In contrast, distance events rely primarily on aerobic metabolism and produce fatigue more gradually. Distance events such as the 1,650-yard freestyle are typically swum as timed finals, giving athletes only one race opportunity.

Sprint events, however, are contested in both prelims and finals, requiring swimmers to perform maximal, anaerobically demanding efforts multiple times within a single day and again on consecutive days, often with only a few hours of recovery between races. This combination of event structure, high-intensity metabolic demands, and limited recovery time underscores the importance of implementing effective recovery strategies to maintain peak performance and minimize accumulated fatigue across successive events.

Various forms of water immersion have become increasingly popular in competitive sport environments as strategies to enhance physiological and perceptual recovery following strenuous training or competition [3]. The most commonly applied modalities are cold-water immersion (CWI), hot-water immersion (HWI), and contrast bath therapy (CBT), which involves alternating between hot and cold-water exposures [3]. Cold water temperatures are typically defined as 8-20°C, while hot water temperatures generally range from 36-42°C, with CBT alternating between those temperature ranges [3,4]. The physiological responses to water immersion are well documented, and these techniques are believed to support recovery by influencing muscle temperature, blood flow, inflammation, and the removal of metabolic byproducts [5]. In sprint-based aquatic sports, where athletes may perform repeated maximal efforts on back-to-back days, the type of recovery intervention used can play an important role in how quickly neuromuscular function and metabolic readiness are restored for the next training or competition session [5]. While water immersion is commonly used among athletes and coaches as a recovery strategy, the scientific evidence supporting these claims remains inconsistent, with some studies reporting clear benefits and others demonstrating minimal or no effect compared to passive recovery [3,6,7].

Therefore, the purpose of this review is to examine and compare the effects of cold-water immersion, hot-water immersion, and contrast bath therapy on next-day sprint performance in Division I collegiate swimmers, and to explore their practical implications for recovery strategies within this population.

Literature Search Strategy

A narrative literature search was conducted using mostly the electronic databases PubMed and Google Scholar. Search terms included combinations of the following keywords: cold water immersion, hot water immersion, contrast bath therapy, contrast water therapy, hydrotherapy, post-exercise recovery, sprint performance, athletic recovery, collegiate swimming, and swimming. Studies were included if they examined at least one water immersion modality as a recovery intervention, assessed physiological or performance-related outcomes, and were published in peer-reviewed journals. Studies were excluded if they did not report recovery- or performance-relevant outcomes as well as if they focused exclusively on non-athletic clinical populations. Reference lists of relevant reviews and meta-analyses were also searched to identify additional eligible studies and make a deeper analysis possible.

Water Immersion Recovery Modalities

Cold water immersion (CWI)

CWI is one of the most widely used post-exercise recovery strategies among athletes, generally involving partial- or whole-body immersion in cold water between 8-20°C for approximately 5-15 minutes, with the specific temperature, immersion depth, and duration varying considerably across both practice and the literature depending on the demands of the training session and the goals of recovery 3,8,9. This variability in protocol design contributes meaningfully to differences in observed recovery outcomes. The physiological mechanisms thought to underlie CWI's effects include rapid cutaneous vasoconstriction, reductions in muscle temperature and metabolic activity, slowed nerve conduction velocity, and attenuation of edema and inflammatory responses, followed by vasodilation and increased blood flow during the rewarming phase, collectively working to limit secondary tissue damage and accelerate the restoration of neuromuscular function [10,11].

Evidence broadly supports CWI as an effective hydrotherapy modality for next-day sprint recovery, particulary in land-based team sport population. In a meta-analysis of 23 studies involving 606 participants, Higgins et al. (2017) [9] found that CWI protocols ranging from 10-15°C for 5-15 minutes produced a statistically significant benefit for all-out sprint performance at 24 hours post-exercise ($p = 0.02$), as well as meaningful improvements in neuromuscular recovery at the same time point. This effect was specific to single, maximal sprint efforts rather than accumulated sprint performance, a distinction particularly relevant to competitive swimming, where events such as the 50-m and 100-m freestyle demand explosive, all-out output.

The mechanisms underlying these neuromuscular benefits are supported by Vaile et al. [12], who applied 15°C full-body immersion for 14 minutes following a DOMS-inducing resistance protocol and found that CWI significantly improved squat jump performance, isometric force recovery, and reduced edema compared to both hot-water immersion and passive recovery. Similarly, Kuligowski et al. [13], using cold whirlpool immersion at 12°C for 24 minutes following eccentric elbow flexor exercise, reported significantly faster reductions in soreness and earlier return of elbow flexion strength compared to no treatment or hot-water immersion. These findings collectively support the premise that CWI accelerates neuromuscular recovery by attenuating inflammation, reducing muscle swelling, and restoring force production capacity.

An important moderating factor appears to be the timing of CWI application relative to exercise. Brophy-Williams et al. [11] compared immediate versus delayed CWI in eight trained male athletes who immersed to the mid-sternum in 15°C water for 15 minutes either immediately post-exercise or three hours later, with passive sitting as a control. Immediate immersion produced the greatest improvement in next-day run performance, while delayed CWI still yielded meaningful benefits over passive recovery [11]. Inflammation assessed via blood biomarkers including C-Reactive Protein (CRP) and indices of muscle damage were lower following both CWI conditions compared to control, confirming physiologically measurable attenuation of muscle damage regardless of timing, though the effect was strongest when CWI was applied without delay [11]. This timing effect is echoed in Tabben et al. [14], who had elite combat sport athletes undergo 15 minutes of full-body CWI at approximately 10°C immediately following a simulated competition bout. While no sprint benefit was observed immediately after the recovery period, 10-m sprint times were significantly faster in the CWI group at the 24-hour assessment compared to passive recovery, with large effect sizes and significantly improved wellness scores, reinforcing that CWI's primary sprint performance benefit manifests the following day rather than acutely [14]. Leeder et al. [15] further extended this finding across a simulated five-day tournament in 21 trained male athletes, demonstrating that sprint speed at 24 hours following the final exercise bout was significantly improved in the CWI group compared to control, alongside attenuated creatine kinase efflux, suggesting that repeated CWI exposure reduces cumulative muscle damage across multi-day competition formats [15].

The translation of these benefits to aquatic sport populations is less straightforward, and findings on competitive swimmers specifically are inconsistent. Parouty et al. [16] tested 10 well-trained swimmers (5 male, 5 female; mean age 19.0 ± 3.9 years) completing two maximal 100-m swim sprints separated by a 30-minute recovery window, during which participants underwent either 5 minutes of CWI at 14°C or remained out of the water as a passive control. While 100-m sprint times did not significantly differ between conditions, CWI meaningfully improved parasympathetic reactivation indexed by heart rate variability (Ln rMSSD) and produced faster lactate clearance, suggesting physiological recovery benefits even in the absence of measurable sprint time improvements over a short same-day window [16]. Batista et al. [17] similarly applied 12 minutes of 14°C shoulder-level immersion immediately post-training in competitive adolescent swimmers across a week-long protocol and found no significant improvements in 100-m freestyle sprint performance compared to thermoneutral or placebo immersion. Notably however, swimmers still reported improved perceived recovery, highlighting a consistent dissociation between objective performance outcomes and subjective recovery experience in aquatic populations [17]. Further complicating the picture, Richards et al. [6] reported that 10 minutes of CWI at 10°C did not enhance performance or reduce fatigue markers the following day in recreationally active individuals following isolated dorsiflexor high-intensity interval exercise, though the localized, non-sport-specific exercise model and recreationally active sample limit direct generalizability to whole-body competitive swimming performance.

Collectively, the available evidence indicates that CWI at 10-15°C applied immediately post-exercise for a minimum of approximately 14 minutes is most consistently associated with reductions in muscle damage markers, improved neuromuscular recovery, and enhanced next-day sprint performance. Benefits appear most pronounced in land-based sprint and team sport populations, while findings in competitive swimmers remain mixed, with physiological and perceptual improvements observed more reliably than direct sprint time gains.

Hot water immersion (HWI)

Hot-water immersion (HWI) is a commonly used hydrotherapy technique aimed at facilitating post-exercise recovery, typically involving partial- or whole-body immersion in water at temperatures at or above 36°C for approximately 10-30 minutes depending on study design [5,12,18]. Foundational work by Craig and Dvorak [4] confirmed that water temperatures at or above 36°C meaningfully elevate core temperature during immersion, establishing this as the physiological threshold for "hot" water, whereas temperatures between 35.0-35.5°C are considered thermoneutral and do not significantly alter thermal status.

By increasing core and intramuscular temperature, HWI induces peripheral vasodilation, elevates local blood flow, and increases tissue elasticity, collectively promoting muscle relaxation and perceived comfort following strenuous exercise [4,21]. Despite these responses, evidence supporting HWI as an effective modality for physiological recovery or next-day sprint performance is mixed and generally less favorable compared to cold-based methods. Several studies demonstrate that HWI provides limited or inconsistent recovery benefits relative to CWI. Vaile et al.[12] compared 14 minutes of recovery across four conditions- CWI at 15°C, HWI at 38°C, contrast water therapy, and passive rest- following a DOMS-inducing resistance protocol in 38 strength-trained men. While CWI and contrast therapy significantly improved squat jump performance, isometric force recovery, and reduced localized swelling, HWI improved only isometric force and failed to meaningfully enhance any other performance or soreness outcome relative to passive control [12]. Similarly, Kuligowski et al. [13] found that a 24-minute warm whirlpool protocol at 40.6°C was less effective than cold whirlpool or contrast therapy in reducing delayed-onset muscle soreness and restoring elbow flexion strength following eccentric exercise, though warm water still produced marginally better outcomes than no treatment at all. These findings suggest that while HWI may confer mild physiological benefits, it is consistently inferior to CWI in accelerating the recovery of neuromuscular function and force production capacity.

Evidence further suggests that HWI provides minimal advantage over passive rest for next-day performance outcomes. Jackman et al. [18] examined the effects of 10 minutes of HWI at 40°C following resistance exercise in 16 trained males and found that although intramuscular temperature increased acutely during immersion, it returned to baseline within approximately two hours. No significant differences emerged between HWI and passive recovery for muscle soreness, neuromuscular function, or inflammatory markers, leading the authors to conclude that short-duration HWI may enhance thermal comfort but does not meaningfully influence next-day recovery outcomes. This is directly supported by another study by Vaile et al. [19] in their cycling-based performance comparison, examining CWI, CBT, and HWI, where HWI at 38°C for 14 minutes applied across five consecutive training days failed to outperform passive rest on any sprint power or time trial metric, while CWI and contrast therapy produced significantly better maintained performance across the same period suggesting better recovery benefits than HWI. Solsona et al. (2023) [20] offer a more nuanced perspective, demonstrating in 12 national-team speed skaters that HWI at 41.1 ± 0.5°C for 20 minutes preserved average sprint cycling power output (766 ± 170 W) comparably to active recovery (767 ± 179 W), both of which were significantly greater than CWI at 12.1 ± 0.7°C for 15 minutes (738 ± 156 W; $p = .026$) when the subsequent sprint effort followed within 1.5 hours. A positive correlation was observed between maintained muscle temperature during recovery and maximal sprint power, suggesting that HWI's temperature-preserving effect on muscle tissue may be advantageous specifically when a second high-intensity effort is required within the same day[20].

Newer work indicates that HWI may produce meaningful vascular responses under specific conditions, though these do not readily translate to athletic sprint performance [21]. Stewart et al. [21] applied 30 minutes of HWI at 40°C in physically inactive middle-aged adults and found that immersion, both alone and following moderate-intensity cycling, significantly increased brachial and superficial femoral artery shear rates and produced higher enjoyment ratings compared to exercise alone, suggesting potential cardiovascular adaptation benefits with repeated use. However, as this study examined a non-athletic population without assessing next-day functional performance, its direct applicability to competitive swimming sprint recovery is limited. Similarly, Wellauer et al. [22] found that 10 minutes of HWI at 40°C produced no significant differences in muscle function, soreness, or blood markers compared to CWI or passive rest in physically active women following an exercise-induced muscle damage protocol, which could be an important finding given the mixed-sex composition of most collegiate swimming programs.

Collectively, the available evidence indicates that HWI is the least supported hydrotherapy modality for next-day sprint performance recovery. While it may offer a situational advantage when a subsequent sprint effort is required within the same day, likely due to its muscle temperature-preserving effects, HWI does not appear to attenuate the primary physiological drivers of fatigue, including inflammation, muscle damage, and neuromuscular impairment, with comparable efficacy to CWI. Its application as a next-day sprint recovery strategy in Division I collegiate swimmers therefore lacks consistent empirical support.

Contrast bath therapy (CBT)

Contrast bath therapy (CBT), also referred to as contrast water therapy (CWT), involves alternating exposures to hot and cold water in repeated cycles and is widely used by athletes as a recovery strategy following intense exercise [3]. Although protocols vary considerably across the literature, most studies apply hot-water phases at temperatures between 36-40°C for 1-3 minutes, alternating with cold-water phases between 8-15°C for approximately one minute, typically repeated across 3-6 cycles for a total duration of 10-15 minutes [9,12,23]. The modality is most commonly initiated with a hot phase and concluded with a cold phase. The physiological rationale behind CBT centers on the rapid alternation between vasodilation during the hot phase and vasoconstriction during the cold phase, which is theorized to create a vascular pumping effect that enhances blood flow, accelerates metabolite clearance, improves oxygen delivery to muscle tissue, and facilitates the removal of inflammatory markers, collectively reducing muscle soreness and restoring neuromuscular function following intense exercise [9,10]. However, direct experimental support for this mechanism remains limited, and the evidence for CBT's effect on next-day sprint performance is considerably more mixed than its widespread use in athletic settings might suggest.

The previously discussed work by Higgins et al. [9] and Vaile et al. [12] provides foundational support for CBT's recovery benefits. In their meta-analysis, Higgins et al. [9] found that CBT was significantly beneficial for perception of fatigue at 24 hours post-exercise (p = .04), and Vaile et al. [12] demonstrated that CBT enhanced recovery of muscle function and reduced soreness following resistance exercise compared to hot-water immersion alone. The combination of alternating temperatures appears to produce both physiological benefits, improved circulation and reduced inflammation, and psychological benefits including enhanced perception of recovery and reduced fatigue, which may be particularly advantageous for swimmers training multiple times per day or competing in multi-event meets [9,12]. Importantly however, Higgins et al. [9] also found that CBT did not produce statistically significant improvements in neuromuscular sprint performance at 24 hours, in direct contrast to CWI, which did, suggesting that CBT's primary recovery benefit within the next-day window may be perceptual rather than neuromuscular.

The sprint-specific evidence for CBT similarly reveals a consistent dissociation between physiological recovery markers and objective performance outcomes. Hamlin [23] examined CBT versus active recovery in 20 junior representative rugby players completing two sets of ten 40-m sprints with 30 seconds of rest between efforts. The CBT protocol involved alternating between 8-10°C cold water immersion to hip height for one minute and a 38°C hot water shower, repeated for three cycles totaling six minutes [23]. Relative to the active recovery group, the CBT group demonstrated significantly lower blood lactate concentrations three minutes post-recovery and lower heart rates both during the recovery period and one hour later during the second sprint set [23]. Despite these favorable physiological responses, no significant differences in repeated sprint performance were observed between groups. Separately, Gill et al. [24] examined CBT's effect on muscle damage recovery in 23 elite rugby players following competitive matches, using a protocol of 1 min cold (8-10°C) alternating with 2 min hot (40-42°C) for ~9 minutes total. They found that CBT enhanced creatine kinase clearance at 36 and 84 hours post-match compared to passive recovery (85.0% vs. 39.0% recovery, $p<0.05$), though it was no more effective than active recovery or compression garments [24]. Taken together, these results suggest that while CBT reliably improves physiological recovery markers such as lactate clearance and muscle damage resolution, this does not consistently translate into measurable sprint performance gains within the first hour post-exercise.

Where CBT demonstrates its clearest sprint-relevant benefits is in neuromuscular and proprioceptive recovery. Li, T et al. [25] specifically studied 40 track sprinters assigned to either CBT or passive recovery following high-intensity sprint training, applying a protocol that alternated between 38°C and 15°C in one-minute cycles for 14 minutes total. At both 24 and 48 hours post-intervention, the CBT group demonstrated significantly improved knee joint proprioception, force sense, and joint reaction angle compared to passive control (all $p < .05$), alongside significantly higher functional scores and lower fatigue markers including creatine kinase and subjective fatigue ratings [25]. While direct sprint times were not captured, the neuromuscular and proprioceptive outcomes assessed are foundational to explosive sprint performance, lending meaningful mechanistic support to CBT's potential utility in sprint athlete recovery contexts.

Overall, CBT appears to offer combined physiological and perceptual recovery benefits, reducing soreness, enhancing circulatory dynamics, lowering cardiovascular stress, and supporting neuromuscular markers of recovery, making it a potentially valuable modality for swimmers completing multiple daily sessions or competing across multi-event meets.

Nevertheless, its ability to directly improve next-day sprint performance remains uncertain and appears inferior to CWI in direct comparisons, emphasizing the need for further sport-specific research in elite aquatic athletes.

Table 1. Literature comparisons.

Reference #, Authors	**Sample Size/ Subject Type**	**Immersion Type**	**Methods, Temperature and Duration, Area immersed**	**Primary Outcome**	**Modality Effectiveness**
6, Richards, AJ, et al.	N= 12, young (23.3+-3.1y), recreationally active individuals	CWI vs room temperature rest (passive control)	immediately after exercise, lower left leg in 10°C for 10 min or kept at room temperature (RT) for 10 min	No enhancement of post-exercise recovery or next-day performance with CWI compared with passive rest	Not effective: 10 min of CWI at 10°C does not enhance post-exercise recovery or next-day exercise performance following HIIE workout.
9, Higgins, TR, et al.	23 studies, n=606 team sport athletes (rugby, soccer, basketball); systematic review & meta-analysis;	CWI vs. CBT vs. control-pooled meta-analysis	CWI: 5-15°C, various immersion types : total of 10 minutes, 2 cycles of 5-minute, 5 cycles of 2-minute, single 15-minute, single 5-minute or 5 cycles of 1-minute immersion; various immersion depths across included studies; applied post-exercise CBT: Hot 38–42°C / cold 10–15°C; immersion times 1-3min across included studies; various immersion depths	CWI significantly beneficial for all-out sprint at 24h. Beneficial for neuromuscular recovery at 24h. No benefit for accumulated sprinting. CWT beneficial for fatigue perception at 24h (p=0.04) but not neuromuscular sprint. CBT significantly beneficial for perception of fatigue at 24h. NOT beneficial for neuromuscular sprint performance at 24h. No benefit for muscle soreness.	Effective: CWI Strongest pooled evidence for next-day sprint Mixed Effect: CBT Perceptual fatigue recovery improved; no direct sprint performance benefit
11, Brophy-Williams, N, et al.	N=8, well trained male athletes (n=1 hockey, n=7 Australian rules football)	CWI (immediately vs 3h delayed), vs passive control	Whole body to the mid-sternum immersion, in 15°C (± 1°C) for 15 minutes	Immediate CWI significantly improved next-day Yo-Yo performance vs control; delayed CWI showed likely beneficial improvement vs control with lower CRP and higher perceived recovery	Effective; immediate and delayed CWI both beneficial, with immediate CWI showing greatest benefit
12, Vaile, J, et al. (a)	N=38, strength trained males	CWI, HWI, CBT, PAS	DOMS-inducing leg press protocol followed by 14 min of either PAS, or one of the water immersion interventions:	CBT and CWI significantly improved recovery of squat jump and isometric force at multiple time points versus passive recovery; CBT also reduced perceived pain; HWI improved	CWI and CBT: effective for reducing physiological and functional deficits of DOMS (force, power, oedema, pain); HWI: partially effective (isometric force only) and less beneficial overall compared with CWI and CBT

			CWI, 15°C, n = 12), HWI, 38°C, n = 11), CBT, 15°C/38°C, n = 15)	isometric force only, with little effect on other markers	
13, Kuligowski, LA, et al.	N= 56 volunteers	Cold whirlpool (CWI), Warm whirlpool (HWI), CBT, or PAS	24-minute either CWI (12°C) or HWI (42°C) or CBT (alternating 1 min hot/ 1min cold) immediately post-exercise and at 24, 48, and 72 h post-exercise; immersion area: elbow flexors (arm) after eccentric elbow-flexor exercise.	Cold whirlpool and CBT most effective for reducing soreness and restoring ROM	CWI and CBT effective; warm whirlpool less effective but better than control in alleviating DOMS in the elbow flexors
14, Tabben, M, et al.	N=12, well trained male combat sport athletes; crossover design, CWI vs. passive recovery	CWI vs PAS	CWI with ~10°C for 15 min, full-body seated immersion to neck, or PAS for 15 min, applied immediately post-simulated competition.	No sprint benefit immediately post-recovery. At 24h, 10-m sprint times significantly faster in CWI vs. passive recovery (large effect size). Wellness scores (Hooper Index) significantly improved at 24h.	Effective- Next-day sprint significantly improved for CWI compared to PAS
15, Leeder, JDC, et al.	n=21 trained male games players (age 19 ± 2 yrs); CWI (n=11) vs. control (n=10)	CWI vs PAS	CWI 14°C for 14 min, in a seated position, applied immediately post-exercise.	CWI significantly improved 10-m sprint time at 24 hrs post-exercise vs. passive recovery (large effect size). Wellness (Hooper Index) also significantly better at 24 hrs.	Effective - Next-day sprint improved
16, Parouty, J, et al.	n=10 well-trained competitive swimmers (5M, 5F); mean age 19.0 ± 3.9 yrs	CWI vs PAS	CWI for 14°C for 5 min during a 30-min passive recovery window between two 100-m sprint swims; lower body/seated immersion vs. out-of-water passive control at 28°C	100-m sprint times did not significantly differ between conditions. CWI improved parasympathetic reactivation (HRV/Ln rMSSD) and produced faster lactate clearance vs. control.	Mixed effective-Physiological recovery improved; sprint time unchanged
17, Batista, NP, et al.	N=20, competitive adolescent swimmers	CWI vs thermoneutral water immersion (TWI) as placebo, vs PAS	CWI in 14 ± 1 °C or TWI in 27 ± 1 °C or PAS for 12 min, lower body immersed (post-resistance, pre-swim) three times per week during a training week	All groups improved sprint times over the week, with no meaningful differences between CWI, TWI, and PAS for swim or functional performance; small	Not effective for performance. CWI did not enhance sprint or functional performance vs placebo or PAS, though athletes preferred CWI/TWI over PAS

				effects on pain/tiredness without clear between-condition differences	
18, Jackman, JS, et al.	N=16, resistance trained males	HWI vs PAS	Resistance exercise, followed by either 10 min HWI (full lower body) at 40°C or 10 min of PAS	HWI produced greater acute increase in intramuscular temperature vs. PAS, but temperature returned to baseline within ~2h. No significant differences in muscle soreness, neuromuscular function, or inflammatory markers between HWI and PAS	HWI not effective- HWI elevated tissue temperature but did not improve recovery outcomes vs. passive rest
19, Vaile, J, et al. (b)	n=12 elite male cyclists; within-subjects crossover (HWI, CWI, CWT, PAS)	HWI vs CWI vs CBT vs PAS; 5-day comparison	For 14 min HWI 38°C or CWI 15°C or CBT alternating the two for 7 cycles applied post-exercise daily across 5 consecutive training days; shoulder height immersion	Sprint power and time trial performance significantly better after CWI and CBT vs. HWI and PAS. HWI did not outperform passive rest on any sprint or time trial metric across 5 days	CWI and CBT effective in improving recovery from high intensity cycling compared to HWI not effective and cannot maintain performance across 5 days as well as CWI and CBT
20, Solsona, R, et al.	n=12 national-team short-track speed skaters (7M, 5F); randomized crossover (HWI vs. CWI vs. active recovery)	HWI vs CWI vs Active Recovery	HWI 41.1±0.5°C for 20 min; or CWI 12.1±0.7°C for 15 min; or active recovery, applied 15 min post-exhaustive skating; repeated sprint cycling 1.5h later	HWI (766±170 W) and active recovery (767±179 W) both preserved sprint power significantly better than CWI (738±156 W; p=.026) at 1.5h post-recovery. Positive correlation between muscle temperature and maximal sprint power	HWI and active recovery more effective than CWI for same-day sprint (1.5h window); advantage likely does not extend to next-day context
21, Stewart, C, et al.	N= 16, physically inactive middle-aged results (9M, 7F)	HWI post-exercise (EX+HWI), HWI alone (HWI+HWI, exercise + rest	30 min cycling on a cycle ergometer followed by 30 minutes of either 1) HWI in 40°C immersion up to the mid sternum or 2) rest	EX+HWI and HWI+HWI increased shear rate, nitrite, IL-6 more than exercise alone; higher enjoyment; no sprint or next day assessed	HWI enhanced vascular responses; no performance data; limited applicability to sprint athletes
22, Wellauer, V, et al.	N=30, physically active women (aged 18-35 years); CWI vs. HWI vs. passive control	HWI vs CWI vs PAS	HWI 40 ± 0.5°C, or CWI 10 ± 0.5°C, or PAS for 10 min post-exercise-induced muscle damage protocol; immersion until sternum	Neither HWI nor CWI produced significant differences in muscle function, soreness, or blood markers vs. passive rest in women. HWI elevated intramuscular temperature but showed no	No benefit for either CWI or HWI for recovery markers important for mixed-sex swim programs

				performance advantage	
23, Hamlin, MJ, et al.	N=20, junior representative rugby players (aged 19 +- 1 year)	CBT vs active recovery	Ten 40 m sprints with a 30 sec turn-around between sprints. Recovery consisted of either 1) 6min slow jogging or 2) 6min of CBT: three 1-min hip-height immersions in cold water (8-10°C) alternated with three 1-min hot water (38°C) showers, test repeated after 1 hour	CBT caused significantly lower blood and heart rate vs. active recovery during and 1h post-recovery. No significant differences in 40-m repeated sprint performance between groups	CBT improved physiological markers but did not improve sprint performance
24, Gill, ND, et al.	N=23 elite rugby players; following competitive matches	CBT vs. active recovery vs. compression garments vs. PAS	CBT for 1 min cold (8-10°C) alternating with 2 min hot (40-42°C) for ~9 min total; full lower-body immersion post-match	CBT enhanced CK clearance at 36h and 84h post-match vs. passive recovery (85.0% vs. 39.0% recovery; $p<0.05$). CBT was no more effective than active recovery or compression garments.	Mixed CBT efficiency- Better than passive rest for muscle damage clearance; not superior to active recovery
25, Li, T, et al.	N=40 track sprinters; CBT (n=20) vs. passive control (n=20)	CBT vs PAS	38 ±1°C hot / 15 ±1°C cold alternating 1 min cycles for 14 min total (7 cycles); full body to neck depth; applied post-high-intensity sprint training	CBT significantly improved knee joint proprioception, force sense, and joint reaction angle at 24h and 48h vs. control (all $p<.05$). Significantly higher IKDC2000/Lysholm scores and lower fatigue markers (CK, subjective fatigue) in CBT group.	Effective CBT, neuromuscular/proprioceptive recovery significantly improved in sprint athletes

Table 1 abbreviations: CWI = cold-water immersion, HWI = hot-water immersion, CBT = contrast bath therapy, TWI = thermoneutral water immersion, PAS = passive recovery, HIIE = high-intensity interval exercise, DOMS = delayed onset muscle soreness, CRP = C-Reactive Protein, EX = exercise, RT = room temperature

NCAA Swimmers

NCAA Division I swimmers face a very demanding schedule, balancing high-volume training with continuous academic obligations. Throughout the fall and spring seasons, swimmers train year-round with minimal breaks, often completing weekly morning and afternoon swim practices, resistance training, and conditioning sessions that collectively exceed 20 hours per week with the end goal to qualify for championship competition time standards [1]. These repeated bouts of high-intensity training generate substantial muscular stress, neuromuscular fatigue, and metabolic by-products that require ongoing recovery to maintain performance capacity.

The competitive structure of college swimming further increases recovery demands. Dual meets, invitationals, and championship meets often occur on consecutive days, requiring swimmers to perform multiple races within the same day, typically a combination of morning preliminaries and evening finals. This results in short recovery windows of only a few hours between races, during which athletes must restore power output, reduce fatigue, and maintain technical precision. Frequent travel during the season, early-morning departures, long bus rides, unfamiliar sleep environments, and time spent sitting can additionally impair circulation, disrupt sleep quality, and elevate physiological stress, further compromising recovery.

Given these constraints, the ability to recover quickly and efficiently becomes essential for sustaining performance across practices, meets, and multi-day competitions. CWI, HWI, and CBT offer practical solutions because they can accelerate immediate physiological recovery within limited timeframes. The proper recovery may help reduce muscle soreness, enhance circulation, moderate inflammation, and restore neuromuscular readiness before the next race or training session. They are also very accessible and time-efficient, as most collegiate training centers and competition venues have immersion tubs or portable setups that allow athletes to perform recovery protocols in 10-15 minutes. At more elite levels, even when traveling, teams are often able to use hotels or visiting facilities to replicate or use their cold, hot, or contrast treatments.

Integrating CWI, HWI, or CBT between sessions or after evening finals may therefore offer NCAA swimmers a competitive advantage by supporting faster recovery, maintaining performance consistency, and minimizing cumulative fatigue across consecutive training days or championship meets.

Limitations

Despite the widespread use of CWI, HWI, and CBT in athletic settings, the existing research examining their effectiveness for recovery and next-day sprint performance in particular contains several notable limitations that warrant careful consideration when applying these findings to Division I collegiate swimmers. Most fundamentally, only a limited number of studies have directly evaluated next-day sprint swimming performance, with the majority of investigations instead assessing strength recovery, muscle soreness, or performance outcomes in non-swimming or land-based exercise modalities. Direct translation of these findings to Division I sprint swimmers should therefore be made cautiously. According to the studies reviewed, sample sizes were consistently small (often fewer than 20 participants) and populations frequently consisted of recreational exercisers, adolescent athletes, or resistance-trained individuals rather than high-performance collegiate swimmers [17,18]. The training volume, physiological demands, and competition schedules of Division I swimmers differ substantially from these groups, limiting generalizability. Participant characteristics also varied in terms of sex distribution and training status, both of which may potentially independently influence physiological and perceptual responses to water immersion.

Considerable variability in immersion protocols across studies further complicates direct comparison and limits the ability to identify an optimal recovery prescription for sprint swimmers. Some CWI protocols were relatively consistent in some respects, for example, Vaile et al. [12] used full-body immersion excluding the head for 14 minutes at 15°C, Brophy-Williams et al. [11] immersed participants to the mid-sternum for 15 minutes at 15 ± 1°C, and Batista et al. [17] applied shoulder-level immersion for 12 minutes at 14 ± 1°C, yet even these seemingly minor differences in depth, duration, and temperature may produce meaningfully different tissue cooling rates, neuromuscular responses, and recovery outcomes. HWI protocols were inconsistent as Jackman et al. (2023) [18] immersed participants at 40°C for 10 minutes, Stewart et al. [21] applied 40°C for 30 minutes, and both studies from Vaile et al. [12,19] used 38°C for 14 minutes. Although the differences may appear subtle, tissue heating rates, vasodilation magnitude, blood flow responses, and neuromuscular recovery are highly temperature- and duration-dependent, meaning these variations are likely physiologically meaningful[4]. CBT protocols varied most substantially of all as Vaile et al. [12] alternated one-minute cold at 15°C and one-minute hot at 38°C for seven total cycles over 14 minutes, while Hamlin [23] used three one-minute hip-height immersions at 8-10°C alternating with three one-minute hot showers at 38°C for a total of only six minutes. The number of cycles, cycle duration, temperature differential, and total immersion time ranged widely, making outcome comparisons across CBT studies particularly difficult.

The timing of immersion relative to exercise also differed across studies and represents a meaningful source of variability, given that lactate clearance and inflammatory cascades change substantially within the first minutes following exercise cessation. Brophy-Williams et al. [11] specifically compared immediate versus three-hour delayed immersion and found meaningfully different outcomes between conditions, while other studies such as Batista et al. [17] reported only that immersion was performed immediately post-exercise without precise timing detail, limiting the ability to draw direct comparisons. The exercise protocols used to induce fatigue prior to recovery interventions also varied considerably, ranging from eccentric elbow flexor contractions [13] and resistance training [18] to DOMS-inducing leg press protocols [12] and high-intensity interval running [11], with only a small number of studies involving a swimming-specific workout [16,17]. Because these exercise types differ substantially in muscle recruitment patterns, lactate production, neuromuscular fatigue profiles, and tissue damage mechanisms, recovery responses observed in one modality cannot be assumed to transfer directly to collegiate sprint swimming.

Finally, outcome measurement approaches varied across studies and introduced additional interpretive challenges. Several studies relied on venous blood sampling, which as noted by Stewart et al. [21] may not accurately reflect local muscular or systemic responses due to differences in vascular compartment sampling locations. Many studies also incorporated perceptual measures such as soreness ratings and perceived recovery scores, which are susceptible to psychological factors and placebo effects. Unlike pharmacological trials, it is impossible to blind athletes to their recovery modality when thermal sensations differ dramatically between conditions, making it difficult to determine the extent to which observed benefits are physiological versus psychological in origin.

Collectively, inconsistencies across participant characteristics, water temperatures, immersion durations, hot-cold cycle structures, body coverage areas, timing relative to exercise, and exercise protocols make it difficult to isolate the true effectiveness of CWI, HWI, and CBT for next-day sprint performance in Division I collegiate swimmers and collectively underscore the need for standardized, swimmer-specific research in this area.

Conclusions

The findings of this brief review highlight both the promise and the limitations of CWI, HWI, and CBT as recovery modalities for next-day sprint performance in Division I collegiate swimmers. Based on the available evidence, CWI at 10-15°C applied immediately post-exercise for a minimum of approximately 14 minutes emerges as the a consistently supported modality for next-day sprint recovery, while HWI shows little empirical support in this context and CBT demonstrates reliable perceptual and physiological benefits that do not always translate into measurable sprint performance gains. The methodological inconsistencies and population limitations discussed throughout this review prevent definitive conclusions from being drawn for competitive sprint swimmers specifically.

Future research should prioritize standardized study designs to improve interpretability and practical relevance. Larger sample sizes (ideally exceeding 20 participants) drawn specifically from high-performance collegiate or elite swimming populations would increase statistical power and improve generalizability to the demands of competitive sprint swimming. Standardizing key protocol parameters including temperature, immersion duration, depth, and timing relative to exercise would substantially reduce the methodological variability that currently limits meaningful comparison across studies. Swimmer-specific exercise protocols should also be used to induce fatigue prior to recovery interventions, as the eccentric resistance and land-based exercise models predominant in the existing literature differ fundamentally from the neuromuscular demands of competitive sprint swimming.

Beyond short-term recovery, future work can examine long-term and season-long intervention effects to determine whether repeated immersion produces cumulative changes in neuromuscular readiness, recovery efficiency, or performance outcomes across a competitive season. Notably, Roberts et al. [26] found that while CWI offers meaningful short-term recovery advantages, consistent use (particularly following strength training) may attenuate anabolic signaling and blunt the muscle-building adaptations that support long-term performance development, a consideration of direct relevance to swimmers engaged in concurrent strength and swim training programs. Investigating combined recovery modalities also represents a valuable area for future study, particularly approaches that integrate active recovery with water immersion, such as aqua jogging, mobility work, or light swimming, to determine whether simultaneous movement and thermal exposure produce superior recovery benefits over immersion alone.

Finally, future research should more rigorously examine the relationship between perceived recovery and objective performance outcomes. Across many of the studies reviewed, improved feelings of recovery and reduced soreness were reported in the absence of measurable performance gains, suggesting that psychological factors including expectancy effects, placebo responses, and thermal perception may play a meaningful independent role in the recovery experience. Clarifying the extent to which these modalities operate through physiological versus psychological mechanisms will help practitioners determine whether interventions that feel effective still offer meaningful practical benefit even when objective performance changes are limited. With improved study design, swimmer-specific populations, and more precise measurement tools, future research can provide the evidence base needed to determine whether these widely used recovery modalities truly translate into meaningful next-day sprint performance benefits for Division I collegiate swimmers.

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References

1. Pollock S, Gaoua N, Johnston MJ, Cooke K, Girard O, Mileva KN. Training regimes and recovery monitoring practices of elite British swimmers. J Sports Sci Med. 2019;18(3):577-585.
2. Stožer A, Vodopivc P, Križančić Bombek L. Pathophysiology of exercise-induced muscle damage and its structural, functional, metabolic, and clinical consequences. Physiol Res. 2020;69(4):565-598.
3. Moore E, Fuller JT, Bellenger CR, et al. Effects of cold-water immersion compared with other recovery modalities on athletic performance following acute strenuous exercise in physically active participants: a systematic review, meta-analysis, and meta-regression. Sports Med. 2023;53:687-705.
4. Craig AB Jr, Dvorak M. Thermal regulation during water immersion. J Appl Physiol. 1966;21(5):1577-1585.
5. Versey NG, Halson SL, Dawson BT. Water immersion recovery for athletes: effect on exercise performance and practical recommendations. Sports Med. 2013;43(11):1101-1130.
6. Richards AJ, Malekzadeh R, Elghobashy ME, et al. Cold water immersion does not enhance recovery and performance after high-intensity interval dorsiflexion exercise. Scand J Med Sci Sports. 2025;35(5):e70061.
7. Hing WA, White SG, Bouaaphone A, Lee P. Contrast therapy — a systematic review. Phys Ther Sport. 2008;9(3):148-161.
8. Klimek K, Bugla K, et al. Effect of cold water immersion and contrast water immersion on selected physiological responses after exercise. J Educ Health Sport. 2024.
9. Higgins TR, Greene DA, Baker MK. Effects of cold water immersion and contrast water therapy for recovery from team sport: a systematic review and meta-analysis. J Strength Cond Res. 2017;31(5):1443-1460.
10. Xiao, F., Kabachkova, A. V., Jiao, L., Zhao, H., & Kapilevich, L. V. Effects of cold water immersion after exercise on fatigue recovery and exercise performance- meta-analysis. Front Physiol. 2023.
11. Brophy-Williams N, Landers G, Wallman K. Effect of immediate and delayed cold-water immersion after a high-intensity exercise session on subsequent run performance. J Sports Sci Med. 2011;10(4):665-670.
12. Vaile J, Halson S, Gill N, Dawson B. Effect of hydrotherapy on the signs and symptoms of delayed onset muscle soreness. Eur J Appl Physiol. 2008;102(4):447-455.
13. Kuligowski LA, Lephart SM, Giannantonio FP, Blanc RO. Effect of whirlpool therapy on the signs and symptoms of delayed-onset muscle soreness. J Athl Train. 1998;33(3):222-228.
14. Tabben M, Ihsan M, Ghoul N, Coquart J, Chaouachi A, Chaabene H, Tourny C, Chamari K. Cold water immersion enhanced athletes' wellness and 10-m short sprint performance 24-h after a simulated mixed martial arts combat. Front Physiol. 2018;9:1542.
15. Leeder JDC, Godfrey M, Gibbon D, Gaze D, Davison G, van Someren K, Howatson G. Cold water immersion improves recovery of sprint speed following a simulated tournament. Eur J Sport Sci. 2019;19(9):1166-1174.
16. Parouty J, Al Haddad H, Quod M, Lepretre PM, Ahmaidi S, Buchheit M. Effect of cold water immersion on 100-m sprint performance in well-trained swimmers. Eur J Appl Physiol. 2010;109(3):483-490.
17. Batista NP, de Carvalho FA, Rodrigues CRD, et al. Effects of post-exercise cold-water immersion on performance and perceptive outcomes of competitive adolescent swimmers. Eur J Appl Physiol. 2024;124(8):2439-2450.
18. Jackman JS, Bell PG, Van Someren K, et al. Effect of hot water immersion on acute physiological responses following resistance exercise. Front Physiol. 2023;14:1213733.
19. Vaile J, Halson S, Gill N, Dawson B. Effect of hydrotherapy on recovery from fatigue. *Int J Sports Med.* 2008;29(7):539-544.
20. Solsona R, Meline T, Borrani F, Deriaz R, Lacroix J, Normand-Gravier T, Candau R, Racinais S, Sanchez AMJ. Active recovery vs hot- or cold-water immersion for repeated sprint ability after a strenuous exercise training session in elite skaters. J Sports Sci. 2023;41(11):1126-1135.
21. Stewart CJ, Hill M, Menzies C, et al. Post exercise hot water immersion and hot water immersion in isolation enhance vascular, blood marker, and perceptual responses when compared to exercise alone. Scand J Med Sci Sports. 2024;34:e14600.
22. Wellauer V, Clijsen R, Bianchi G, Riggi E, Hohenauer E. No acceleration of recovery from exercise-induced muscle damage after cold or hot water immersion in women: a randomised controlled trial. PLOS ONE. 2025;20(5):e0322416.
23. Hamlin MJ. The effect of contrast temperature water therapy on repeated sprint performance. J Sci Med Sport. 2007;10(6):398-402.

24. Gill ND, Beaven CM, Cook C. Effectiveness of post-match recovery strategies in rugby players. Br J Sports Med. 2006;40(3):260-263.
25. Li, T., Xiang, H., Li, L., & Zhao, C. Effects of contrast water therapy on proprioception of the knee joint and degree of fatigue in sprinters after high-intensity training. J Clin Med. 2024. PMC11236656.
26. Roberts LA, Raastad T, Markworth JF, et al. Post-exercise cold water immersion attenuates acute anabolic signaling and long-term adaptations in muscle to strength training. J Physiol. 2015;593(18):4285-4301.