



Cold-Water Immersion and Athletic Recovery: A Systematic Review of Randomized Controlled Trials (2000–2024)

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Abstract

Background. Cold-water immersion (CWI) is a commonly used recovery strategy among athletes, but evidence of its effectiveness remains inconsistent due to variations in protocols and outcome measures.

Objectives. This systematic review aimed to evaluate the effects of CWI on post-exercise recovery in athletes, focusing on physiological, performance, and perceptual outcomes.

Materials and Methods. Following PRISMA guidelines and PROSPERO registration (CRD420251068097), four electronic databases (PubMed, Web of Science, Scopus, and ProQuest) were searched for randomized controlled trials (RCTs) published between 2000 and 2024. Studies were included if they achieved a PEDro score ≥ 6 . Twelve RCTs met the inclusion criteria. Data were synthesized narratively, supported by vote-counting and harvest plots, as heterogeneity prevented meta-analysis.

Results. CWI consistently reduced delayed-onset muscle soreness (DOMS) and muscle damage biomarkers (e.g., creatine kinase, lactate dehydrogenase) within 24–48 hours post-exercise. Several trials also reported improvements in subjective recovery. The effects on neuromuscular performance (e.g., sprinting, countermovement jump) were mixed and appeared context-dependent. Evidence regarding inflammatory markers (e.g., IL-6, CRP) was limited and inconclusive. Variability in water temperature, immersion duration, and timing contributed to inconsistent outcomes across studies.

Conclusions. The findings indicate that moderate-to-strong evidence supports the short-term use of CWI to reduce muscle soreness and damage, as well as to enhance perceptual recovery. The effects on performance and inflammation remain unclear, emphasizing the need for protocol standardization. CWI remains a practical tool for athletes, especially in high-load or congested schedules, but its application should be individualized.

Keywords: cold-water immersion, athletic recovery, muscle soreness, randomized controlled trials, exercise-induced muscle damage.

Introduction

Muscle recovery is a critical component of athletic training and performance maintenance. Intense or prolonged physical activity induces structural and metabolic stress in skeletal muscle, resulting in exercise-induced muscle damage (EIMD) (Mielgo-Ayuso & Fernández-

Lázaro, 2021). Common symptoms of EIMD include reduced muscular strength, stiffness, swelling, and delayed onset muscle soreness (DOMS), all of which can negatively impact subsequent performance if not adequately addressed (Peake et al., 2017). Efficient recovery is particularly essential in competitive sports settings, where athletes are often required to perform multiple bouts of high-intensity effort within limited recovery windows. Inadequate recovery has been associated with increased fatigue, elevated risk of injury, and impaired long-term performance adaptations

(Doherty et al., 2021; Kellmann et al., 2018). In contrast, the application of effective recovery strategies promotes the restoration of muscle function, reduces inflammation, replenishes energy stores, and enhances psychological readiness (Edholm et al., 2024a). Recovery is now widely recognized as an active phase of the training cycle, involving integrated physiological, biochemical, and psychological processes that aim to restore homeostasis and prepare the athlete for subsequent workloads (Rebello et al., 2025). Among the various recovery strategies studied in recent decades, cold-water immersion (CWI) has garnered substantial attention for its potential to alleviate DOMS and accelerate muscle recovery. CWI typically involves submerging the body or limbs in cold water (10°C–15°C) for 10–15 minutes following exercise. The proposed benefits of CWI include reduced muscle soreness, attenuated inflammation, and expedited return to baseline performance levels. Mechanistically, CWI is believed to act via peripheral vasoconstriction, reduced metabolic activity, hydrostatic pressure effects, and altered neuromuscular signalling, though these mechanisms remain incompletely understood (Algaflly & George, 2007; Peake et al., 2017). Several randomized controlled trials (RCTs) and meta-analyses have evaluated the efficacy of CWI for enhancing post-exercise recovery. A 2025 network meta-analysis concluded that medium-duration CWI at moderate temperatures (11°C–15°C) significantly reduced DOMS and improved markers of muscle function, such as jump performance (Wang et al., 2025). Similarly, Xiao et al. reported that immediate application of CWI following strenuous exercise resulted in reduced subjective fatigue and enhanced perceptual recovery (Xiao et al., 2023). Despite such findings, the literature remains inconclusive due to inconsistencies in CWI protocol parameters (e.g., temperature, immersion depth, duration), variation in study populations, and heterogeneity in outcome measures.

These methodological discrepancies hinder direct comparisons between studies and limit the generalizability of findings. Therefore, a systematic synthesis of high-quality evidence is warranted to clarify the role of CWI in post-exercise recovery. This systematic review aims to critically evaluate randomized controlled trials published between 2000 and 2024 that investigated the effects of cold-water immersion on post-exercise recovery outcomes. The review focuses on key domains such as muscle soreness, muscle function, biochemical markers of muscle damage, inflammation, fatigue, and overall athletic performance. The findings will help establish the current state of evidence, identify optimal CWI protocols, and provide evidence-based recommendations for practitioners in sports science and athletic rehabilitation.

Materials and Methods

Registration

The present systematic review was guided by the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement (Page et al., 2021) and registered in an international database of systematic reviews in health and social care (PROSPERO CRD420251068097).

Literature Search: Administration and Update

A systematic literature search was performed, and updated up to May 2025, in the electronic databases PubMed,

Web of Science, SCOPUS and ProQuest using the Boolean operators AND/OR, in combinations with the keywords: “muscle damage”, “muscle soreness”, “cold-water immersion”, “cooling intervention”, “cold exposure”, “rct”, “random”, “sport”, “athlete”, “player”, “muscle recovery”, “post-exercise recovery”. One author (RD) conducted the initial search and removed duplicates. Two authors (AS and SP) independently screened the titles, abstracts, and full-texts of the retrieved studies. The search results were then analysed according to the eligibility criteria (Table 1). A third author (RS) resolved potential disagreements between AS and SP.

Inclusion and Exclusion Criteria

Studies were selected based on predefined eligibility criteria using the PICOS framework (Participants, Interventions, Comparators, Outcomes, and Study Design) (Liberati et al., 2009). Only original, peer-reviewed, full-text articles published in English were considered for inclusion. Additional exclusion criteria are detailed in Supplementary File 1.

Table 1 Inclusion criteria according to the PICOS conditions

Items	Details Inclusion Criteria
Population	Athletes
Intervention	effects of recovery strategies, specifically cold-water immersion, Contrast water immersion on post-exercise recovery and performance.
Comparison	Two or more groups
Outcome	muscle recovery (e.g., markers of muscle damage, inflammation) and/or performance indicators (e.g., strength, power, endurance)
Study Design	randomised controlled trials (RCT)

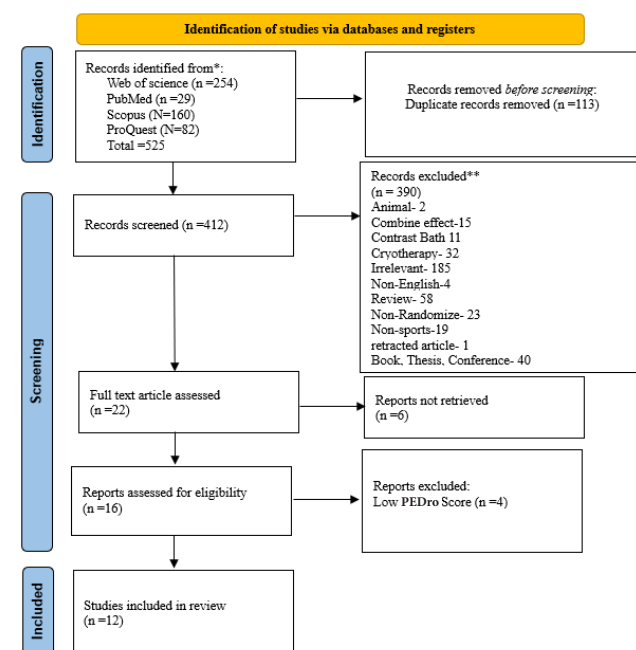


Fig. 1 PRISMA flow chart of the study selection process

Table 2. Characteristics of the studies examined in the present review

Author (Year)	Design	Participants	Intervention	Comparator	Outcomes Measured	Main Findings
(Micheletti et al., 2019)	RCT	64 male youth footballers (13–17 yrs)	CWI (13°C, 15 min)	Passive rest	Lactate, HRV, DOMS, MVIC, agility, sprint, recovery score	CWI improved lactate clearance and HRV; no significant effect on performance outcomes
(Leeder et al., 2019)	RCT	16 male athletes (rugby, hockey, football)	CWI post-tournament	Control	Sprint performance, soreness	CWI maintained sprint speed and reduced soreness at 24–48h
(Chow et al., 2018)	RCT	24 amateur rugby players	CWI (ice bath) vs room temp water	Room temp immersion (25°C)	Jump height, agility, pain threshold	Mixed results: improved jump recovery, no significant effect on agility
(Halson et al., 2014)	RCT	24 cyclists	CWI (15°C, 15 min) after training blocks	Control	Power output, CMJ, adaptation markers	No significant long-term benefit; acute power unchanged
(Parouty et al., 2010)	RCT	14 competitive swimmers	CWI (10°C, 15 min) post-sprint	Passive rest	100m freestyle time, HR, lactate, RPE	CWI improved 100m performance and reduced RPE/lactate
(Roonkiani et al., 2020)	RCT	20 young male soccer players	CWI (10°C, 15 min post-match)	Control	CK, LDH, muscle soreness	CWI reduced CK, LDH and soreness significantly at 24–48h
(Elias et al., 2013)	RCT	21 elite male footballers	CWI post-match (10°C for 10 min)	Passive recovery	CMJ, MVC, soreness, fatigue	CWI improved CMJ and soreness at 24–48h; faster neuromuscular recovery
(Ascensão et al., 2011)	RCT	20 junior soccer players (18.2 ± 1.3 yrs)	CWI at 10°C for 10 min post-match	Thermoneutral water immersion (35°C, 10 min)	CK, Myoglobin, CRP, DOMS (quad, calf, adductors), Strength, Jump, Sprint (0–20m)	CWI reduced CK and CRP at 24–48h; improved strength and reduced quadriceps and calf soreness at 24h
(Duñabeitia et al., 2022)	RCT	34 recreational runners	Massage + CWI	Control	Running economy, lower-limb biomechanics	CWI + massage preserved running economy; limited effects on biomechanics
(Leeder et al., 2015)	RCT	15 trained athletes	Seated vs standing CWI (10°C, 10 min)	Passive control	Sprint recovery, DOMS	Standing CWI more effective in reducing DOMS and improving sprint performance
(Barber et al., 2020)	RCT	20 male rugby players	Repeated CWI at 14°C for 15 min	Passive rest	CMJ, strength, RPE, DOMS, fatigue	Improved strength and power at 24–48h; reduced perceived fatigue
(Tavares et al., 2020)	RCT	12 highly trained volleyball athletes (age: 20.7 ± 2.6 years; all male)	12 min cold-water immersion (10°C) after each training session for 5 days	Passive recovery (rest in seated position)	CMJ height, muscle soreness, perceived recovery, muscle damage markers (CK), fatigue ratings, training loads	No significant group × time interaction for performance. CWI group had significantly lower soreness and fatigue during training week; no effect on CMJ or CK.
(Janusiak et al., 2025)	RCT	48 basketball players	Recovery including CWI	Active recovery	Pressure pain threshold	Significant improvement in pressure pain threshold post-intervention
(Stearns et al., 2018)	RCT	33 elite triathletes (22 males, 11 females); mean age 40 ± 11 years; participated in Ironman WC	10 min cold-water immersion (CWI) at 10°C immediately post-race	Passive rest (no CWI)	DOMS, CK, myoglobin, IL-6, CRP, cortisol, hydration (Usg, BML), Tgi	No significant group × time effects for any outcome. CWI did not enhance recovery of muscle damage or inflammation markers within 40 hrs post-race.
(Guo et al., 2022)	RCT	30 elite male race walkers (3 groups, n=10 each)	CWI: 10°C for 10 min daily post-training over 15 days	CWT and Control (stretching only)	IL-6, PGE2, RPE, Muscle soreness (VAS)	CWI reduced IL-6 and PGE2 vs CWT; no significant change in RPE or soreness
(Sánchez-Ureña et al., 2017)	RCT	10 male adolescent basketball players (14 ± 0.4 yrs)	Continuous CWI: 12 min at 12°C; Intermittent: 4×2 min + 1 min rest	Passive seated recovery (12 min)	Muscle soreness (VAS), CMJ, thigh muscle volume	Both CWI protocols reduced soreness and preserved CMJ; no volume change

Data Extraction

After the final inclusion, the following data were extracted from the articles: a) First author name and publication year; b) Study design; c) Types of athletes; d) Participants' characteristics age, sex, height, weight and sample size by group; e) Session; f) Duration; g) Type of exercise training; h) Characteristics of WCI (water temperature) ; i) Characteristics of control group intervention, and j) The main findings are related to predefined outcomes from the experimental and control groups, comparing each other. Data from the included studies were extracted independently by one reviewer (RD), who consulted with another reviewer (SP), and any discrepancies were resolved by a consensus by the third reviewer (RS). Then, the data were transferred to an Excel spreadsheet. This process follows Cochrane Consumer and Communication Review Group's standardised data extraction protocol (Prictor & Hill, 2013).

Study Selection

The study selection process was conducted in multiple stages. Initially, one reviewer (S.P.) performed the preliminary screening, during which duplicate records were removed using Zotero reference management software (Ivey & Crum, 2018). Titles and abstracts were then reviewed to identify studies that potentially met the predefined inclusion criteria focusing on cold water immersion and post-exercise recovery in athletes. In the next stage, the full texts of the shortlisted studies were independently assessed by two reviewers (S.P. and A.S.) to confirm eligibility. Any disagreements regarding study inclusion were resolved through discussion or consultation with a third reviewer (R.D.). Ultimately, twelve randomized controlled trials evaluating the effects of CWI on recovery outcomes in athletic populations were included in this systematic review.

Risk of Bias Assessment

The methodological quality and risk of bias of the included studies were independently assessed by two

reviewers (R.D. and A.C.) using the Physiotherapy Evidence Database (PEDro) scale, a valid and reliable tool (De Morton, 2009; Maher et al., 2003; Yamato et al., 2017), widely used in CWI research (Cain et al., 2025; Malta et al., 2021; Nye et al., 2016). Although referred to as a «methodological quality» scale, the PEDro scale primarily evaluates elements associated with the potential for bias in clinical trials. The overall risk of bias of studies was interpreted using the following convention (Cashin & McAuley, 2020) ≤ 3 points was considered as «poor» quality (i.e., high risk of bias), 4–5 points was considered as «moderate» quality, while 6–7 points and 8–10 points was considered as «good» and «excellent» quality, respectively. For practical purposes and given the nature of the research field, we considered studies with ≥ 6 points to have low risk of bias. Two authors (R.D. and A.C.) independently assessed risk of bias, and a third author (R.S.) helped to resolve discrepancies.

Results

A comprehensive search strategy was developed and tailored for each database to optimize both sensitivity and specificity. A total of 525 references were identified through the search. After the removal of 113 duplicate records, 412 unique articles remained. Titles and abstracts were screened, resulting in the exclusion of 383 records due to irrelevance, conference proceedings, or review articles. The remaining 24 full-text articles were assessed for eligibility.

Risk of Bias of the Included Studies

According to the PEDro checklist results (Table 3), the median (i.e., non-parametric) score was 6.0 (low risk of bias – good quality), with four studies (Guo et al., 2022; Janusiak et al., 2025; Micheletti et al., 2019; Sánchez-Ureña et al., 2017) attaining 4–5 points (some risk of bias – moderate quality), and 12 studies attaining 6 points (low risk of bias – good quality).

Table 3 Rating of studies according to the Physiotherapy Evidence Database (PEDro) scale

Study	1	2	3	4	5	6	7	8	9	10	11	Score
1 (Micheletti et al., 2019)	✓	✓	×	×	×	×	×	✓	✓	✓	✓	5
2 (Leeder et al., 2019)	×	✓	×	✓	×	×	×	✓	✓	✓	✓	6
3 (Chow et al., 2018)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	6
4 (Halson et al., 2014)	×	✓	×	✓	×	×	×	✓	✓	✓	✓	6
5 (Parouty et al., 2010)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	6
6 (Roonkiani et al., 2020)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	6
7 (Elias et al., 2013)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	6
8 (Ascensão et al., 2011)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	6
9 (Duñabeitia et al., 2022)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	6
10 (Leeder et al., 2015)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	6
11 (Barber et al., 2020)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	6
12 (Tavares et al., 2020)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	6
13 (Janusiak et al., 2025)	✓	✓	×	✓	×	×	×	✓	×	✓	✓	5
14 (Stearns et al., 2018)	✓	✓	×	✓	×	×	×	✓	✓	✓	✓	6
15 (Guo et al., 2022)	×	✓	×	×	×	×	×	✓	×	✓	✓	4
16 (Sánchez-Ureña et al., 2017)	✓	✓	×	✓	×	×	×	✓	×	✓	✓	5

Participant Characteristics and Intervention Overview

The characteristics of the participants and the cold-water immersion (CWI) interventions from the included studies are summarised in Table 3. A total of 12 studies involving 301 competitive athletes (261 males and 40 females) were analysed. Participants were drawn from a variety of sports disciplines, including football $n = 3$; (Ascensão et al., 2011; Elias et al., 2013; Roonkiani et al., 2020), team sports combining rugby, football, and hockey $n = 2$; (Leeder et al., 2015, 2019), swimming $n = 1$; (Parouty et al., 2010), cycling $n = 1$; (Halsen et al., 2014), rugby $n = 3$; (Barber et al., 2020; Chow et al., 2018), running $n = 1$; (Duñabeitia et al., 2022), triathlon $n = 1$; (Stearns et al., 2018), and volleyball $n = 1$; (Tavares et al., 2020). Participant ages ranged from approximately 18 to 41 years, with most studies focusing on young adult athletes (18–22 years). Endurance-based cohorts such as triathletes and runners included older individuals (mean ages ~36–41 years). Anthropometric characteristics were generally homogenous within studies, with reported body mass spanning 62–86 kg and height between 168–188 cm. Female athletes were underrepresented and were included in studies involving rugby, swimming, and triathlon. All included participants were reported as well-trained or elite-level athletes. Cold-water immersion was the primary intervention across all studies, with variations in protocol duration, frequency, and water temperature. Control groups typically received either passive rest or alternative recovery modalities such as massage or contrast water therapy. The consistent application of structured recovery interventions across diverse athletic populations enhances the comparability and relevance of findings for performance recovery research.

Interventions Characteristics

The CWI protocols employed across the 12 included studies demonstrated considerable consistency in certain parameters while also exhibiting methodological diversity reflective of practical applications in sport recovery. Water temperatures used for CWI ranged from as low as 5 °C to approximately 15 °C, with the majority of studies utilizing temperatures between 10 °C and 14 °C to induce the intended physiological cooling effects. Immersion durations typically spanned 10 to 15 minutes, although shorter exposure (e.g., 1-minute immersion at 5 °C) and intermittent protocols (e.g., two 5-minute immersions separated by rest) were also reported. The depth of immersion was generally standardized to include the lower limbs up to the level of the iliac crest or hips, and athletes were commonly positioned in a seated posture within temperature-controlled water baths. One study directly compared seated versus standing CWI and reported significantly different hydrostatic pressures at the ankle, highlighting the influence of posture on immersion efficacy. Timing of the intervention was also a critical parameter, with all studies initiating CWI either immediately or within 30 minutes following physical exertion, aligning with recommendations for post-exercise recovery. Control conditions varied across studies and included passive rest at ambient room temperature (approximately 20–28 °C), thermoneutral water immersion (25–35 °C), or no treatment. Additionally, some studies included alternative

recovery modalities for comparison, such as contrast water therapy – where participants alternated between hot (38 °C) and cold (12 °C) immersion cycles—and therapeutic massage involving standard friction and pressure techniques applied by trained professionals. These variations reflect the comparative interest in evaluating the relative benefits of CWI versus other commonly used post-exercise recovery strategies. Overall, while the core features of CWI – cold temperature, post-exercise timing, and immersion of the lower limbs – were consistently applied, the specific designs, durations, and supplementary interventions differed across studies. Such heterogeneity in protocols should be carefully considered when interpreting pooled outcomes or assessing the generalizability of findings within athletic populations.

Outcome Measures

The results of the included studies were categorized based on the effects of CWI on various components of physical performance and recovery in athletes. Outcome measures were grouped according to specific fitness or physiological parameters assessed across the studies, such as muscle soreness, strength recovery, inflammatory markers, and performance metrics. All included articles were independently classified by the review authors based on their primary outcome domains. Any discrepancies in classification were resolved through discussion until consensus was achieved. A summary of the studies along with their predefined outcome measures is presented in Table 4.

Effects of Cold-Water Immersion on Recovery Outcomes

Muscle soreness: Several studies have reported significant reductions in delayed-onset muscle soreness (DOMS) following cold-water immersion (CWI) compared to passive recovery or alternative modalities. For example, one trial found that a 14-min immersion in ~14°C water immediately after match-play significantly attenuated perceived soreness at 48 h relative to contrast-water therapy or passive rest (ES ≈ 0.59). Similarly, a soccer study reported that a single 10-min CWI at 10°C after a competitive match significantly lowered soreness in the quadriceps and calf at 24 h, a reduction interpreted by the authors as reflecting accelerated neuromuscular recovery. In a simulated rugby match protocol, two 5-min immersions at 10°C (with a short intermission) likewise yielded markedly lower soreness scores at 24 and 48 h (large effect sizes) compared to a non-immersed control, indicating a pronounced analgesic effect. By contrast, another investigation found no overall soreness difference between CWI and control, but observed that DOMS at 48 h was significantly lower when immersion was performed in a seated versus standing posture ($p = .001$, ES = 1.86), suggesting that hydrostatic pressure may influence recovery. Collectively, these findings support the efficacy of post-exercise CWI in attenuating DOMS, especially during the 24–48 h window following high-intensity or competitive exercise (Ascensão et al., 2011; Barber et al., 2020; Elias et al., 2013; Leeder et al., 2015).

Muscle damage markers: Several studies have evaluated the effect of cold-water immersion (CWI) on markers of muscle damage following simulated sports protocols. Across

Table 4 Research Output

Study	N	Sport	MS	MD	IM	STR	PERF	SUBJ	POW
(Leeder et al., 2019)	21	Team sports	0	+	+	0	+	0	0
(Chow et al., 2018)	18	Rugby	0	0	0	-	0	0	0
(Halsen et al., 2014)	21	Cycling	0	0	0	0	+	-	+
(Parouty et al., 2010)	10	Swimming	0	0	0	0	-	0	0
(Roonkiani et al., 2020)	20	Athletes	0	+	0	0	0	0	0
(Elias et al., 2013)	16	Soccer	+	0	0	0	+	+	+
(Ascensão et al., 2011)	21	Team sports	+	0	0	0	0	+	0
(Duñabeitia et al., 2022)	20	Running	0	0	0	0	0	+	0
(Leeder et al., 2015)	21	Team sports	+	0	0	0	0	+	0
(Barber et al., 2020)	16	Rugby	+	+	0	+	0	0	+
(Tavares et al., 2020)	13	Volleyball	0	0	0	0	0	0	0
(Stearns et al., 2018)	33	Triathlon	0	0	0	0	0	0	0

MS = Muscle Soreness, MD = Muscle Damage Markers, IM = Inflammatory Markers, STR = Strength, PERF = Performance, SUBJ = Subjective Recovery or Fatigue, POW = Jump or Power Performance. '+' indicates a significant beneficial effect of CWI, '-' indicates a significant detrimental effect, '0' indicates no significant difference.

these investigations, creatine kinase (CK) consistently emerged as a key biomarker of muscle membrane disruption. In a simulated tournament scenario, CK levels significantly increased following each bout of exercise, with progressive accumulation across three sessions ($p < .001$). However, participants in the CWI group demonstrated significantly lower CK concentrations before ($p = .004$) and after ($p = .001$) the final bout compared to controls, though this effect did not persist at 24 hours post-exercise, suggesting transient protective effects. Interleukin-6 (IL-6) levels were acutely elevated post-exercise ($p < .001$) but were significantly lower in the CWI group after the first ($p = .003$) and third bouts ($p = .038$), indicating an acute anti-inflammatory effect, while C-reactive protein (CRP) also increased over time ($p < .05$), yet no between-group differences were observed at 24 hours, suggesting minimal influence of CWI on prolonged systemic inflammation (Leeder et al., 2019). Similarly, in a soccer-specific study, significant group \times time interactions were found for CK ($F(4,64) = 6.64$, $p = .0012$, $\eta^2 = 0.293$) and lactate dehydrogenase (LDH) ($F(4,64) = 2.86$, $p = .0471$, $\eta^2 = 0.152$), with the CWI group exhibiting significantly lower levels of CK at 24 ($p = .031$) and 48 hours ($p = .045$), and reduced LDH at 24 hours ($p = .015$), confirming the muscle-protective effects of CWI in prolonged intermittent exercise (Roonkiani et al., 2020). In another investigation involving a simulated rugby protocol, repeated CWI (2×5 min at 10°C) led to large reductions in CK concentrations at 24 hours ($d = -2.63$) and 48 hours ($d = -2.20$), compared to the control group, indicating substantial attenuation of muscle damage (Barber et al., 2020). Collectively, these findings suggest that CWI is effective in blunting post-exercise elevations in CK and IL-6, with more modest or inconsistent effects on systemic inflammatory markers such as CRP and LDH, particularly within the initial 48-hour recovery window.

Inflammatory Markers: Among the twelve studies included in this review, only one study Leeder and his colleagues evaluated the effect of CWI on inflammatory markers. This study assessed interleukin-6 (IL-6) and C-reactive protein

(CRP) as indicators of systemic inflammation following repeated sprint exercise. While both IL-6 and CRP levels increased post-exercise, reflecting a typical inflammatory response to high-intensity physical exertion, the application of CWI did not significantly attenuate these elevations compared to the control condition. These findings suggest that, within the context of repeated sprint activity, CWI may have a limited influence on modulating acute inflammatory responses. Therefore, evidence for the anti-inflammatory effects of CWI remains inconclusive and warrants further investigation in future research (Leeder et al., 2019).

Performance outcomes: Performance outcomes across the included studies were assessed through various metrics such as sprint speed, countermovement jump (CMJ), maximal voluntary contraction (MVC), repeated time-trial efforts, and agility-based tasks. The findings revealed mixed effects of CWI on performance, with variations depending on the type of activity, measurement timing, and athletic context. Leeder et al. reported a significant group \times time interaction in sprint speed at 24 hours following repeated intermittent running (LIST protocol), with the CWI group maintaining sprint performance while the control group exhibited a decline ($p = .034$; $ES = 0.83 \pm 0.59$). In contrast, CMJ and MVC demonstrated only trivial, non-significant reductions in both groups, suggesting that CWI did not substantially influence neuromuscular recovery in terms of power or strength capacity (Leeder et al., 2019). In a longitudinal training context, researcher found that CWI during a simulated cycling Grand Tour enhanced performance in short, high-intensity efforts. The CWI group showed likely beneficial improvements in 1-second peak power ($+4.4\% \pm 4.2\%$) and repeat maximal 4-minute cycling bouts ($+3.0\% \pm 3.8\%$), without hindering adaptation to longer-duration efforts such as the 10-minute time trial. These findings support the role of CWI in preserving or enhancing repeated power output under heavy training loads (Halsen et al., 2014). Conversely, a group of authors observed a performance decrement in well-trained swimmers following CWI. Athletes recorded significantly slower 100-meter sprint

times after CWI (65.6 ± 3.4 s) compared to passive recovery (64.2 ± 3.5 s; $p < .05$), despite perceiving better recovery. This suggests that CWI may impair short-term explosive performance, potentially due to residual cooling effects affecting neuromuscular contractility (Parouty et al., 2010). A team of researchers investigated performance in elite footballer's post-match and found no statistically significant benefits of CWI on sprint (10 m and 20 m), agility (505 test), or CMJ. However, CMJ height was better maintained in the CWI group relative to the control group, implying a possible neuromuscular preservation effect, although between-group differences were not significant (Elias et al., 2013). Overall, the evidence indicates that CWI may offer selective benefits for performance recovery, particularly for short-duration, high-intensity efforts. However, its effects on explosive or agility-based performance are less consistent, and in some cases, may even be detrimental if applied prior to competition. These variations likely reflect differences in protocol, sport specificity, and physiological demands.

Strength recovery: Two randomized controlled trials investigated the effects of cold-water immersion (CWI) on strength recovery following exercise-induced muscle damage, with contrasting outcomes influenced by differences in protocol. Chow et al. examined the acute effects of a single brief immersion at 5°C and found a significant reduction in isokinetic peak torque of the knee extensors (-8.15% , $p = .018$) and countermovement jump (CMJ) height (-3.23% , $p = .030$) post-intervention, indicating impaired muscular strength and explosive power (Chow et al., 2018). In contrast, researchers employed a repeated immersion protocol (2×5 min at 10°C) and reported enhanced recovery of maximal voluntary isometric contraction (MVIC), with strength returning to baseline by 48 hours post-exercise (100.4% in the CWI group vs. 85.8% in control) (Barber et al., 2020). These findings suggest that while very cold, short-duration CWI may negatively affect immediate strength performance, repeated immersion at moderate temperatures is more effective in promoting strength recovery during the post-exercise period.

Subjective recovery/fatigue: Cold-water immersion (CWI) appears to be an effective strategy for improving subjective recovery and reducing fatigue in athletes following intense training or competition. Multiple studies have reported that CWI significantly enhances perceived recovery and reduces fatigue-related symptoms. Athletes who underwent CWI interventions (typically 10 minutes at 10°C) consistently reported better recovery perceptions at 24–48 hours post-exercise compared to control groups, as evidenced in studies involving footballers (Ascensão et al., 2011; Elias et al., 2013), endurance runners (Duñabeitia et al., 2022), and team sport athletes (Leeder et al., 2015). These benefits were reflected through higher perceived recovery scores, lower ratings of fatigue, and reduced delayed onset muscle soreness (DOMS) using tools such as Likert scales, visual analogue scales, and RPE. However, findings by Halson et al. suggest that while CWI may offer short-term perceptual benefits during periods of intensified training, it might have detrimental effects on recovery perception during taper phases (Halson et al., 2014). Overall, the evidence supports CWI as a beneficial recovery modality for improving subjective outcomes in the short term, particularly during high training loads or competitive periods.

Power Performance: Cold-water immersion (CWI) has shown mixed effects on power performance outcomes, with evidence suggesting that its efficacy may depend on the training context and recovery timeline. Several studies report positive effects of CWI on restoring lower-limb power, particularly as measured by countermovement jump (CMJ) height and maximal voluntary isometric contraction (MVIC). In elite footballers and rugby athletes, CWI was effective in attenuating post-exercise declines in CMJ performance and promoting faster recovery of muscle strength within 24–48 hours (Barber et al., 2020; Elias et al., 2013). Barber et al. further demonstrated that repeated CWI sessions significantly restored both CMJ and MVIC values to baseline levels, with large effect sizes supporting its utility in high-impact team sports. Conversely, Halson et al. found no significant benefit of CWI in preserving CMJ performance during prolonged intensified training or taper phases in competitive cyclists, indicating that CWI may be less effective in mitigating chronic training-induced power loss (Halson et al., 2014). Overall, CWI appears to be beneficial for short-term recovery of explosive power following acute bouts of strenuous activity, especially in collision-based or intermittent sports.

Summary of inconsistencies: Across domains, findings were not uniform. Variability likely reflects differing protocols and exercise types. Notably, one study using very cold water (5°C) found some negative outcomes (Chow et al.), whereas studies with milder temperatures (~ 10 – 12 °C) more often saw benefits. The frequency and timing of immersion (single post-event vs repeated daily exposures) and the nature of the exercise (contact sports vs endurance events) also varied widely among trials. These factors may explain why some studies observed no effect or even slight impairments with CWI, despite a general pattern of reduced soreness, lower damage markers, and faster subjective recovery. Overall, while most evidence favors a beneficial role of CWI for soreness, muscle damage, and some performance and strength outcomes, the magnitude of benefit appears context-dependent.

Discussion

Summary of Key Findings: This systematic review examined the effects of CWI on post-exercise recovery in athletes, synthesizing evidence from 12 randomized controlled trials involving 301 participants from various sporting disciplines. The analysis revealed that CWI consistently reduces delayed-onset muscle soreness (DOMS) within the first 24–48 hours following intense exercise. Reductions in muscle damage biomarkers, particularly CK and lactate dehydrogenase (LDH), were also frequently reported, suggesting CWI's protective effects on muscle integrity. Improvements in subjective recovery metrics such as perceived fatigue and recovery ratings were observed across multiple trials. However, the effects of CWI on neuromuscular performance outcomes, including sprinting, jumping, and maximal voluntary contraction, were heterogeneous and context-dependent. Limited evidence was available on systemic inflammatory markers, restricting conclusions in this domain.

Comparison with Existing Literature: The findings of the present review align with existing literature that highlights

the short-term benefits of CWI in attenuating post-exercise soreness and muscle damage. Meta-analyses by (Dupuy et al., 2018; Machado et al., 2016; Wang et al., 2025) support the analgesic and biochemical benefits of CWI, particularly when immersion is conducted shortly after exercise using water temperatures between 10–15 °C for 10–15 minutes. Similarly, recent systematic reviews have indicated moderate-to-large effect sizes for CWI in reducing DOMS and CK concentrations (Hohenauer et al., 2015; Poppendieck et al., 2013). However, the literature presents divergent findings on performance outcomes. While some trials have reported improved or preserved sprint performance and explosive power following CWI (Elias et al., 2013; Leeder et al., 2019), others have documented either no change or performance decrements, especially with very cold immersion (<6°C) or when applied before competition (Halson et al., 2014; Parouty et al., 2010). These inconsistencies are also reflected in prior reviews (Croft et al., 2012; White et al., 2014), emphasizing the importance of protocol specificity, sport context, and timing relative to the performance task.

Mechanistic Explanations: The observed effects of CWI can be explained by several interrelated physiological mechanisms. Cold exposure leads to peripheral vasoconstriction, which reduces local blood flow, limiting edema formation and the infiltration of inflammatory cells (Peake et al., 2016; Wilcock et al., 2006). Hydrostatic pressure exerted during immersion enhances venous return and lymphatic drainage, contributing to the clearance of metabolic byproducts (Xiao et al., 2023). Additionally, reduced tissue temperature slows metabolic activity, decreases nerve conduction velocity, and dampens nociceptor sensitivity—thereby producing analgesic effects and improving perceived recovery (Algaflly & George, 2007; White et al., 2014). On the molecular level, CWI may modulate the expression of heat shock proteins, pro-inflammatory cytokines (e.g., IL-6), and oxidative stress markers, although these effects appear to be transient and vary across individuals and exercise types (Howatson & Van Someren, 2008). Conversely, the application of CWI at excessively low temperatures or for prolonged durations may impair muscle contractility by decreasing excitation-contraction coupling efficiency and enzymatic function, potentially explaining the short-term performance decrements observed in some trials (Pointon & Duffield, 2012; Vaile et al., 2008).

Clinical and Practical Implications: These findings carry significant implications for coaches, athletes, and sports medicine professionals. CWI appears to be a valuable recovery tool for mitigating muscle soreness, minimizing muscle damage, and improving perceptual recovery following high-intensity or collision-based sports. It is particularly useful during congested competition schedules, where rapid recovery is essential. However, CWI should be applied with caution prior to performance tasks requiring maximal neuromuscular output due to potential residual cooling effects. Protocols should be tailored to individual needs, considering sport type, recovery window, and immersion parameters. Integrating CWI with other modalities—such as sleep hygiene, nutrition, and compression—may optimize recovery outcomes (Edholm et al., 2024b; Kellmann et al., 2018).

Strengths and Limitations: This review presents several methodological strengths. A comprehensive search strategy,

use of standardized data extraction (Cochrane protocol), and rigorous quality assessment using the PEDro scale (with most studies scoring ≥ 6) enhance the internal validity of the findings. The focus on randomized controlled trials strengthens causal inference. However, limitations should be noted. Considerable heterogeneity in CWI protocols—such as immersion temperature, duration, and timing—complicates cross-study comparisons. Most participants were young, male, well-trained athletes, limiting generalizability to other populations such as females, adolescents, or recreational athletes. Furthermore, small sample sizes, lack of blinding, and limited long-term follow-up in most trials restrict the external validity and clinical applicability of findings. Publication bias could not be ruled out due to the absence of formal funnel plot analysis.

Recommendations for Future Research: Future studies should aim to standardize CWI protocols by systematically varying immersion parameters to determine optimal dosing strategies for different sports and recovery timelines. Research involving female athletes, older populations, and underrepresented sports (e.g., endurance disciplines) is warranted to enhance generalizability. Further exploration of the molecular and systemic effects of CWI—particularly its influence on cytokine profiles, oxidative stress markers, and long-term adaptations—would clarify the underlying mechanisms. High-powered, multi-centre trials with adequate follow-up are needed to evaluate the chronic effects of CWI on performance, recovery kinetics, injury risk, and training adaptation.

Conclusion

This systematic review provides moderate-to-strong evidence supporting the short-term efficacy of cold-water immersion (CWI) as a post-exercise recovery strategy. CWI was consistently effective in attenuating delayed-onset muscle soreness and reducing biochemical markers of muscle damage, particularly creatine kinase, within 24 to 48 hours post-exercise. Improvements in subjective recovery ratings further reinforce its practical utility in high-performance and competitive sport settings. However, the effects on neuromuscular performance outcomes such as sprint speed, countermovement jump, and maximal strength were variable and context-dependent. Similarly, evidence on inflammatory markers remains limited and inconclusive. The therapeutic benefit of CWI appears to be influenced by protocol characteristics, including water temperature, immersion duration, and timing of application. Therefore, individualized application based on sport demands, athlete characteristics, and recovery objectives is recommended. Given the heterogeneity in study designs and underrepresentation of female and recreational athletes, further high-quality randomized controlled trials with standardized protocols are warranted. Long-term studies investigating the chronic effects of CWI on training adaptation, performance, and injury prevention are also necessary to optimize its role in sports recovery frameworks.

Key Points

- Cold-water immersion (CWI) consistently reduces delayed-onset muscle soreness (DOMS) and muscle

damage markers (e.g., creatine kinase, LDH) within 24–48 hours post-exercise.

- Subjective recovery (fatigue, perceived recovery) is frequently improved with CWI, supporting its practical use in competitive and high-load athletic contexts.
- Effects on neuromuscular performance (sprint, jump, strength) are variable, showing benefits in some settings but neutral or even negative outcomes in others.
- Evidence on inflammatory markers remains limited and inconclusive, highlighting the need for further research.
- Protocol standardization (temperature, duration, timing) is crucial, as heterogeneous methods contribute to inconsistent findings.

Conflict of Interest

The authors declare that there is no conflict of interest

References

- Mielgo-Ayuso, J., & Fernández-Lázaro, D. (2021). Nutrition and Muscle Recovery. *Nutrients*, 13(2), 294. <https://doi.org/10.3390/nu13020294>
- Peake, J.M., Neubauer, O., Della Gatta, P.A., & Nosaka, K. (2017). Muscle damage and inflammation during recovery from exercise. *Journal of Applied Physiology*, 122(3), 559–570. <https://doi.org/10.1152/jappphysiol.00971.2016>
- Doherty, R., Madigan, S.M., Nevill, A., Warrington, G., & Ellis, J.G. (2021). The Sleep and Recovery Practices of Athletes. *Nutrients*, 13(4), 1330. <https://doi.org/10.3390/nu13041330>
- Kellmann, M., Bertollo, M., Bosquet, L., Brink, M., Coutts, A.J., Duffield, R., Erlacher, D., Halson, S.L., Hecksteden, A., Heidari, J., Kallus, K.W., Meeusen, R., Mujika, I., Robazza, C., Skorski, S., Venter, R., & Beckmann, J. (2018). Recovery and Performance in Sport: Consensus Statement. *International Journal of Sports Physiology and Performance*, 13(2), 240–245. <https://doi.org/10.1123/ijspp.2017-0759>
- Edholm, P., Ørtenblad, N., Holmberg, H.-C., & Sperlich, B. (2024a). Optimizing recovery strategies for winter athletes: Insights for Milano-Cortina 2026 Olympic Games. *Sport Sciences for Health*, 20(4), 1169–1182. <https://doi.org/10.1007/s11332-024-01245-1>
- Rebelo, A., Pereira, J.R., Broek, G.V., Coelho-e-Silva, M.J., Elferink-Gemser, M.T., & Valente-dos-Santos, J. (2025). Optimizing recovery: The impact of training load in elite volleyball players. *International Journal of Sports Medicine*, 46(05), 356–365. <https://doi.org/10.1055/a-2519-9330>
- Algaflly, A.A., & George, K.P. (2007). The effect of cryotherapy on nerve conduction velocity, pain threshold and pain tolerance. *British Journal of Sports Medicine*, 41(6), 365–369. <https://doi.org/10.1136/bjism.2006.031237>
- Wang, H., Wang, L., & Pan, Y. (2025). Impact of different doses of cold water immersion (duration and temperature variations) on recovery from acute exercise-induced muscle damage: A network meta-analysis. *Frontiers in Physiology*, 16, 1525726. <https://doi.org/10.3389/fphys.2025.1525726>
- Xiao, F., Kabachkova, A.V., Jiao, L., Zhao, H., & Kapilevich, L.V. (2023). Effects of cold water immersion after exercise on fatigue recovery and exercise performance-Meta analysis. *Frontiers in Physiology*, 14. <https://doi.org/10.3389/fphys.2023.1006512>
- Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, n71. <https://doi.org/10.1136/bmj.n71>
- Liberati, A., Altman, D.G., Tetzlaff, J., Mulrow, C., Gotzsche, P.C., Ioannidis, J.P. A., Clarke, M., Devereaux, P.J., Kleijnen, J., & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: Explanation and elaboration. *BMJ*, 339(jul21 1), b2700–b2700. <https://doi.org/10.1136/bmj.b2700>
- Pictor, M., & Hill, S. (2013). Cochrane Consumers and Communication Review Group: Leading the field on health communication evidence. *Journal of Evidence-Based Medicine*, 6(4), 216–220. <https://doi.org/10.1111/jebm.12066>
- Ivey, C., & Crum, J. (2018). Choosing the right citation management tool: EndNote, Mendeley, RefWorks, or Zotero. *Journal of the Medical Library Association*, 106(3). <https://doi.org/10.5195/jmla.2018.468>
- Micheletti, J., Vanderlei, F., Machado, A., de Almeida, A., Nakamura, F., Netto, J., & Pastre, C. (2019). A New Mathematical Approach to Explore the Post-exercise Recovery Process and Its Applicability in a Cold Water Immersion Protocol. *Journal Of Strength And Conditioning Research*, 33(5), 1266–1275. <https://doi.org/10.1519/JSC.0000000000003041>
- Leeder, J., Godfrey, M., Gibbon, D., Gaze, D., Davison, G., van Someren, K., & Howatson, G. (2019). Cold water immersion improves recovery of sprint speed following a simulated tournament. *European Journal Of Sport Science*, 19(9), 1166–1174. <https://doi.org/10.1080/17461391.2019.1585478>
- Chow, G., Chung, J., & Fong, S. (2018). Differential effects of post-exercise ice water immersion and room temperature water immersion on muscular performance, vertical jump, and agility in amateur rugby players: A randomized controlled trial. *Science & Sports*, 33(6), E271–E279. <https://doi.org/10.1016/j.scispo.2018.04.005>
- Halson, S., Bartram, J., West, N., Stephens, J., Argus, C., Driller, M., Sargent, C., Lastella, M., Hopkins, W., & Martin, D. (2014). Does Hydrotherapy Help or Hinder Adaptation to Training in Competitive Cyclists? *Medicine And Science In Sports And Exercise*, 46(8), 1631–1639. <https://doi.org/10.1249/MSS.0000000000000268>
- Parouty, J., Al Haddad, H., Quod, M., Leprêtre, P., Ahmaidi, S., & Buchheit, M. (2010). Effect of cold water immersion on 100-m sprint performance in well-trained swimmers. *European Journal Of Applied Physiology*, 109(3), 483–490. <https://doi.org/10.1007/s00421-010-1381-2>
- Roonkiani, S., Ebrahimi, M., & Majelan, A. (2020). Effect of cold water immersion on muscle damage indexes after simulated soccer training in young soccer players. *Biomedical Human Kinetics*, 12(1), 236–241. <https://doi.org/10.2478/bhk-2020-0030>
- Elias, G.P., Wyckelsma, V.L., Varley, M.C., McKenna, M.J., & Aughey, R.J. (2013). Effectiveness of water

- immersion on postmatch recovery in elite professional footballers. *International Journal of Sports Physiology and Performance*, 8(3), 243-253. Scopus. <https://doi.org/10.1123/ijpspp.8.3.243>
- Ascensão, A., Leite, M., Rebelo, A.N., Magalhães, S., & Magalhães, J. (2011). Effects of cold water immersion on the recovery of physical performance and muscle damage following a one-off soccer match. *Journal of Sports Sciences*, 29(3), 217-225. <https://doi.org/10.1080/02640414.2010.526132>
- Duñabeitia, I., Arrieta, H., Rodriguez-Larrad, A., Gil, J., Esain, I., Gil, S., Irazusta, J., & Bidaurrazaga-Letona, I. (2022). Effects of Massage and Cold Water Immersion After an Exhaustive Run on Running Economy and Biomechanics: A Randomized Controlled Trial. *Journal Of Strength And Conditioning Research*, 36(1), 149-155. <https://doi.org/10.1519/JSC.0000000000003395>
- Leeder, J., Van Someren, K., Bell, P., Spence, J., Jewell, A., Gaze, D., & Howatson, G. (2015). Effects of seated and standing cold water immersion on recovery from repeated sprinting. *Journal Of Sports Sciences*, 33(15), 1544-1552. <https://doi.org/10.1080/02640414.2014.996914>
- Barber, S., Pattison, J., Brown, F., & Hill, J. (2020). Efficacy Of Repeated Cold Water Immersion On Recovery After A Simulated Rugby Union Protocol. *Journal Of Strength And Conditioning Research*, 34(12), 3523-3529. <https://doi.org/10.1519/JSC.0000000000002239>
- Tavares, F., Simoes, M., Matos, B., Smith, T., & Driller, M. (2020). The Acute and Longer-Term Effects of Cold Water Immersion in Highly-Trained Volleyball Athletes During an Intense Training Block. *Frontiers In Sports And Active Living*, 2. <https://doi.org/10.3389/fspor.2020.568420>
- Janusiak, M., Rui Miguel da Silva, Francisco Tomás González Fernández, Smoter, M., Kisilewicz, A., & Klich, S. (2025). Eficacia de estrategias de recuperación en umbrales de presión del dolor en jugadores de baloncesto. *Retos*, 65, 569-578. <https://doi.org/10.47197/retos.v65.110201>
- Stearns, R., Nolan, J., Huggins, R., Maresh, C., Munoz, C., Pagnotta, K., Volk, B., & Casa, D. (2018). Influence of cold-water immersion on recovery of elite triathletes following the ironman world championship. *Journal Of Science And Medicine In Sport*, 21(8), 846-851. <https://doi.org/10.1016/j.jsams.2017.12.011>
- Guo, C., Fan, Y., Kong, X., & Zhao, C. (2022). The effect of different water immersion strategies on delayed onset muscle soreness and inflammation in elite race walker. *Journal Of Mens Health*, 18(3). <https://doi.org/10.31083/j.jomh1803064>
- Sánchez-Ureña, B., Martínez-Guardado, I., Crespo, C., Timón, R., Calleja-González, J., Ibañez, S., & Olcina, G. (2017). The use of continuous vs. Intermittent cold water immersion as a recovery method in basketball players after training: A randomized controlled trial. *Physician And Sportsmedicine*, 45(2), 134-139. <https://doi.org/10.1080/00913847.2017.1292832>
- De Morton, N.A. (2009). The PEDro scale is a valid measure of the methodological quality of clinical trials: A demographic study. *Australian Journal of Physiotherapy*, 55(2), 129-133. [https://doi.org/10.1016/S0004-9514\(09\)70043-1](https://doi.org/10.1016/S0004-9514(09)70043-1)
- Maher, C.G., Sherrington, C., Herbert, R.D., Moseley, A.M., & Elkins, M. (2003). Reliability of the PEDro scale for rating quality of randomized controlled trials. *Physical Therapy*, 83(8), 713-721.
- Yamato, T.P., Maher, C., Koes, B., & Moseley, A. (2017). The PEDro scale had acceptably high convergent validity, construct validity, and interrater reliability in evaluating methodological quality of pharmaceutical trials. *Journal of Clinical Epidemiology*, 86, 176-181. <https://doi.org/10.1016/j.jclinepi.2017.03.002>
- Cain, T., Brinsley, J., Bennett, H., Nelson, M., Maher, C., & Singh, B. (2025). Effects of cold-water immersion on health and wellbeing: A systematic review and meta-analysis. *PLOS ONE*, 20(1), e0317615. <https://doi.org/10.1371/journal.pone.0317615>
- Malta, E.S., Dutra, Y.M., Broatch, J.R., Bishop, D.J., & Zagatto, A.M. (2021). The Effects of Regular Cold-Water Immersion Use on Training-Induced Changes in Strength and Endurance Performance: A Systematic Review with Meta-Analysis. *Sports Medicine*, 51(1), 161-174. <https://doi.org/10.1007/s40279-020-01362-0>
- Nye, E.A., Edler, J.R., Eberman, L.E., & Games, K.E. (2016). Optimizing Cold-Water Immersion for Exercise-Induced Hyperthermia: An Evidence-Based Paper. *Journal of Athletic Training*, 51(6), 500-501. <https://doi.org/10.4085/1062-6050-51.9.04>
- Cashin, A.G., & McAuley, J.H. (2020). Clinimetrics: Physiotherapy Evidence Database (PEDro) Scale. *Journal of Physiotherapy*, 66(1), 59. <https://doi.org/10.1016/j.jphys.2019.08.005>
- Dupuy, O., Douzi, W., Theurot, D., Bosquet, L., & Dugué, B. (2018). An Evidence-Based Approach for Choosing Post-exercise Recovery Techniques to Reduce Markers of Muscle Damage, Soreness, Fatigue, and Inflammation: A Systematic Review With Meta-Analysis. *Frontiers in Physiology*, 9, 403. <https://doi.org/10.3389/fphys.2018.00403>
- Machado, A.F., Ferreira, P.H., Micheletti, J.K., De Almeida, A.C., Lemes, Í.R., Vanderlei, F.M., Netto Junior, J., & Pastre, C.M. (2016). Can Water Temperature and Immersion Time Influence the Effect of Cold Water Immersion on Muscle Soreness? A Systematic Review and Meta-Analysis. *Sports Medicine*, 46(4), 503-514. <https://doi.org/10.1007/s40279-015-0431-7>
- Hohenauer, E., Taeymans, J., Baeyens, J.-P., Clarys, P., & Clijsen, R. (2015). The Effect of Post-Exercise Cryotherapy on Recovery Characteristics: A Systematic Review and Meta-Analysis. *PLOS ONE*, 10(9), e0139028. <https://doi.org/10.1371/journal.pone.0139028>
- Poppendieck, W., Faude, O., Wegmann, M., & Meyer, T. (2013). Cooling and Performance Recovery of Trained Athletes: A Meta-Analytical Review. *International Journal Of Sports Physiology And Performance*, 8(3), 227-242. <https://doi.org/10.1123/ijpspp.8.3.227>
- Croft, M., Keely, B., Morris, I., Tann, L., & Lappin, G. (2012). Predicting Drug Candidate Victims of Drug-Drug Interactions, using Microdosing. *Clinical Pharmacokinetics*, 51(4), 237-246. <https://doi.org/10.2165/11597070-000000000-00000>
- White, G.E., Rhind, S.G., & Wells, G.D. (2014). The effect of various cold-water immersion protocols on exercise-induced inflammatory response and functional recovery from high-intensity sprint exercise. *European Journal of Applied Physiology*, 114(11), 2353-2367. <https://doi.org/10.1007/s00421-014-2954-2>
- Peake, J., Roberts, L., Raastad, T., Figueiredo, V., Cameron-Smith, D., Coombes, J., & Markworth, J. (2016). The

- effects of cold water immersion on inflammation, growth and neurotrophic factors in skeletal muscle after resistance exercise. *The FASEB Journal*, 30(S1).
https://doi.org/10.1096/fasebj.30.1_supplement.1291.4
- Wilcock, I.M., Cronin, J.B., & Hing, W.A. (2006). Physiological Response to Water Immersion: A Method for Sport Recovery? *Sports Medicine*, 36(9), 747-765.
<https://doi.org/10.2165/00007256-200636090-00003>
- Howatson, G., & Van Someren, K.A. (2008). The Prevention and Treatment of Exercise-Induced Muscle Damage. *Sports Medicine*, 38(6), 483-503.
<https://doi.org/10.2165/00007256-200838060-00004>
- Pointon, M., & Duffield, R. (2012). Cold Water Immersion Recovery after Simulated Collision Sport Exercise. *Medicine & Science in Sports & Exercise*, 44(2), 206-216.
<https://doi.org/10.1249/mss.0b013e31822b0977>
- Vaile, J., Halson, S., Gill, N., & Dawson, B. (2008). Effect of Hydrotherapy on Recovery from Fatigue. *International Journal of Sports Medicine*, 29(7), 539-544.
<https://doi.org/10.1055/s-2007-989267>
- Edholm, P., Ørtenblad, N., Holmberg, H.-C., & Sperlich, B. (2024b). Optimizing recovery strategies for winter athletes: Insights for Milano-Cortina 2026 Olympic Games. *Sport Sciences for Health*, 20(4), 1169-1182.
<https://doi.org/10.1007/s11332-024-01245-1>

Занурення у холодну воду та спортивне відновлення: Систематичний огляд рандомізованих контрольованих досліджень (2000–2024)

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 12 с., 4 табл., 1 рис., 48 джерел.

Історія питання. Занурення у холодну воду (ЗХВ) є поширеною стратегією відновлення серед спортсменів, проте докази її ефективності залишаються суперечливими через розбіжності в протоколах та методах оцінки результатів.

Мета дослідження. Цей систематичний огляд мав на меті оцінити вплив методики ЗХВ на відновлення спортсменів після тренувань, зосередившись на фізіологічних, продуктивних та перцептивних показниках.

Матеріали та методи. Згідно з рекомендаціями переважних елементів звітності для систематичних оглядів і мета-аналізів (PRISMA) та міжнародного проспективного реєстру систематичних оглядів (PROSPERO) (CRD420251068097), проведено пошук у чотирьох електронних наукометричних базах даних (PubMed, Web of Science, Scopus та ProQuest) щодо рандомізованих контрольованих досліджень (РКД), опублікованих у період з 2000 по 2024 рік. До аналізу включено дослідження, які отримали показник PEDro ≥ 6 . Критеріям включення відповідало 12 РКД. Синтез даних здійснено у формі опису, підкріпленого підрахунком голосів та графіками збору інформації, оскільки гетерогенність перешкождала проведенню метааналізу.

Результати. Застосування методики занурення у холодну воду сприяло послідовному зменшенню синдрому відстроченого м'язового болю (СВМБ) та біомаркерів пошкодження м'язів (наприклад, креатинкінази, лактатдегідрогенази) протягом 24–48 годин після тренування. У кількох дослідженнях також повідомлялося про поліпшення суб'єктивного відновлення. Вплив на нервово-м'язову продуктивність (наприклад, спринт, стрибок із контррухом) був неоднозначним і, як виявилось, залежав від контексту. Доказові дані щодо маркерів запалення (наприклад, IL-6, CRP) були обмеженими і непереконливими. Варіабельність температури води, тривалості занурення та часових рамок сприяло неоднорідності результатів у різних дослідженнях.

Висновки. Результати дослідження свідчать про наявність помірних та переконливих доказів доцільності коротко-строгового застосування методики ЗХВ з метою зменшення м'язового болю та пошкодження, а також поліпшення перцептивного відновлення. Вплив на продуктивність та запалення залишається нез'ясованим, що підкреслює необхідність стандартизації протоколу. ЗХВ залишається практичним інструментом для спортсменів, зокрема при високих навантаженнях або напруженому графіку, однак застосування цієї методики має бути індивідуалізовано.

Ключові слова: занурення у холодну воду, спортивне відновлення, м'язовий біль, рандомізовані контрольовані дослідження, пошкодження м'язів, спричинене фізичними навантаженнями.

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