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Cold Water Immersion Protocol Optimization Across Exercise Modalities: A Systematic Review and Network Meta-Analysis of Resistance Training, Endurance Exercise, and Team Sport Applications

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ADMINISTRATIVE INFORMATION

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Review Stage at time of this submission - Completed but not published.

Conflicts of interest - None declared.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 24 July 2025 and was last updated on 24 July 2025.

INTRODUCTION

Review question / Objective This systematic review and network meta-analysis aims to determine the optimal cold water immersion (CWI) protocols across different exercise modalities and to quantify the differential effects of CWI on performance and physiological recovery markers. The review seeks to address the following primary research questions:
1.Do optimal CWI protocols (temperature, duration, timing) differ between resistance training, endurance exercise, and team sports?
2.What are the differential effects of CWI on performance and physiological markers across exercise modalities?
3.How do sport-specific demands influence CWI protocol effectiveness for recovery outcomes?.

Rationale Cold water immersion has become increasingly popular as a post-exercise recovery strategy among athletes across various disciplines. However, recent evidence suggests that CWI effectiveness may vary significantly depending on the type of exercise performed. Xiao et al. (2023) demonstrated that CWI can effectively reduce muscle soreness and accelerate fatigue recovery after high-intensity exercise, with immediate benefits observed for delayed-onset muscle soreness and rate of perceived exertion. However, the authors noted that different CWI protocols and exercise types may produce varying recovery responses. More recently, Wang et al. (2025) conducted a comprehensive network meta-analysis examining different CWI doses on recovery from acute exercise-induced muscle damage. Their findings revealed that medium-duration low-temperature CWI (10-15 min, 5°C-10°C) was most effective for biochemical markers and neuromuscular recovery, while medium-duration medium-temperature CWI (10-15 min, 11°C-15°C) was optimal for.

Condition being studied This review will examine post-exercise recovery responses following cold water immersion across three primary exercise modalities: resistance training, endurance exercise, and team sports. The focus will be on healthy athletic populations undergoing various exercise protocols with subsequent CWI interventions for recovery enhancement.

METHODS

Search strategy A comprehensive literature search will be conducted in the following databases: PubMed, Scopus, SPORTDiscus, and Web of Science. The search will cover the period from January 1, 2014, to April 30, 2025, limited to English language publications.
Search terms will include combinations of: ("cold water immersion" OR "CWI" OR "ice bath" OR "cryotherapy") AND ("resistance training" OR "strength training" OR "endurance training" OR "aerobic exercise" OR "team sport" OR "soccer" OR "basketball" OR "rugby") AND ("recovery" OR "performance" OR "muscle soreness" OR "fatigue" OR "muscle damage") AND ("randomized" OR "controlled trial" OR "crossover"). Reference lists of included studies and relevant systematic reviews will be manually searched to identify additional eligible studies.

Participant or population Studies involving healthy athletes or physically active individuals aged 18 years and older will be included. Participants must have engaged in organized resistance training, endurance exercise, or team sport activities. Studies involving clinical populations, injured athletes, or individuals with contraindications to cold water immersion will be excluded.

Intervention The intervention of interest is cold water immersion applied post-exercise. CWI will be defined as immersion in water at temperatures ≤20°C for any duration. Various CWI protocols will be categorized based on water temperature (5-8°C, 9-12°C, 13-20°C) and immersion duration (15 minutes) to enable network meta-analysis comparisons.

Comparator Comparators will include passive recovery (control), active recovery, thermoneutral water immersion, contrast water therapy, or alternative recovery modalities. Studies must include at least one control or comparison group to be eligible for inclusion.

Study designs to be included Randomized controlled trials (RCTs) and randomized crossover studies will be included. Quasi-randomized studies, non-randomized controlled trials, observational studies, case reports, and review articles will be excluded.

Eligibility criteria
Inclusion criteria:
1.RCTs or randomized crossover studies
2.Healthy athletes or physically active adults (≥18 years)
3.Post-exercise CWI intervention (≤20°C water temperature)
4.Comparison with control or alternative recovery method
5.Outcomes measured within 72 hours post-exercise
6.Published in English between January 1, 2014, and April 30, 2025
7.Quantitative data available for meta-analysis
Exclusion criteria:
1.Studies involving clinical populations or injured athletes
2.Non-randomized study designs
3.CWI combined with other interventions (unless separately analyzed)
4.Insufficient data for effect size calculation
5.Conference abstracts without full-text availability.

Information sources Primary information sources will include peer-reviewed journals accessed through PubMed, Scopus, SPORTDiscus, and Web of Science databases. Additional sources will include reference lists of included studies, relevant systematic reviews, and grey literature where appropriate.

Main outcome(s) Primary outcomes will be categorized by exercise modality:
a)Resistance Training: Strength measures (1RM, isometric force), power output (jump height, peak power), muscle hypertrophy markers, and training adaptation indicators.
b)Endurance Exercise: Aerobic performance (VO2max, time trial performance), endurance capacity, lactate kinetics, and cardiovascular recovery markers.
c)Team Sports: Sport-specific performance measures (sprint times, agility, skill performance), repeated effort capacity, and match/game simulation outcomes.
d)All Modalities: Muscle damage biomarkers (creatine kinase, lactate dehydrogenase), inflammatory markers, and perceived recovery measures.

Quality assessment / Risk of bias analysis The Cochrane Risk of Bias tool (RoB 2.0) will be used to assess methodological quality of included RCTs.

The quality assessment will evaluate random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other potential sources of bias. The Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach will be used to assess the overall certainty of evidence for each outcome.

Strategy of data synthesis A network meta-analysis will be conducted using a frequentist approach to compare different CWI protocols across exercise modalities. Standardized mean differences (SMD) with 95% confidence intervals will be calculated for continuous outcomes. The analysis will be structured to compare combinations of exercise modality and CWI protocol (e.g., resistance training + cold CWI vs. resistance training + control).
Separate networks will be constructed for different outcome domains (performance, physiological, perceptual). Random-effects models will be used to account for heterogeneity between studies. Network geometry will be assessed, and consistency between direct and indirect evidence will be evaluated using node-splitting methods. Surface Under the Cumulative Ranking Curve (SUCRA) will be used to rank interventions. Publication bias will be assessed using funnel plots and statistical tests where appropriate.

Subgroup analysis Pre-planned subgroup analyses will be conducted based on:
1.Exercise intensity (high vs. moderate intensity)
2.Training status (elite vs. recreational athletes)
3.CWI timing (immediate 15 minutes post-exercise)
4.Study quality (low vs. high risk of bias)
5.Age groups (young adults vs. older athletes).

Sensitivity analysis
Sensitivity analyses will include:
1.Exclusion of studies with high risk of bias
2.Analysis limited to specific CWI temperature ranges
3.Exclusion of crossover studies
4.Analysis by outcome measurement timing (immediate vs. delayed).

Language restriction Only studies published in English will be included in this review.

Country(ies) involved China.

Keywords Cold water immersion; cryotherapy; exercise recovery; resistance training; endurance exercise; team sports; network meta-analysis; athletic performance; systematic review.

Dissemination plans Results will be submitted for publication in a high-impact peer-reviewed sports medicine or exercise science journal. Findings will be presented at relevant scientific conferences and shared with sports medicine practitioners through professional networks and organizations.

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