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Cold Water Immersion in Football Players: Effects on Recovery, Performance, and Training Adaptation — A Narrative Review

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Abstract

Background. Cold water immersion (CWI) is widely used in football to accelerate recovery, although its effects on training adaptations and performance remain debated.

Aim. This narrative review synthesised current evidence on the effects of CWI in football players, focusing on recovery, athletic performance, and training adaptations.

Materials and methods. PubMed, Scopus, and Google Scholar were searched for English-language studies published between 2010 and 2026. Studies involving football players of any age, sex, or competitive level were included in a narrative synthesis.

Results. CWI consistently reduced perceived muscle soreness and, in some studies, creatine kinase, accelerating short-term recovery following matches and training. However, findings on neuromuscular performance, including sprint and jump, were inconsistent. Regular CWI use did not enhance, and may attenuate, resistance training adaptations, whereas endurance adaptations appeared largely unaffected. Comparisons with alternative modalities produced mixed findings, and protocol, habituation, and expectancy effects may have influenced outcomes. Evidence on female players and sleep remained limited.

Conclusions. CWI provides measurable short-term recovery benefits but should be applied selectively, particularly during strength-focused training, given its potential to attenuate long-term adaptations. Future research should prioritise standardised protocols and greater representation of female players.

Keywords: cold water immersion; football; recovery; athletic performance; training adaptation.

1. Introduction

Optimising recovery between matches and training sessions represents a central challenge in modern football, particularly given increasingly congested fixture schedules involving multiple matches per week across domestic, continental, and international competitions [1]. Fatigue and incomplete recovery are commonly regarded as predisposing factors for reduced physical performance and increased injury risk, prompting practitioners to implement a range of recovery strategies aimed at accelerating the restoration of physiological and neuromuscular function [1]. Among these strategies, cold water immersion (CWI) has become one of the most widely adopted post-exercise recovery modalities in football, owing to its practicality and perceived effectiveness among players and coaching staff [9].

A substantial body of research has examined the acute effects of CWI following football-specific exercise. Evidence from single-match and simulated match-play protocols indicates that CWI can reduce perceived muscle soreness and markers of muscle damage, such as creatine kinase, while accelerating the short-term recovery of physical performance [3]. However, findings regarding the mechanisms underlying these benefits remain inconsistent; some studies have reported that faster recovery of physical performance following CWI is not necessarily associated with reduced biochemical markers of muscle damage, suggesting that additional factors, potentially perceptual or neurological, may contribute to its effects [4]. Furthermore, the extent to which CWI reflects a true physiological benefit rather than an expectancy-driven response remains debated, with at least one study reporting no clear separation between CWI and placebo conditions during recovery from simulated match-play [6].

Beyond its acute effects, an emerging body of evidence has raised concerns regarding the impact of regularly applied CWI on training-induced adaptations. A recent randomised controlled trial in national-level soccer players found that neither cold- nor hot-water immersion improved recovery of physical performance or training adaptations over a 15-week period compared with placebo [7]. These findings align with a broader systematic review and meta-analysis demonstrating that regular post-exercise CWI use may attenuate resistance training-induced gains in strength and power, while endurance training adaptations appear largely unaffected [8]. This apparent trade-off between short-term recovery benefits and potential long-term costs represents

a central, unresolved challenge in the application of CWI within football, where both acute match recovery and sustained physical development across a season are of practical importance.

Despite the popularity of CWI, survey-based evidence suggests a notable gap between its widespread practical use and coaches' and practitioners' understanding of the underlying evidence, with many expressing confidence in its benefits despite limited understanding of the physiological mechanisms involved [9]. This gap is compounded by considerable heterogeneity across the existing literature, including variation in immersion protocols (temperature, duration, and timing), comparator interventions, and study populations, which complicates efforts to draw consistent and practically applicable conclusions [10,11]. Furthermore, evidence specific to female football players, as well as the potential interaction between CWI and sleep-related recovery outcomes, remains comparatively limited within the current literature.

Therefore, the aim of this narrative review is to synthesise current evidence on the effects of cold water immersion in football players, with particular emphasis on acute recovery, athletic performance, and training adaptations, while also considering methodological factors, alternative recovery modalities, and understudied populations within the existing literature.

2. Research materials and methods

2.1. Study design and eligibility criteria

This study was conducted as a narrative review aimed at synthesising current evidence regarding the effects of cold water immersion on recovery, athletic performance, and training adaptations in football players. A structured literature search and narrative synthesis were used to identify and summarise the available evidence.

Studies were considered eligible if they met the following criteria: (i) published in English; (ii) conducted in human football (soccer) players; (iii) published between 2010 and 2026; and (iv) investigated at least one outcome related to post-exercise recovery, muscle damage, athletic performance, or training-induced adaptations following cold water immersion or comparable cold-based recovery interventions.

No restrictions were applied regarding participants' age, sex, or competitive level to capture the broadest available evidence across youth, amateur, and professional football populations.

Studies involving non-football athletes were considered only when they provided directly relevant mechanistic, methodological, or comparative context (e.g., sex-related differences in CWI responses or comparisons between recovery modalities) that was unavailable within the football-specific literature. Studies involving animal models, non-human research, conference abstracts, or articles without accessible full text were excluded.

2.2. Literature search strategy

A literature search was conducted using three electronic databases: PubMed, Scopus, and Google Scholar. The search was performed in July 2026 to identify studies examining the effects of cold water immersion on recovery, athletic performance, and training adaptations in football players, together with relevant methodological and comparative evidence.

In addition to the database search, the reference lists of relevant articles were manually screened to identify further eligible studies not captured during the primary search.

2.3. Search terms

The search strategy combined terms related to cold water immersion, football, and recovery outcomes. The following search string was applied:

("cold water immersion" OR "cryotherapy" OR "cold-water therapy") AND ("football" OR "soccer") AND ("recovery" OR "performance" OR "muscle damage" OR "training adaptation")

Search terms were adapted where necessary according to the requirements of each database.

2.4. Study selection process

The identified records were screened according to the predefined eligibility criteria. Titles and abstracts were assessed by the authors for relevance to the objectives of the review, followed by full-text evaluation of potentially eligible studies. Studies meeting the inclusion criteria were incorporated into the final narrative synthesis.

For each included study, data were extracted by the authors on study design, participant characteristics, intervention protocol, comparator condition, outcome measures, and principal findings relevant to the objectives of this review.

2.5. Data synthesis and analysis

Due to considerable heterogeneity among the included studies regarding participant characteristics, competitive level, immersion protocols, comparator interventions, and outcome measures, a quantitative meta-analysis was not considered appropriate. Instead, findings were synthesised narratively and organised into the following six thematic categories:

1. Acute effects of cold water immersion on recovery, muscle damage, and performance;
2. Cold water immersion and long-term training adaptations;
3. Comparisons with alternative recovery modalities;
4. Methodological and psychological considerations: protocols, habituation, and expectancy effects;
5. Cold exposure and sleep quality in football players;
6. Understudied populations: sex differences and female football players.

Within each thematic area, studies were compared to identify consistent findings, areas of uncertainty, methodological limitations, and implications for practical application in football.

3. Research results

3.1. Acute effects of cold water immersion on recovery, muscle damage, and performance

Cold water immersion has been consistently investigated as a strategy to accelerate recovery following football match-play and training, with a substantial proportion of the available evidence focusing on acute, single-exposure protocols. Following a one-off competitive match, CWI has been shown to reduce perceived muscle soreness in the quadriceps, calf, and hip adductor muscles, alongside differential changes in creatine kinase, myoglobin, and C-reactive protein compared with thermoneutral water immersion, consistent with faster recovery of neuromuscular function [3]. Similarly, CWI applied after simulated match-play has been found to improve the recovery of both central and peripheral neuromuscular fatigue, with corresponding improvements in maximal voluntary contraction, squat jump, countermovement jump, and sprint performance relative to a thermoneutral water immersion condition used as a sham comparator [5].

However, the relationship between CWI-induced recovery and underlying muscle damage appears more complex than a simple causal relationship. In professional football players completing an intermittent shuttle test, CWI accelerated the recovery of physical performance relative to thermoneutral water immersion, yet this faster recovery was not associated with a correspondingly greater reduction in biochemical markers of muscle damage, indicating that mechanisms beyond tissue-level repair, potentially perceptual or neurological in nature, may contribute to the observed benefits [4].

Findings from elite academy football settings further illustrate the nuanced nature of CWI's acute effects. Although not representing conventional CWI, cryo-compression therapy (Game Ready®) produced a significant reduction in countermovement jump performance immediately after the intervention, an effect not observed following passive recovery, while no significant effects were found for isometric adductor strength or hamstring flexibility [1]. In contrast, a separate investigation comparing CWI with passive recovery in elite footballers during a standard mid-season training cycle reported significant improvements in eccentric hamstring strength, sleep-related recovery, fatigue, and muscle soreness, suggesting that CWI may help attenuate reductions in eccentric hamstring strength relevant to training and match readiness [2].

Overall, current evidence indicates that CWI provides measurable acute benefits for perceived muscle soreness, selected biochemical markers, and short-term recovery following football-specific exercise. However, findings regarding objective neuromuscular performance, particularly sprint and jump performance, remain inconsistent, and the dissociation between biochemical and functional recovery observed in some studies suggests that the mechanisms underlying these acute effects remain incompletely understood.

3.2. Cold water immersion and long-term training adaptations

While the acute effects of CWI on recovery have received considerable attention, an increasing body of evidence has focused on whether its regular application influences training-induced physiological adaptations over time, a question of particular relevance given the frequency with which CWI is used throughout a competitive football season. A randomised controlled trial in national-level soccer players directly addressed this question by comparing cold-water immersion, hot-water immersion, and a placebo condition following an initial simulated match, with repeated application of these recovery strategies throughout a subsequent

15-week training programme. Neither cold- nor hot-water immersion improved the recovery of physical performance following the initial simulated match, and repeated use of either modality throughout the training period did not enhance training-induced adaptations in aerobic performance, sprint ability, jump performance, or knee extension strength compared with placebo [7].

These findings from a football-specific context align closely with broader evidence from the resistance and endurance training literature. A systematic review and meta-analysis reported that regular post-exercise CWI use attenuated resistance training-induced adaptations, with moderate negative effects observed for maximal strength, isometric strength, strength endurance, and ballistic power. In contrast, endurance-related outcomes, including aerobic power and time-trial performance, were not significantly affected, suggesting that the attenuating effects of CWI may be more specific to resistance-based than endurance-based physical qualities [8].

However, not all evidence supports a consistent attenuating effect of regular CWI use. In a 12-week resistance training programme involving academy rugby players, a team-sport population sharing physical demands relevant to football, repeated post-exercise cold- or hot-water immersion produced no significant effects on body composition or neuromuscular jump performance compared with a control condition, contrasting with findings reported in some resistance training studies [22]. This discrepancy suggests that the magnitude and consistency of CWI's influence on training adaptations may depend on factors such as training modality, athlete population, competitive context, and the specific performance outcomes assessed, rather than representing a uniform phenomenon across all training settings.

Taken together, current evidence suggests that regular CWI use is unlikely to enhance, and may in some contexts attenuate, adaptations to resistance-based training, whereas its impact on endurance-based adaptations appears limited. For football players, whose training programmes combine both resistance- and endurance-oriented components, these findings suggest that the timing and context of CWI application, particularly during phases emphasising strength development, should be carefully considered to balance immediate recovery requirements with long-term training adaptations.

3.3. Comparisons with alternative recovery modalities

Given the mixed evidence regarding CWI's acute and long-term effects, several studies have directly compared CWI with alternative recovery modalities to determine whether comparable or superior benefits can be achieved through other approaches. In young male soccer players, a randomised crossover study comparing CWI with percussive massage therapy (PMT) following a fatiguing protocol found that both interventions reduced perceived muscle soreness relative to a control condition, while PMT additionally improved isometric strength recovery. However, effects on neuromuscular properties assessed using tensiomyography were inconsistent, indicating that neither modality demonstrated clear superiority across all outcome measures [14].

Comparisons have also extended to alternative cold-based modalities. Although conducted in healthy trained participants rather than football players, a single session of whole-body cryotherapy (WBC), involving brief exposure to extreme cold air rather than water immersion, enhanced maximal cycling performance and increased resting vagal activity, suggesting that different cooling modalities may exert distinct effects on autonomic and performance outcomes beyond their shared cooling mechanism [17]. Similarly, in a study comparing cryocompression, a combined cryotherapy and compression modality, with cryotherapy alone and normothermic compression following eccentric exercise, cryocompression produced the most consistent reductions in limb swelling and muscle soreness. However, none of the interventions significantly influenced proprioception or functional performance, highlighting that combining cooling with mechanical compression may enhance selected recovery markers without necessarily improving neuromuscular function [18].

Evidence from broader syntheses of the cold-therapy literature supports the view that outcome-specific effects, rather than uniform superiority of one modality, characterise this body of evidence. A network meta-analysis comparing hydrotherapy and cryotherapy interventions across various temperatures identified cryotherapy as the most effective modality for improving jump recovery, whereas hot- and thermoneutral-water immersion showed comparable or superior effects for several other recovery outcomes, indicating that recovery modality selection may need to be tailored to the specific performance objective [19]. Similarly, a systematic review and meta-analysis examining CWI applied to different body regions found that whole-body and partial-

body immersion produced comparable reductions in creatine kinase concentrations and delayed-onset muscle soreness, with no significant benefits for jump or isometric strength recovery. These findings suggest that the extent of body surface area immersed may be less influential than previously assumed [20].

Collectively, these comparative findings suggest that CWI does not consistently outperform alternative recovery modalities, and that the relative effectiveness of different approaches may depend heavily on the specific outcome being targeted, whether perceptual, biochemical, or functional. This underscores the importance of clearly defining recovery goals when selecting between CWI and alternative modalities in applied football settings.

3.4. Methodological and psychological considerations: protocols, habituation, and expectancy effects

Beyond comparisons between recovery modalities, the existing CWI literature is characterised by considerable methodological heterogeneity that complicates direct comparison across studies and may partly explain the inconsistent findings described in previous sections. Immersion protocols vary substantially in water temperature, duration, timing relative to exercise, and the extent of body surface area immersed, with relatively few studies adopting standardised or consensus-based approaches. This variability, combined with differences in exercise protocols and outcome measures across studies, represents an important methodological limitation when attempting to synthesise practical recommendations from the available evidence.

A further consideration concerns the extent to which the benefits attributed to CWI reflect genuine physiological effects rather than expectancy-driven, placebo-like responses. In a crossover study comparing CWI with a placebo recovery beverage and passive rest following a simulated match protocol in soccer players, no clear separation was observed between the CWI and placebo conditions across several recovery outcomes, raising the possibility that psychological expectation may contribute meaningfully to the perceived benefits of CWI, independent of its physiological cooling effects [6].

Individual prior experience with cold exposure may also influence the effectiveness of CWI as a recovery strategy. In young soccer players without previous experience of cold water immersion, a four-week habituation period was found to influence subsequent recovery responses

following a simulated match, suggesting that unfamiliarity with the sensory discomfort associated with cold exposure may itself act as a confounding factor in acute CWI studies involving cold-naïve participants [13]. This finding raises an important methodological consideration when interpreting single-exposure CWI studies, particularly in populations with limited prior exposure to cold-water recovery protocols, and suggests that habituation status should be considered in both the design and interpretation of future CWI research.

Taken together, these methodological and psychological factors indicate that the effectiveness of CWI cannot be fully understood in isolation from the conditions under which it is studied and applied. Variability in intervention protocols, the potential contribution of expectancy effects, and individual differences in prior cold exposure collectively suggest that the reported benefits of CWI may be influenced by contextual and psychological factors as well as direct physiological mechanisms. These findings underscore the need for greater protocol standardisation and improved control of psychological influences in future research.

3.5. Cold exposure and sleep quality in football players

Beyond its established effects on post-exercise recovery and physical performance, cold exposure has also been investigated as a potential strategy for improving sleep quality in football players, an outcome of particular relevance given the well-established role of sleep in athletic recovery and readiness. However, the limited evidence available suggests that the relationship between cold-based interventions and sleep may depend substantially on the specific modality and duration of exposure.

In professional soccer players, partial-body cryostimulation applied after training, which involves brief exposure to extremely cold air rather than water immersion, was found to reduce nocturnal movement during sleep, as measured using three-dimensional accelerometry, although this effect was observed only following a 180-second exposure, with shorter or interrupted protocols producing no comparable benefit [12]. These findings suggest that the duration of cold-air exposure may be an important determinant of sleep-related outcomes, rather than cold exposure uniformly improving sleep regardless of protocol characteristics.

In contrast, evidence regarding water-based cold water immersion is less consistent. As described in Section 3.1, one investigation comparing CWI with passive recovery in elite

footballers reported improvements in subjective sleep alongside other recovery measures following CWI during a standard training cycle [2], suggesting that water-based cooling may support sleep-related recovery under certain conditions.

Taken together, the available evidence suggests that cold exposure may support sleep-related recovery in football players under selected conditions; however, the findings remain limited and heterogeneous, particularly given the differing modalities investigated (air-based cryostimulation versus water immersion). Consequently, further football-specific research is required before firm conclusions can be drawn regarding the routine use of cold-based interventions to improve sleep-related recovery.

3.6. Understudied populations: sex differences and female football players

Although CWI is widely used across football populations of all sexes, the majority of research examining its physiological and performance effects has historically been conducted in male athletes, leaving important questions regarding its effectiveness and optimal application in female players comparatively underexplored. Emerging evidence suggests that sex may represent a meaningful, yet insufficiently studied, moderator of the response to cold-based recovery interventions.

Direct evidence in female football players remains very limited. In one study examining the effects of cold water immersion and whole-body cryotherapy on muscle oxygen content and physical performance specifically in female football players, both cold-based interventions were investigated as potential recovery strategies, representing one of the few studies to address this population directly rather than extrapolating findings from predominantly male cohorts [16].

Beyond football specifically, broader evidence from other physically active female populations provides some insight into potential sex-specific responses to cold-based recovery. In a randomised controlled trial comparing cold-water immersion, partial-body cryotherapy, and passive recovery following exercise-induced muscle damage in females, CWI produced generally greater physiological effects than partial-body cryotherapy, with both interventions reducing delayed-onset muscle soreness relative to control; however, neither intervention significantly affected functional performance measures or muscle swelling [15]. Although conducted outside football, a study examining repeated intermittent muscular contractions following cold water

immersion at different temperatures demonstrated that male participants experienced greater performance improvements than female participants despite similar oxygen kinetics between sexes, suggesting that standardised CWI protocols developed predominantly in male populations may not translate directly to female athletes [21].

Taken together, the limited evidence specific to female football players, combined with suggestive findings of sex-based differences in response to cold-based recovery interventions from other athletic populations, indicates that current recommendations regarding CWI use in football are based predominantly on evidence derived from male athletes. Given the continued growth and professionalisation of women's football, further research directly examining the effects of CWI in female football players across different protocols and outcome measures should be considered a priority.

4. Discussion

The findings synthesised in this narrative review indicate that cold water immersion (CWI) provides measurable acute recovery benefits in football players, particularly with respect to perceived muscle soreness and selected biochemical markers of muscle damage. However, its effects on objective neuromuscular performance, long-term training adaptations, and sleep-related outcomes remain considerably less consistent. Across the six thematic areas synthesised in this review, a consistent pattern emerges: CWI appears to be more reliably beneficial for subjective and biochemical indicators of recovery than for functional performance outcomes. Moreover, its regular application may involve a trade-off between short-term recovery benefits and long-term physical development that warrants careful consideration in applied football settings.

The acute effects of CWI on recovery are relatively well supported, with reductions in perceived muscle soreness and improvements in short-term neuromuscular function reported across several football-specific studies [3,5]. However, the dissociation between faster recovery of physical performance and reduced biochemical markers of muscle damage observed in some studies [4] suggests that the mechanisms underlying these benefits extend beyond direct tissue repair and may involve perceptual, neurological, or central regulatory pathways. This mechanistic uncertainty is further reinforced by evidence showing that certain cold-based recovery modalities

may acutely impair, rather than enhance, neuromuscular performance immediately after treatment [1], highlighting that the acute response to cold exposure is neither uniform nor fully understood.

The relationship between CWI and long-term training adaptations represents one of the most practically important findings of the current evidence base. Evidence from a football-specific randomised controlled trial [7], supported by a broader systematic review and meta-analysis [8], indicates that regular CWI use is unlikely to enhance, and may attenuate, adaptations to resistance-based training, whereas endurance-related adaptations appear largely unaffected. Nevertheless, this pattern is not universal. Findings from academy rugby players demonstrating no significant attenuation of training adaptations [22] suggest that the magnitude of this effect may depend on training modality, athlete characteristics, intervention protocols, and competitive context. For football players, whose physical preparation combines both resistance- and endurance-based components, these findings suggest that indiscriminate, year-round use of CWI after every training session may be counterproductive during phases primarily focused on strength and power development.

Comparisons with alternative recovery modalities further reinforce the view that no single intervention, including CWI, consistently outperforms all others across every recovery outcome [14,17,18,19,20]. Rather, the relative effectiveness of different recovery strategies appears to depend on the specific outcome being prioritised, whether perceptual, biochemical, functional, or sport-specific. Consequently, recovery strategy selection should be guided by clearly defined objectives rather than the assumption that one modality is universally superior.

The methodological and psychological considerations identified in this review are particularly important when interpreting the current evidence base. Considerable heterogeneity in immersion protocols, including water temperature, immersion duration, timing, and body surface area immersed, limits direct comparisons across studies [9,10,11]. In addition, evidence demonstrating only limited separation between CWI and placebo conditions [6] raises important questions regarding the extent to which perceived benefits reflect genuine physiological effects rather than expectancy-related responses. Similarly, findings suggesting that habituation to cold exposure may influence recovery responses [13] indicate that acute, single-exposure studies involving cold-naïve participants may not accurately reflect the responses of athletes who routinely use CWI in real-world settings. Together, these factors highlight a persistent gap

between the complexity of the available evidence and the relatively uniform manner in which CWI is often implemented in practice. This discrepancy is further reflected in survey-based evidence demonstrating widespread practitioner confidence in CWI despite a limited understanding of its underlying physiological mechanisms [9].

The comparatively limited evidence regarding cold exposure and sleep quality in football players represents another important gap in the literature. While partial-body cryostimulation has demonstrated beneficial effects on selected objective sleep parameters under specific exposure durations [12], and CWI has been associated with improved subjective sleep in at least one football-specific investigation [2], the small number of available studies and the use of different cooling modalities preclude firm conclusions regarding the routine use of cold-based interventions to enhance sleep-related recovery.

Finally, the scarcity of evidence directly examining CWI in female football players represents a significant limitation of the current literature. The limited football-specific evidence available [16], together with findings suggesting sex-related differences in responses to cold-based recovery interventions in other athletic populations [15,21], indicates that current practical recommendations are based predominantly on evidence derived from male athletes. Given the continued growth and professionalisation of women's football, research specifically examining the effectiveness of CWI in female football players across different intervention protocols and recovery outcomes should be considered a priority for future investigation.

Practical implications

Based on the available evidence, several practical recommendations can be proposed for football practitioners. First, CWI may be considered an appropriate short-term recovery strategy following matches or high-intensity training sessions when the primary objective is to reduce perceived muscle soreness and support subjective recovery. Second, practitioners should exercise caution regarding the routine, year-round use of CWI following resistance-training sessions specifically designed to develop maximal strength or power, given its potential to attenuate long-term training adaptations. Third, because no single recovery modality consistently demonstrates superiority across all outcomes, the selection of CWI or alternative recovery strategies should be guided by the specific recovery objective within a given training or competition context. Finally, practitioners working with female football players should recognise that current CWI protocols

are based predominantly on studies involving male athletes and should therefore consider individual responses when implementing recovery strategies.

Limitations and future directions

Several limitations should be considered when interpreting the findings of this review. The included studies varied substantially with respect to immersion protocols, participant characteristics, competitive level, and outcome measures, limiting direct comparability and precluding quantitative synthesis. Furthermore, many studies involved relatively small sample sizes and single-exposure designs that may not adequately represent the effects of habitual CWI use in applied football settings. In addition, because some mechanistic and comparative evidence was derived from non-football populations, the applicability of these findings to football-specific contexts should be interpreted with appropriate caution.

As a narrative review, this review provides a qualitative synthesis of the available evidence rather than pooled quantitative effect estimates. Future research should prioritise the development of standardised CWI protocols to improve comparability across studies, conduct longer-term controlled trials examining training adaptations specifically in football populations, and increase the representation of female football players across all outcome domains. Further investigation into the interaction between CWI and sleep-related recovery, as well as the psychological and expectancy-related mechanisms underlying its perceived benefits, would further clarify the practical value of this widely used recovery strategy.

5. Conclusions

This narrative review indicates that cold water immersion (CWI) provides measurable short-term recovery benefits in football players, particularly by reducing perceived muscle soreness and improving selected markers of muscle damage. However, its effects on objective neuromuscular performance remain inconsistent. Regular CWI use does not appear to enhance, and may attenuate, adaptations to resistance-based training, whereas endurance-related adaptations appear largely unaffected, although these findings are influenced by differences in study populations and intervention protocols.

Current evidence also indicates that no single recovery modality, including CWI, consistently outperforms alternative approaches across all recovery outcomes. Therefore,

recovery strategies should be selected according to the specific objectives of training or competition rather than applied routinely. The substantial methodological heterogeneity of the available literature, together with the potential influence of placebo effects and habituation to cold exposure, further complicates interpretation of the existing evidence.

Evidence regarding the effects of CWI on sleep-related recovery and its effectiveness in female football players remains limited. Consequently, current practical recommendations are based predominantly on studies involving male athletes and should be interpreted with appropriate caution.

Overall, CWI should be considered a selective recovery strategy rather than a universal intervention. Its use appears most appropriate when rapid short-term recovery is prioritised, whereas routine application during periods focused on strength and power development should be approached cautiously. Future research should prioritise standardised intervention protocols, longer-term controlled studies conducted in football populations, and greater inclusion of female players to support the development of more robust and population-specific recommendations for clinical and applied practice.

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Author Contributions

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