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Review Article

The Efficacy of Cold-Water Immersion in Mitigating Fatigue in Soccer

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Abstract
Soccer, as the world's most popular sport, features numerous organized and prestigious competitions and leagues across the globe. Throughout a typical nine-month season, soccer players engage in frequent training sessions and a high number of matches, exposing them to both substantial physical volume and intensity. Such demanding schedules often lead to fatigue, as evidenced by elevated markers of muscle damage, inflammation, lactate accumulation, delayed onset muscle soreness (DOMS), and increased ratings of perceived exertion (RPE). If both central and peripheral fatigue are not promptly addressed, subsequent performance may decline, and in some cases, serious injuries may occur. Among the various recovery modalities employed, cold therapy, particularly cold-water immersion, has gained significant popularity. This study systematically examined the effectiveness of cold-water immersion in alleviating fatigue-related factors among soccer players. English-language studies retrieved from the PubMed and Google Scholar databases were analyzed. Findings revealed that cold-water immersion can enhance subsequent performance in soccer players by reducing levels of creatine kinase (CK), lactate dehydrogenase (LDH), lactate, DOMS, and RPE, thereby moderating post-activity fatigue. Although a minority of studies report negligible or null effects of cold-water immersion on recovery in soccer players, the overall evidence supports its use as a cost-effective, accessible, and beneficial method for improving subsequent performance.
Keywords: Soccer, Fatigue, Recovery, Inflammation, Damage

Introduction

Existing evidence supports the assertion that soccer is the world's most popular sport. Its global appeal has created a substantial economic ecosystem, thereby fostering numerous organized and reputable competitions and leagues across various age groups in many countries.[1–3] Professional and elite soccer players typically participate in approximately 40 to 80 matches during a season lasting about nine months, often playing two to three matches per week.[4,5] In addition to frequent match play, players are required to attend regular training sessions. During both matches and training, soccer players engage in diverse activities—including running at variable intensities, jumping, tackling, rapid directional changes, and shooting. In elite-level matches, players cover distances ranging from roughly 10 to 13 km, of which approximately 10 km consist of low-to-moderate intensity movements and 2 to 3 km involve high-intensity efforts. Training sessions typically involve total distances between 3 and 7 km.[1,6–8]

The substantial physical demands placed on soccer players induce fatigue via several mechanisms, including the depletion of energy reserves, the accumulation of metabolic byproducts (i.e., metabolic acidosis), micro-injuries in muscle tissues, and psychological stressors. Fatigue manifests through increased markers of muscle damage, such as creatine kinase (CK) and lactate dehydrogenase (LDH), and inflammatory biomarkers, including C-reactive protein (CRP) and interleukin-6 (IL-6), heightened levels of delayed onset muscle soreness (DOMS), and higher ratings of perceived exertion (RPE).[9-15] The effects of both central and peripheral fatigue following a soccer match can persist for up to 72 hours. If these symptoms are not alleviated expeditiously, there is a heightened risk of diminished subsequent performance and, in some instances, serious injury. Accordingly, effective recovery strategies are essential for soccer players, not only to mitigate the adverse effects of fatigue but also to maintain readiness for the demanding physical requirements of upcoming matches. Furthermore, insights into the mechanisms of fatigue and recovery processes play a pivotal role in designing optimized training regimens and enhancing overall performance.[8,16-18]

Historically, cold has been widely used as a recovery intervention and continues to be a popular practice among athletes today. Cold-water immersion (CWI), in particular, has gained recognition due to its lower cost and accessibility. Typically performed after physical

activity, CWI involves immersion in water maintained between 10 and 15 ˚C for 10 to 15 minutes. This method has been shown to decrease inflammation, reduce muscle damage and stiffness, and enhance subsequent athletic performance.[19–22] However, some studies have reported that CWI does not significantly influence fatigue markers and, under certain conditions, may adversely affect performance. These discrepancies in outcomes may be attributed to variations in application protocols across studies. The present study aimed to systematically evaluate the effectiveness of CWI in reducing fatigue-related factors among soccer players.

Methods

This study was designed as a systematic review. Comprehensive searches were conducted in the PubMed and Google Scholar databases, using the keywords "Recovery," "Fatigue," "Soccer," and "Cold water immersion." Only English-language studies were included. Initially, titles were screened, followed by abstract evaluation, and finally full-text review. Studies that did not examine CWI use within soccer or soccer-related training contexts were excluded. The remaining eligible studies were analyzed and synthesized to formulate the findings of this systematic review.

Results

Creatine Kinase

One study involving 23 male semi-professional soccer players under 20 years of age compared two recovery methods following a preseason training session. One group engaged in 10 minutes of passive sitting rest, while the other underwent 10 minutes of CWI at 10 ˚C. The CWI group exhibited a significant reduction in CK levels compared to the control group.[23]

Furthermore, a meta-analysis investigating the effects of CWI across various sports, including soccer, reported that CK levels were significantly reduced in the CWI group 24 and 48 hours post-intervention compared to control conditions.[24] In another study involving 12 semi-professional soccer players, CWI resulted in markedly lower CK levels up to 24 hours post-intervention relative to passive recovery.[25] Similarly, a study comparing CWI (8–10 ˚C) with warm water immersion (26–30 ˚C) in 12 male soccer players aged 18–28 found that CK levels remained significantly lower for up to 48 hours in the cold-water group.[26]

Additionally, research involving eight male professional soccer players compared CWI at 10 ˚C with warm-water immersion at 28 ˚C for 10 minutes. CK levels in the cold-water group were significantly lower up to 48 hours post-intervention, although both groups returned to baseline by 72 hours.[27] Conversely, one study comparing CWI with infrared light therapy found no significant reductions in CK levels compared to a control group at any time point from immediately post-intervention to 48 hours later.[28] Likewise, another study involving 20 young male soccer players over four consecutive match days using cold-water and warm-water immersion revealed no significant differences in CK levels relative to a control group.[29]

Lactate Dehydrogenase

Bouchiba et al evaluated 12 soccer players and compared CWI (8–10 ˚C) with warm-water immersion (26–30 ˚C) over 10 minutes. LDH levels were significantly lower immediately after the intervention and remained lower for up to 72 hours in the cold-water group compared to the warm-water group.[26] A recent study from China involving runners whose LDH levels increased post-exercise compared whole-body cryotherapy, CWI, and combined cold/warm water immersion. All three recovery methods produced significantly lower LDH levels up to 48 hours post-intervention compared to controls, with whole-body cryotherapy demonstrating the greatest reduction.[30]

In another study involving 41 elite athletes from multiple sports, including soccer, following an exhaustive interval training session, CWI led to a greater reduction in LDH levels at one hour post-intervention, which persisted for up to 24 hours, compared to warm-water immersion, hot-water immersion, and passive rest.[31] In contrast, a study in which young soccer players underwent CWI at 15 ˚C for 15 minutes after each match for four weeks reported no significant changes in LDH levels pre- and post-intervention.[32] Similarly, research by Coelho et al, comparing CWI, infrared light therapy, and passive rest, noted no significant effects on LDH levels up to 48 hours post-intervention.[28] Another study conducted on 20 young soccer players (aged 16–18) using CWI at 10 ˚C versus warm-water immersion at 34 ˚C over four consecutive match days also found no significant reductions in LDH levels in either group.[29]

Lactate

A recent meta-analysis on the effects of CWI on post-exercise fatigue markers, including soccer, found that blood lactate levels did not significantly change immediately after the intervention. However, significant reductions in lactate levels were observed at 24 and 48 hours post-intervention in the CWI group compared to controls.[24] Micheletti et al studied 64 semi-professional soccer players who, after high-intensity interval training, were assigned to either a passive recovery group (15 minutes rest) or a CWI group (15 minutes at 12˚C). The CWI group exhibited significantly lower blood lactate levels two hours post-intervention.[33]

Another investigation, in which soccer players underwent high-intensity cycling to elevate blood lactate, compared passive rest, active recovery, and CWI. The CWI group returned to baseline lactate levels more rapidly than the other groups.[34]

Similarly, Bastos et al examined 20 male participants who were subjected to a training session designed to elevate lactate levels and compared three recovery methods: passive rest, active recovery (static and dynamic

stretching), and CWI at 15 ˚C for 15 minutes. Significant reductions in blood lactate were observed at 11, 13, and 15 minutes post-intervention in both the active recovery and CWI groups, with the latter showing the greatest reductions.[35]

However, a study involving 16 male professional soccer players training in hot and humid conditions compared passive rest, CWI at 13 ˚C for 15 minutes, and whole-body cryotherapy. No significant differences in lactate levels were observed among the three groups immediately after the intervention or 20 minutes later.[36]

C-Reactive Protein

A meta-analysis evaluating three recovery strategies—enhanced sleep quality, compression garments, and CWI—found that all methods improved CRP levels, with CWI exhibiting the greatest rate of reduction [21]. Another meta-analysis comparing recovery methods such as massage, CWI, compression garments, and cryotherapy identified cold-based interventions (e.g., CWI and cryotherapy) as the most effective in reducing CRP levels.[37]

In one study conducted on 20 soccer players, a comparison between cold-water and warm-water immersion after a match revealed that the cold-water group exhibited significantly lower CRP levels at 24 and 48 hours post-intervention.[38] Likewise, a meta-analysis examining the immediate effects of CWI post-activity across multiple sports, including soccer, reported that CRP levels were significantly lower in the CWI group compared to controls at the 48-hour mark.[24]

Conversely, a study by Nasser et al assessing recovery following a soccer match using CWI, a placebo drink, or passive rest, observed no significant differences in CRP levels among the groups up to 48 hours post-intervention.[25]

Interleukin-6

IL-6, another inflammatory marker, increases after physical exertion and typically requires targeted recovery interventions for normalization. In four studies examining the effects of CWI on IL-6, disparate results were reported. One meta-analysis that evaluated several recovery modalities found that massage led to the greatest reduction in IL-6 levels, followed by CWI.[37]

A study focusing on novice athletes reported that IL-6 levels were significantly lower in the CWI group 24 hours post-intervention, although no significant differences were noted at 48 hours. In general, other studies have not found significant alterations in IL-6 levels following CWI.[39] Furthermore, another meta-analysis explicitly examining CWI's effects on fatigue markers concluded that this method did not significantly affect IL-6 levels compared to controls up to 48 hours post-intervention.[24] Similarly, Leeder et al divided 21 trained male soccer players into passive rest and CWI groups following the LIST test and reported no significant differences in IL-6 levels between groups up to 24 hours post-intervention.[40]

Rating of Perceived Exertion

A meta-analysis investigating the impact of CWI as a recovery strategy across various sports, including soccer, demonstrated that Borg scale ratings of perceived exertion (RPE, 6–20) were significantly lower in the CWI group immediately and up to 24 hours post-intervention compared to controls.[24]

In another study involving 16 male professional soccer players subjected to high-intensity cycling in a hot, humid environment, participants were assigned to three recovery protocols: passive rest, whole-body cryotherapy, or CWI. Those employing cold-based recovery interventions reported significantly lower RPE values for up to 20 minutes post-intervention compared to those undergoing passive rest.[36]

A crossover study of 20 male athletes (aged 20–24) who completed interval training followed by either passive rest or CWI reported that RPE scores were significantly lower in the CWI group at both 6 and 20 minutes after the intervention.[41] Another meta-analysis similarly noted that although RPE levels were significantly reduced in the CWI group immediately and up to 24 hours post-intervention, no significant changes were observed between 24 and 96 hours afterward.[42]

In contrast, a recent study in which trained athletes ran for 45 minutes at 95% of their lactate threshold and subsequently underwent passive rest, warm-water immersion at 40 ˚C, or CWI at 14 ˚C, found no significant differences in RPE among the groups within six hours post-intervention.[43]

Delayed Onset Muscle Soreness

A meta-analysis evaluating the effects of CWI on fatigue indicators across various sports, including soccer, reported that DOMS was significantly lower immediately following the intervention and up to 48 hours later.[24] In a study involving 60 male novice athletes from diverse sports performing lower-body plyometric exercises, participants were divided into four groups: passive rest, massage, CWI, and a combined method. The results indicated that the CWI group experienced a significant decrease in DOMS levels, whereas no significant changes were noted in the other groups.[44] Another meta-analysis focusing specifically on elite and semi-professional soccer players demonstrated that DOMS was significantly reduced in those undergoing CWI immediately after and up to 48 hours following the intervention.[21]

A recent investigation comparing partial cryotherapy with CWI in female athletes post-exercise indicated that DOMS levels were significantly lower in both intervention groups, particularly in the CWI group, up to 72 hours post-recovery, relative to passive rest controls.[42] In another study by Siqueira et al, 30 active male athletes were divided into either a control group (passive rest) or a CWI group following an exercise protocol. The CWI

group, which underwent 20 minutes of immersion at 10 ˚C, returned to baseline DOMS levels within 168 hours, while the control group maintained elevated DOMS levels.[45] Finally, a meta-analysis of different recovery methods across different sports confirmed that DOMS significantly decreased following recovery interventions such as massage and CWI.[37]

Discussion

After reviewing the literature on the effects of CWI following training sessions, simulated matches, or actual soccer matches, the present study found that this recovery method can significantly alleviate fatigue-related factors and symptoms. The mechanisms underlying these effects have been extensively discussed in previous research. For instance, strenuous physical activity typically increases the production of reactive oxygen species and reactive nitrogen species, which diminish calcium sensitivity and activity, thereby impairing performance. These free radicals also reduce neurosignaling, contributing to central fatigue. CWI appears to mitigate these effects by inhibiting free radical production, thereby reducing inflammation and fatigue.[46] Moreover, CWI lowers core body temperature and decreases vascular permeability, which enhances venous return. This process accelerates the clearance of metabolic waste products, reduces inflammation, and diminishes muscle damage indicators.[47] Additionally, the reduction in core and surface body temperatures decreases nerve conduction velocity and blood flow to peripheral tissues, which helps alleviate muscle pain, inflammation, lactate accumulation, and other markers of muscle damage.[48] Another proposed mechanism is the anti-gravitational effect of cold water, which may lessen the subjective perception of fatigue.[49] Furthermore, cold exposure promotes endorphin release, thereby improving mood and reducing sensations of pain and stress.[50]

Conclusion

CWI is widely used as a recovery modality in soccer and other sports. The evidence synthesized in the present study indicates that CWI, when applied after training, simulated matches, or competitive games, significantly reduces markers of muscle damage, inflammation, perceived exertion, and delayed-onset muscle soreness. Although some studies have reported that CWI does not significantly improve certain fatigue indicators, the overall findings suggest that it remains an effective method to alleviate fatigue and enhance subsequent performance, particularly during periods of high activity volume among soccer players. Future research should include well-controlled studies that consider participant gender, performance level, age group, the volume and intensity of pre-intervention activity, and the specific temperature and dosage of cold water applied. Such research would contribute to more reliable and nuanced findings in this field.

Authors' Contribution

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Competing Interests

None.

Ethical Approval

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