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Effectiveness of recovery methods in reducing delayed onset muscle soreness (DOMS): A narrative review

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Abstract

Background. Delayed onset muscle soreness (DOMS) represents a significant physiological challenge in professional and recreational sports, characterized by muscle tenderness, stiffness, and reduced force production peaking 24–72 hours post-exercise.

Aim. The primary aim of this study is to evaluate the effectiveness of widely implemented recovery strategies—stretching, massage, foam rolling, cryotherapy, compression garments, and nutritional supplementation—in reducing DOMS.

Material and methods. A narrative review was conducted based on an analysis of peer-reviewed literature indexed in PubMed, Scopus, and Web of Science. The review focuses on mechanisms of action, practical application protocols, and reported outcomes of interventions targeting exercise-induced muscle damage (EIMD).

Results. Current evidence indicates that stretching has a negligible influence on DOMS reduction. Conversely, massage and foam rolling significantly alleviate perceived soreness through neuromuscular and myofascial modulation. Cryotherapy yields mixed results, offering short-term analgesic benefits while potentially blunting long-term hypertrophic adaptations. Compression garments demonstrate moderate effectiveness in reducing swelling and perceived fatigue. Nutritional strategies, particularly omega-3 fatty acids and polyphenols, show potential for modulating inflammation.

Conclusions. Effective recovery requires a multimodal approach. While mechanical therapies (massage, foam rolling) provide superior symptom relief, thermal and nutritional interventions should be periodized according to training goals. Stretching should not be employed as a primary tool for DOMS reduction.

Key words: DOMS, recovery, foam rolling, cryotherapy, compression garments, muscle damage, regeneration.

1. Introduction

Delayed onset muscle soreness (DOMS) is a ubiquitous phenomenon in sports and rehabilitation, typically manifesting after unaccustomed high-intensity physical activity, particularly those involving significant eccentric muscle contractions. From a physiological perspective, DOMS is classified as a type 1b muscle strain injury, characterized by ultrastructural damage to myofibrils (specifically Z-line streaming), degradation of structural proteins such as desmin and titin, and a subsequent acute inflammatory response [1]. The sensation of pain and stiffness usually initiates 12 to 24 hours after exercise, peaks between 24 and 72 hours, and can persist for up to 5–7 days depending on the intensity of the stimulus and the individual's training status [2].

Although DOMS is often viewed as a necessary precursor to adaptation, its presence can significantly impair athletic performance. The functional deficits associated with DOMS include reduced range of motion (ROM), decreased maximal voluntary contraction (MVC), altered muscle recruitment patterns, and compromised proprioception [3]. In a high-performance environment where training frequency is high, these impairments can disrupt training continuity and increase the risk of secondary injuries.

Consequently, the global increase in performance-oriented training has intensified scientific and practical interest in recovery modalities. Coaches and physiotherapists employ a diverse arsenal of strategies, ranging from traditional methods like stretching and massage to modern technologies such as whole-body cryotherapy and pneumatic compression. However, the scientific consensus regarding the efficacy of these interventions remains fragmented. While some methods like foam rolling have gained strong empirical support recently, others have seen their efficacy challenged by rigorous meta-analyses [4].

Research Purpose. The primary aim of this study is to critically evaluate the effectiveness of commonly used recovery methods in reducing DOMS through a comprehensive review of current scientific evidence.

Research Problem. Which recovery strategies yield measurable and clinically significant reductions in DOMS intensity according to peer-reviewed studies?

Research Hypothesis. Based on the current body of literature, it is hypothesized that mechanical interventions (massage, foam rolling) will demonstrate greater effectiveness in reducing subjective soreness compared to passive stretching or cryotherapy.

2. Research materials and methods.

2.1. Study Design

This article is designed as a narrative literature review. This methodological approach was selected due to the heterogeneity of recovery protocols (e.g., varying durations, intensities, and timings) and the diversity of outcome measures (subjective pain scales vs. objective biomarkers) found in the literature. A narrative review allows for a holistic synthesis of experimental, observational, and meta-analytic data to provide a coherent overview of the state of the art.

2.2. Data Collection

A structured literature search was conducted using major scientific databases, including PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar. The search strategy focused on articles published primarily in the last two decades (2000–2024), although seminal works describing the fundamental mechanisms of DOMS were also included.

The search algorithms employed Boolean logic with the following keywords and phrases: "delayed onset muscle soreness" OR "DOMS" OR "exercise-induced muscle damage" AND "recovery methods" OR "foam rolling" OR "cryotherapy" OR "massage" OR "stretching" OR "compression garments" OR "nutritional supplementation".

2.3. Inclusion and Exclusion Criteria

To ensure the high quality of the review, the following inclusion criteria were applied:

- Studies involving healthy human participants (both athletes and recreationally active individuals).
- Interventions applied post-exercise with the specific intent of recovery.
- Outcomes reporting either subjective measures of soreness (e.g., Visual Analogue Scale - VAS, Likert scales) or objective markers of recovery (e.g., Creatine Kinase - CK, range of motion, force production).
- Publication in English-language peer-reviewed journals.

Exclusion criteria included non-peer-reviewed articles, studies involving animal models, and research focusing on injury rehabilitation rather than post-exercise recovery.

3. Results

The literature search yielded a vast array of studies investigating various recovery modalities. The findings are categorized below by intervention type.

3.1. Stretching

Stretching remains arguably the most traditional and culturally embedded recovery method in sports. The prevailing dogma suggests that elongating the muscle-tendon unit reduces stiffness, enhances blood flow, and thereby alleviates DOMS. However, contemporary scientific evidence largely refutes this assumption.

A landmark Cochrane systematic review by Herbert and de Noronha, which analyzed data from over 2,500 participants, concluded that stretching—whether performed before, during, or after exercise—does not produce a clinically meaningful reduction in DOMS. The pooled data indicated that stretching reduced soreness by less than 2 points on a 100-point scale, a magnitude considered trivial and imperceptible to the athlete. Furthermore, aggressive static stretching immediately following eccentric exercise may theoretically exacerbate microtrauma in the Z-lines, potentially prolonging the recovery phase rather than shortening it. While stretching is vital for long-term flexibility and ROM maintenance, its isolated application as an acute antidote to DOMS is not supported by data [5].

3.2. Massage Therapy

In contrast to stretching, manual massage therapy is widely recognized as one of the most effective strategies for alleviating the symptoms of DOMS. Hilbert et al. demonstrated that a deep tissue massage applied 2 hours post-exercise did not significantly alter neutrophil infiltration or muscle function but dramatically reduced perceived soreness intensity at 48 hours [6].

The effectiveness of massage is attributed to several mechanisms:

1. **Hemodynamic Changes:** Massage may enhance local microcirculation, theoretically facilitating the clearance of metabolic by-products, although the clearance of lactate is irrelevant for DOMS (which is structurally mediated). More likely, improved blood flow assists in the delivery of nutrients required for tissue repair.

2. **Neural Modulation:** Mechanical pressure stimulates cutaneous and subcutaneous mechanoreceptors, which may inhibit nociceptive transmission at the spinal cord level (Gate Control Theory) [7].

3. **Psychological Effect:** The reduction in anxiety and perception of fatigue contributes to an improved subjective state of recovery.

A meta-analysis by Dupuy et al. ranked massage as the single most effective technique for reducing DOMS compared to active recovery, cryotherapy, and compression, with a moderate to large effect size [4].

3.3. Foam Rolling (Self-Myofascial Release)

Foam rolling (FR) has emerged as a cost-effective and logistically viable alternative to manual massage. It involves the athlete using their body weight to apply pressure to soft tissues over a dense foam cylinder. Research by MacDonald et al. was pivotal, demonstrating that a 20-minute bout of FR immediately post-exercise, and repeated at 24 and 48 hours, significantly attenuated perceived muscle soreness and improved vertical jump height compared to a control group [8].

Pearcey et al. corroborated these findings, reporting that FR (5 sets of 30 seconds per muscle group) improved pain pressure threshold (PPT) and sprint performance [9]. The mechanisms of FR are believed to be similar to massage but also include the restoration of fascial sliding surfaces (thixotropy) and acute improvements in arterial stiffness. Importantly, unlike static stretching, FR appears to improve range of motion without inducing performance impairments (force deficits), making it a superior choice for both warm-up and recovery [10]. Recent meta-analyses confirm these beneficial effects on performance recovery [11].

3.4. Cryotherapy and Cold Water Immersion (CWI)

Cryotherapy, particularly Cold Water Immersion (CWI), is a staple in team sports. The premise is that cold exposure induces vasoconstriction, reduces fluid filtration into the interstitial space (reducing edema), and slows nerve conduction velocity, providing an analgesic effect [12].

Bleakley et al. found that CWI (typically 10–15 minutes at 10–15°C) provides significantly better management of muscle soreness than passive rest up to 96 hours post-exercise [13][14]. However, the data regarding objective markers (CK, CRP, IL-6) are inconsistent. While effective for symptom management (pain relief), there is a growing body of evidence, such as the work by Roberts et al., suggesting that CWI may be detrimental during hypertrophy phases. By suppressing the acute inflammatory response, CWI may blunt the upregulation of satellite cells and the mTOR pathway, essentially "freezing" the adaptive signal. Therefore, CWI is best utilized during congested competitive schedules where performance restoration is prioritized over physiological adaptation [15].

3.5. Compression Garments

Compression garments (CGs) have become ubiquitous in endurance and power sports. They are designed to apply a mechanical pressure gradient to the limbs, thereby enhancing venous return, reducing exercise-induced edema, and minimizing muscle oscillation during movement.

A meta-analysis by Brown et al. indicated that wearing compression garments for 24 hours post-exercise led to moderate reductions in DOMS and perceived fatigue [16]. This is supported by Hill et al., who highlighted the recovery of muscle function [17]. The constant external pressure serves as a "dynamic cast," limiting space for swelling and providing proprioceptive feedback. While CGs may not drastically accelerate the repair of structural damage, their ability to maintain limb function and reduce the sensation of heaviness makes them a valuable, low-effort recovery tool that can be used passively (e.g., during travel or sleep) [18].

3.6. Nutritional Strategies

Nutritional interventions target the biochemical cascade of DOMS.

- **Omega-3 Fatty Acids:** Tartibian et al. highlighted that chronic supplementation with Omega-3s (rich in EPA and DHA) reduces the production of pro-inflammatory cytokines (IL-6, TNF-a) and decreases perceived soreness following eccentric exercise [19].
- **Polyphenols:** Compounds found in tart cherry juice and pomegranate extract have been shown to accelerate the recovery of isometric strength and reduce oxidative stress markers. These antioxidants likely neutralize reactive oxygen species (ROS) generated during the secondary phase of muscle damage [20].
- **Creatine Monohydrate:** Beyond its ergogenic role, creatine may stabilize sarcolemmal membranes and maintain intracellular calcium homeostasis, potentially mitigating the extent of secondary muscle damage [21].

Table 1. Summary of Evidence for Common Recovery Modalities.

Recovery Method	Efficacy for DOMS Reduction	Effect on Function/Performance	Primary Mechanism	Best Application Context
Stretching	Low Negligible	/Neutral	Change in stretch tolerance	Flexibility training, relaxation
Massage	High	Moderate Positive	Neural inhibition, fluid dynamics	Post-competition, heavy training blocks
Foam Rolling	High	Moderate Positive	Fascial release, neural modulation	Daily maintenance, acute recovery

Cryotherapy (CWI)	Moderate to High	Mixed (Context dependent)	Vasoconstriction, analgesia	Congested fixtures, tournaments
Compression	Moderate	Low to Moderate	Edema reduction, venous return	Travel, passive recovery periods
Active Recovery	Low	Neutral	Metabolite clearance (blood flow)	Post-exercise cool-down

4. Discussion

The synthesis of current literature reveals a complex landscape where "one-size-fits-all" recovery protocols are obsolete. The effectiveness of a recovery strategy is not binary but depends on the interaction between the physiological mechanism of the intervention and the specific phase of DOMS.

4.1. The Disconnect Between Physiology and Perception

A recurring theme in the review is the dissociation between subjective feelings of soreness and objective markers of muscle damage. Mechanical interventions like massage and foam rolling consistently score highest for reducing perceived pain [4]. This is likely due to their impact on the nervous system rather than the actual acceleration of sarcomere repair. By stimulating mechanoreceptors (Ruffini and Pacinian corpuscles), these therapies may override nociceptive signals. This "perceptual recovery" is crucial for athlete adherence and psychological readiness to train, even if the underlying tissue histology remains in a state of repair.

4.2. The Inflammation Paradox

The discussion regarding cryotherapy and anti-inflammatory supplementation (NSAIDs, high-dose antioxidants) highlights a critical balance. Inflammation is a double-edged sword: it causes pain and secondary damage (via oxidative stress), but it is also the primary signal for tissue remodeling and hypertrophy. As shown by Roberts et al. [14], blunting this response via aggressive cooling can impair long-term gains. Furthermore, the use of NSAIDs has also been debated regarding its impact on skeletal muscle development [22]. Therefore, practitioners must periodize recovery. During the off-season or hypertrophy phases, allowing the natural inflammatory process to occur (avoiding CWI) may be superior. Conversely, during playoffs or multi-stage races, managing inflammation to restore function takes precedence.

4.3. Practical Integration

Based on the results, a hierarchical approach to DOMS management is recommended:

1. **Immediate Phase (0-2h post-exercise):** Active cool-down and nutrition (protein/carbohydrate resynthesis) are priorities. Foam rolling can be applied here.

2. **Acute Phase (2-24h post-exercise):** Compression garments and nutritional support (omega-3, polyphenols) offer passive benefits. Sleep optimization is critical.

3. **Peak DOMS Phase (24-72h post-exercise):** Massage and foam rolling are most effective here to manage symptoms and restore ROM. Light active recovery (e.g., cycling, swimming) can assist in "flushing" tissues without adding eccentric load.

4.4. Limitations of Current Research

While the evidence base is growing, limitations persist. Many studies utilize untrained participants, whose response to eccentric load is vastly different from elite athletes (the "repeated bout effect"). Additionally, the placebo effect in recovery research is difficult to control; athletes who believe a therapy works often report better outcomes, confounding the physiological data.

5. Conclusions

This narrative review underscores that DOMS is a multifaceted physiological event requiring a nuanced recovery approach.

1. **Massage and Foam Rolling** are currently the most evidence-based interventions for reducing the sensation of soreness and restoring range of motion, likely through neurophysiological and mechanical pathways.

2. **Compression Garments** provide a useful, passive recovery tool effective for managing swelling and perceived fatigue.

3. **Cryotherapy** is a potent analgesic tool but should be periodized; its chronic use may be detrimental to muscle adaptation.

4. **Stretching** has minimal impact on DOMS symptoms and should not be relied upon as a primary recovery modality for muscle soreness.
5. **Nutrition** acts as a foundational support system, with promising roles for specific anti-inflammatory nutrients.

Ultimately, the most effective recovery protocol is likely a multimodal strategy tailored to the specific demands of the sport and the immediate goals of the athlete (adaptation vs. performance restoration).

Disclosure:

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