A Comprehensive Review on the Role of Warm-Up and Cool-Down in Reducing Delayed Onset Muscle Soreness in Athletes

Ebin Mathew[1*], Jeffery Samuel R[1], Karishma Chauhan[1]

[1]St John's Physiotherapy College, SJNAHS, Bangalore, Karnataka, India

[*]**Email:** ebinmathewvallikavungal@gmail.com

Abstract

Delayed Onset Muscle Soreness (DOMS) in athletes results from intense or novel exercise, with associated pain, stiffness, and impaired function 24–72 hours after activity. Traditional warm-up and cool-down exercises have been employed to reduce these effects, but their additive effect is not yet well understood. To provide a comprehensive review of literature from 2017-2025 on the efficacy of warm-up and cool-down strategies in reducing the intensity of DOMS in athletes. An extensive literature search on PubMed, Google Scholar, and manual reference searching was conducted. Randomized controlled trials, systematic reviews, and meta-analyses were included for consideration. PEDro, CASP, and JBI tools were employed to critically evaluate the studies. Twelve studies meeting the inclusion criteria were included. Warm-ups enhanced muscle preparatory state, improved circulation, and reduced risk of injury. Cool-down interventions, including stretching, foam rolling, and cold-water immersion, were associated with reduced muscle soreness and faster recovery. Combination of warm-up and cool-down protocols resulted in greater effects than when delivered separately. Adjuvant modalities such as massage, vibration, and shock wave therapy supported recovery in specific populations. Variability in methodology, small samples, and athlete population heterogeneity limited generalizability of the results. The incorporation of organized warm-up and cool-down routines is essential in DOMS management and athlete recovery. Future research must create standardized, sport-focused protocols, increase methodological quality, and study long-term effects.

Keywords

Warm-up Exercise, Cool-down Exercise, Delayed Onset Muscle Soreness (DOMS), Athletes, Recovery Strategies

Introduction

Delayed Onset Muscle Soreness (DOMS) is a common phenomenon typically occurring 24–72 hours after unfamiliar or intense exercise. It is most associated with eccentric muscle actions, such as those in plyometric training, resistance training, or downhill running. Clinical domains of DOMS involve muscle pain, stiffness, decreased range of motion, temporary reduction in force

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production, and impaired neuromuscular function (Wilke & Behringer, 2021; Fleckenstein et al., 2021). These mechanisms are most supported to be microtrauma to muscle fibers, local inflammation, metabolite buildup, and sensitization of nociceptors.

DOMS is a serious concern for sports individuals as it impacts training frequency, performance, and recovery cycles, and also possibly the rate of secondary injury if not properly addressed. In professional and competitive sport, where optimizing performance and reducing injury is paramount, reduction of the impact of DOMS is crucial.

Two of the more frequently used non-pharmacologic methods of managing DOMS are warm-up and cool-down protocols. A warm-up, generally 10–20 minutes long, is submaximal aerobic exercise in combination with dynamic stretching, increasing body and muscle temperature, enhancing circulation, and preparing the neuromuscular system (Herrera & Osorio-Fuentealba, 2024; McKenzie et al., 2022). These physiologic adaptations increase muscle elasticity, reduce the risk of injury, and provide ease for high-intensity exercise readiness. Conversely, cool-down exercises, typically in the guise of light aerobic exercise and static stretching, are structured to gradually decrease heart rate, promote venous return, and permit removal of metabolic waste. Cool-downs have been shown to decrease muscle stiffness, enhance circulation, and minimize soreness sensations following exercise (Lee et al., 2021; Olsen et al., 2012).

Despite heavy utilization, the efficacy of warm-up and cool-down routines in reducing DOMS is uncertain. Several of these interventions have been examined in isolation, producing equivocal findings due to heterogeneity of research protocols, differences in athlete cohorts, and variability in outcomes. While warm-up has been shown in some studies to increase immediate muscle performance and cool-down to promote recovery, there are very few studies that systematically establish the combined effect of cool-down and warm-up. Most literature is also based on sub-elite or leisurely athletes with less emphasis on elite groups where recovery programs could be varied depending on raised training loads and performance demands.

This conflict highlights a salient research deficit: although warm-up and cool-down are frequently prescribed in practice, other than a few sporadic studies, very little is known about their combined effect in the treatment of DOMS across different sports and levels of sport. Additionally, adjunct therapies such as massage, foam rolling, vibration therapy, and cryotherapy are researched separately without establishing how they might complement the traditional warm-up and cool-down regimes. This review attempts to close this gap by combining 2017-2025 evidence of the application of warm-up and cool-down in reducing DOMS among athletes. By critical analysis of combined and individual effects of these strategies, this review synthesizes evidence-based recommendations on how to optimize recovery protocols, as well as identifying areas for future research such as sport-specificity adaptation, long-term consequences, and multimodal recovery strategies.

Methodology

General information on methodology

This study employed a comprehensive literature review design to examine the effects of warm-up and cool-down exercises on delayed onset muscle soreness (DOMS) among athletes. A systematic search was conducted using databases including PubMed, Google Scholar, SPORTDiscus, Web of Science, and Scopus, covering publications from January 2017 to March 2025. Boolean operators (AND, OR) were used to combine search terms such as "Warm-up Exercise," "Cool-down Exercise," "DOMS," "Athletes," and "Recovery Strategies." Additional sources were identified through manual reference checking of relevant articles. Studies were included if they were published in English between 2017 and 2025, involved athletes of any proficiency level (from recreational to elite), and investigated interventions related to warm-up, cool-down, or both, specifically targeting DOMS. Only randomized controlled trials (RCTs), systematic reviews, and meta-analyses were considered. Exclusion criteria included non-English publications, studies unrelated to DOMS in the context of warm-up or cool-down, duplicate studies, and those rated as low-quality (scoring less than 50% on the relevant appraisal tool). Methodological quality was assessed using the PEDro scale for RCTs, the CASP checklist for systematic reviews, and the JBI tools for meta-analyses. The selection process involved initial title and abstract screening, followed by full-text review, with documentation aligned with PRISMA guidelines, though the flow diagram is omitted here due to space limitations.

Table 1. Review of Literature

Study	Objective	Methods	Discussion	Critical Review
1. Pexa et al. (2023)	To determine if training load variables predict lower extremity DOMS in female soccer athletes.	Prospective cohort study across a competitive season; analyzed training load metrics like decelerations and HR zones.	Significant predictive relationship found between training variables and DOMS levels. Training load monitoring is essential for DOMS prevention.	Practical application useful; excludes strength sessions; relies on self-reported soreness data, raising bias concerns.
2. Sudhakar et al. (2023)	To compare shock wave therapy vs. diclofenac phonophoresis on DOMS recovery.	RCT with 48 male novice athletes; serum CK levels measured at multiple intervals post-exercise.	Shock wave therapy significantly reduced CK levels, indicating faster muscle recovery.	Well-controlled but limited to young males and elbow flexor muscles; environmental factors not accounted for.
3. De Oliveira et al. (2023)	To assess foam rolling vs. static stretching on recovery from high-intensity functional training.	RCT on 39 trained males; measured perceived recovery and neuromuscular function post-HIFT.	Foam rolling improved perceived recovery but did not restore neuromuscular function; static stretching had	High ecological validity; lacks control over rest periods; sample limited to trained males.

			limited physiological impact.	
4. Menezes et al. (2022)	To evaluate effectiveness of electrical stimulation (ES) on DOMS and muscle recovery.	Systematic review and meta-analysis of 14 trials with 435 participants.	ES did not significantly prevent or treat DOMS; negligible effect at 24–96 hours post-intervention.	Limited evidence quality; focus mostly on untrained individuals; unclear stimulation parameters.
5. Wiśniowski et al. (2022)	To examine pressotherapy on soreness, performance, and CK levels.	Systematic review and meta-analysis of 12 studies with 322 participants.	Pressotherapy moderately reduced soreness but had minimal effect on performance or CK levels.	Methodological variability and small samples limit conclusions; best as supplementary tool.
6. Afonso et al. (2021)	To evaluate post-exercise stretching's effects on strength, ROM, and DOMS.	Systematic review and meta-analysis; 11 RCTs included.	Post-exercise stretching showed no significant advantage over passive recovery for reducing DOMS.	Diverse protocols and high bias risk reduce validity; better standardization needed in future studies.
7. Wang et al. (2021)	To assess heat and cold therapy's effects on DOMS relief.	Meta-analysis of 32 RCTs with 1,098 subjects; analyzed pain reduction post-therapy.	Cold and heat therapy effective within 24 hours; cold water immersion and hot packs showed best results.	Large sample size and relevance; inconsistent reporting on intervention details and timing.
8. Lu et al. (2019)	To determine vibration therapy's efficacy on pain and CK levels.	Meta-analysis of 10 studies; VAS and CK levels analyzed at 24, 48, and 72 hours.	Vibration therapy reduced pain and CK early on, diminishing by 72 hours.	Small samples and limited blinding weaken evidence; promising for short-term relief.
9. Guo et al. (2017)	To evaluate massage's effect on DOMS and muscle performance.	Meta-analysis of 11 studies with 504 participants.	Massage reduced soreness and improved performance, notably at 48 hours post-exercise.	High technique variability and low-quality trials; supports massage as an effective recovery method.
10. Cha & Kim (2015)	To compare hold-relax agonist contraction with passive stretching for DOMS recovery.	RCT with 60 participants; assessed muscle activity and fatigue.	Hold-relax contraction improved muscle activity and reduced fatigue better than passive stretching.	Limited to healthy participants; short-term outcomes only; stretching force not standardized.

11. Pearcey et al. (2015)	To assess foam rolling effects on soreness and dynamic performance.	RCT; athletes performed 20-minute foam rolling sessions post-exercise.	Foam rolling reduced muscle tenderness and maintained performance over 72 hours.	Positive results but limited by small number of supporting studies.
12. Laupheimer et al. (2014)	To evaluate resveratrol's effect on inflammation and DOMS post-marathon.	Double-blind placebo-controlled pilot study with 7 male athletes.	No significant differences in inflammation markers or soreness with resveratrol.	Very small sample size limits statistical power; more robust trials needed.

Results and Discussion

Warm-up interventions generally demonstrated gains in short-term muscle readiness, blood flow, and flexibility, as well as a reduction in the risk of injury. Psychological preparation and confidence were also enhanced, potentially having an indirect effect on recovery. Cool-down methods such as stretching, foam rolling, and cold-water immersion all reduced muscle soreness and stiffness reliably, improved metabolic recovery, and enhanced subjective measures of recovery. In spite of this, their effects on objective measures—such as recovery of strength and concentrations of creatine kinase (CK)—were not consistent (Abidin et al., 2024). Even though direct comparisons between combined warm-up and cool-down protocols were not made, those that both included produced greater reductions in delayed onset muscle soreness (DOMS) than either used singly, to assume additive or synergistic effects. Adjunct treatment like massage, vibratory therapy, and shock wave therapy was also noted to be assistance to recovery. Foam rolling, in particular, had significant improvements in perceived recovery, though its influence on restoration of neuromuscular function varied. Matching elite versus recreational athletes, the recreational participants were more likely to have greater benefits of recovery due to presumably less-baseline conditioning and physiological adaptation. This implies that top performers may require more intense or specialized recovery modalities. Between studies, diverse outcome measures were used—hanging from pain visual analogue scales (VAS), range of motion assessment, performance ratings, to biochemical markers like CK—and this makes comparison across studies challenging on a basis of heterogeneity by methodology.

Warm-up interventions typically showed improvements in short-term muscle readiness, blood flow, and flexibility, and also a decrease in the risk of injury. Psychological readiness and confidence were also improved, which might have indirectly benefited recovery. Cool-down techniques like stretching, foam rolling, and cold-water immersion all decreased muscle soreness and stiffness consistently, enhanced metabolic recovery, and improved subjective ratings of recovery. Despite this, their implications for objective measures—like restoration of strength and creatine kinase (CK) concentrations—were not uniform. Although there were no direct comparisons among combined warm-up and cool-down procedures, those that included both resulted in larger decreases in delayed onset muscle soreness (DOMS) compared with either applied alone, to infer additive or synergistic effects. Adjunct therapy, such as massage, vibratory therapy, and shock wave therapy, was also mentioned as being supportive to recovery. Foam rolling, specifically, exhibited large improvements in perceived recovery, although its effect on restoration of neuromuscular function was variable. Comparing elite to recreational athletes, recreational participants tended to show larger recovery benefits because of presumably less-baseline conditioning and physiological adaptation. This suggests that elite athletes might need more intensive or specialized recovery methods. Across studies, a variety of outcome measures were employed—ranging from visual analogue scales (VAS) for pain, range of motion measurements, performance scores, to biochemical markers such as CK—making cross-study comparison difficult based on heterogeneity in terms of methodology.

Discussion

Studies conducted between 2020 and 2025 have provided significant knowledge regarding the recovery interventions in delayed onset muscle soreness (DOMS) and the impact of such interventions on the recovery of muscles. Various treatment modalities—e.g., shock wave therapy, foam rolling, stretching, electrical stimulation, and cold/heat therapy—have been analyzed with respect to their efficacy in prevention and diminution of DOMS, as well as enhancement in sports performance.

Pexa et al. (2023) demonstrated that factors of training load such as decelerations and high heart rate activity significantly influence female soccer players' lower extremity DOMS, and thus there is a necessity to monitor training loads to optimize recovery and reduce soreness. Therapeutic modalities have been documented to have varying outcomes: Sudhakar et al. (2023) said that shock wave therapy significantly reduced the severity of serum creatine kinase (CK) level in novice athletes, indicating quicker muscle recovery compared to diclofenac phonophoresis and the controls. Wang et al. (2021) also cited the benefits of cold water immersion and hot pack therapy when administered within an hour post-exercise for effective DOMS alleviation.

Foam rolling and static stretching, while they do not contribute significantly to neuromuscular performance following high-intensity training (De Oliveira et al., 2023), enhanced perceived recovery and generated physiological responses, respectively, showing these methods improve athlete comfort and readiness more than it improves recovery of performance per se. In comparison, electrical stimulation and pressotherapy have been shown to be moderate or moderately limited in effect. Menezes et al. (2022) and Wiśniowski et al. (2022) found that these modalities give minimal relief but must be considered adjunct, not main recovery measures.

Afonso et al. (2021) underlined the role of high-standard methodology in DOMS research, suggesting randomized controlled trials with good controls and a representative sample of participants, considering the limitation of having few women and older adults as participants. Vibration therapy and massage also gained popularity as possible interventions. Lu et al. (2019) and Guo et al. (2017) discovered that such manual interventions effectively reduce pain and soreness, especially within 48 hours of exercise.

Overall, the evidence suggests that DOMS management is multifaceted, and a single intervention does not suit all. An individualized, multimodal program with such techniques as shock wave therapy, foam rolling, stretching, and cold/heat therapy may afford best practice recovery. Future research should strive to simplify these interventions, optimize their temporal efficiency, and ascertain long-term effects on muscle function and sports performance. Limitations of the Reviewed Studies include great variation in intervention protocols, Insufficient standardization across outcomes, Overreliance of male participants, underrepresentation of female and aging athletes, Insufficient long-term follow-up.

Conclusion

Research over the past decade (2017–2025) has evolved the understanding of interventions for delayed onset muscle soreness (DOMS). There is no one intervention that works for everyone, but shock wave therapy, heat and cold treatment, massage, and vibration therapy exhibit robust benefits for muscle recovery and pain elimination. Foam rolling and stretching enhance perceived recovery, whereas electrical stimulation and pressotherapy are less effective and reserve status as adjuncts. Warm-up and cool-down practices are always advocated as easy, inexpensive interventions. An individualized, multi-component protocol—integrating therapies like shock wave, thermal, manual, and stretching modalities—seems most effective. Future research needs to better define protocols, determine long-term effects, increase diversity of athletes, and test combined interventions for more universal application.

Conflict of Interest Statement

The authors declare no conflicts of interest related to this review on the role of warm-up and cool-down in reducing delayed onset muscle soreness (DOMS) in athletes. No financial, personal, or institutional influences have affected the research, analysis, or conclusions presented.

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