Thermal Modalities Including Hot Baths and Cold Plunges Play a Unique Role in Injury Prevention and Recovery

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Abstract: There are several different modalities for injury prevention to consider in order to help our patients' reach their ultimate goals. The purpose of this review is to analyze the use of hot and cold therapies to prevent injury. Thermotherapy has been used in clinical rehabilitation settings to treat health conditions. The therapeutic use of cold, known as cryotherapy, is historically the most popular treatment for acute musculoskeletal injury or fatigue. Cold therapy was seen to decrease delayed-onset muscle soreness and help resolve global or generalized muscle injury or fatigue. In sum, both cold and hot therapy play similar but unique roles in injury prevention and recovery. The key to effective use of either depends on understanding the nature of the injury and mastering the appropriate timing of therapeutic application. By leveraging the unique mechanisms of each modality, athletes can optimize their recovery process and reduce the risk of future injury.
Level of Evidence: Level V, expert opinion.

There is a plethora of modalities to consider when it comes to effective injury prevention. Cold therapy, also known as cryotherapy, uses applications of cold to decrease the temperature of the tissue. This decrease in temperature can be achieved through ice massage, ice packs, whirlpools, or cryotherapy devices. In contrast, hot therapy, also known as thermotherapy, employs applications of heat to increase tissue temperature. This escalation in temperature can be achieved using hot packs, paraffin baths, dry heat therapy, hydrotherapy, ultrasonography, microwave diathermy, and infrared radiation.[1] Often patients who undergo strenuous activity or exercise will experience the development of delayed-onset muscle soreness (DOMS), which is a type of ultrastructural muscle injury and a result of eccentric muscle contractions or unfamiliar exercises.[2] DOMS often begins 6 to 12 hours postexercise and reaches its peak between 48 and 72 hours. DOMS eventually subsides between 5 and 7 days.[3] To prevent injury, avoid overtraining, and promote peak physical performance to improve the quality of subsequent training sessions, it is critical to accelerate the recovery period of neuromuscular function after exercise. This can be achieved by decreasing the development of DOMS through either hot or cold modalities.[4] However, the literature lacks consensus regarding the efficacy of these treatments in injury prevention. The purpose of this article is to review and compare the current use of hot and cold therapies to prevent injury.

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Hot Modalities

Methods

A systematic literature search was conducted to investigate the effects of heat therapy on injury prevention and muscle recovery. Three databases, PubMed, EMBASE, and Cochrane, were searched using the following search terms: ("heat therapy" or "superficial heat therapy" or "hot water immersion" or "heat stress" or "thermotherapy") and ("recovery" or "injury prevention"). The reference lists of the articles initially obtained were then searched manually to obtain

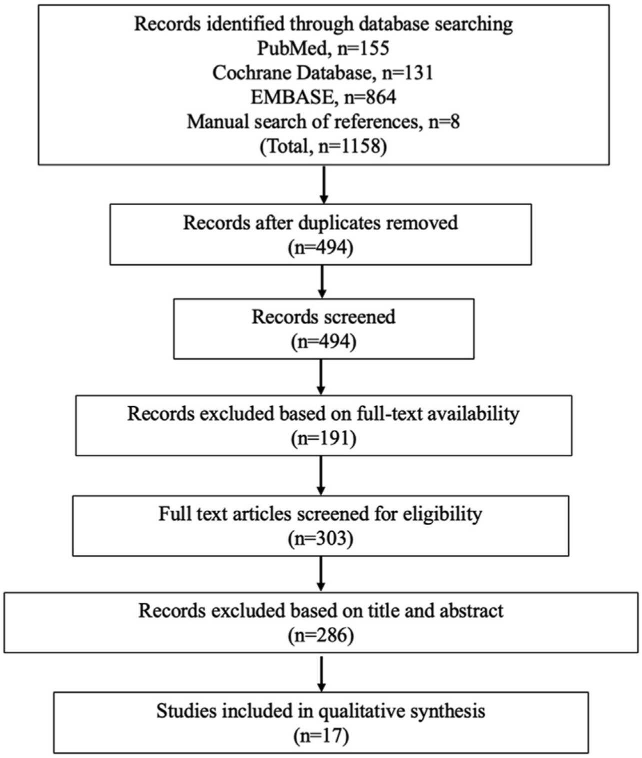

Fig 1. Flow chart of data availability for hot modalities.

additional studies that were not originally identified. Studies were eligible for inclusion if they met the following criteria: (1) peer-reviewed original research articles, (2) studies involving human participants, and (3) studies that were published within the past 10 years (after 2014). Exclusion criteria included (1) any non-English publications, (2) articles published before 2014, and (3) editorials or case reports. Data extracted included study design, sample size, treatment type, and specific outcomes measured. Ultimately, 17 studies met the inclusion criteria for review (Fig 1 and Table 1).[1,5-18]

Results

Thermotherapy, known as heat therapy, has been used in both clinical and sports rehabilitation settings to treat a variety of health conditions, including soft-tissue injuries.[1,5,6] The underlying principle of heat therapy is its ability to increase blood flow, reduce muscle stiffness and increase range of motion, enhance tissue flexibility, and alleviate pain, all ultimately aiding in the recovery process to prevent future injury.[7-9] Heat therapy can be categorized by mode of heat transfer: conduction (heat packs/wraps and paraffin wax baths), convection (dry heat therapy and hydrotherapy), and radiation via conversion (ultrasonography, microwave diathermy, and infrared radiation). Further classification involves the depth of penetration into the tissues, with most modalities being superficial compared with deep or both, as in the case of ultrasonography, depending on the frequency used.[1] Each modality offers unique benefits, making heat therapy a versatile and essential tool in the prevention and management of musculoskeletal injuries. Despite its widespread use, there remains a lack of consensus regarding the scientific understanding and efficacy of heat therapy and the optimal conditions under which it should be applied for rehabilitation or prevention strategies.

Consensus regarding heat therapy—whether whole body or localized thermotherapy—for injury prevention is mixed and not definitive. Although substantial evidence exists supporting the benefits of heat therapy for pain relief, muscle relaxation, and increased blood flow during the recovery phase after clinical peak of DOMS, the actual mechanism by which thermotherapy prevents injury is less clear and remains a subject of ongoing research and debate.[2,3,7,10] In some studies, the use of heat improves skeletal muscle recovery either through a reduction in muscle loss, recovery of force and endurance of exercised muscle, as well as reduced sensation of soreness.[11,12] Moreover, it has also been hypothesized that heat therapy induces metabolic changes involving glycogen resynthesis rates that aid in muscle recovery, although this has yet to be proven in humans.[12] Conversely, other studies show thermotherapy to have no significant impact on the recovery of muscle strength or is no more effective than a passive approach in handling overall muscle recovery, soreness, and evidence of muscle cell disruption and inflammation.[8,13,14] Another physiologic mechanism yet to be fully elucidated is the upregulation of angiogenesis, which ultimately promotes vascular growth in skeletal muscle to enhance recovery and avoid injury.[15,16] Specifically, by using pulsed-wave diathermy or water-perfused sleeves, acute, localized heating to the quadriceps was shown to upregulate specific proangiogenic factors and mitochondrial-related signaling.[15,16] However, other studies, such as that of Ihsan et al.[17] from 2023 refute this physiologic explanation, claiming that 6 weeks of localized heat therapy provides no significant benefit on muscle oxidative or microvascular function, albeit using a different thermal modality and on different muscle types. One reason for the lack of current understanding may be the result of an absence of substantial muscle temperature increase that can confer meaningful adaptations of skeletal muscle by localized heating methods.[17,18] Localized thermotherapy, such as the use of heating pads or tube-lined garments, are used extensively because of their ease of use, commercial availability, cost effectiveness, and overall reasonable safety profile.[10,15] However, if used at high temperatures, superficial, localized thermotherapy can cause burns or skin ulcerations.[9] It has been postulated that whole-body thermotherapy, such as the use of hot water immersion or sauna therapy,

Table 1. Literature Reporting on Hot Modalities

Author, Year	Modality Studied	Benefits	Risks/Complications
Logan et al., 2017[1]	Thermotherapy, including ultrasonography	• Increased elasticity of connective tissues • Reduced pain • Increased blood flow • Increased tissue metabolism	• Soft-tissue irritation or burns with prolonged exposure
McGorm et al., 2018[5]	Thermotherapy	• Increased metabolism in tissues • Muscle relaxation • Vasodilation	• Skin sensitization upon greater temperatures; heat acclimatation
Rodrigues et al., 2020[6]	Passive heat therapy (environmental chamber, heating/ steam-generating sheet, diathermy, water-perfusing garment)	• Induced muscle hypertrophy • Minimized muscle atrophy • Improved muscle strength	
Malanga et al., 2015[7]	Heat therapy	• Pain relief • Vasodilation • Increased metabolic demand • Increased connective tissue elasticity	
Jackman et al., 2023[8]	Hot water immersion (HWI)	• Equivalent to passive recovery on muscle fatigue	
Freiwald et al., 2021[9]	Superficial heat therapy (heat wrap therapy and others)	• Analgesic effect • Muscle relaxation	• Burns and skin ulcerations at high temperatures
Petrofsky et al., 2017[10]	Superficial heat therapy (heat wrap)	• Acute application • Reduced muscle soreness and tissue damage	
Hotfiel et al., 2019[3]	Cryotherapy/whole-body thermotherapy	• Tissue repair • Regeneration processes involving tissue nutrition and circulation	
Heiss et al., 2019[2]	Heat therapy	• Tissue perfusion • Increased in blood flow circulation	
Sabapathy et al., 2021[11]	Whole-body hot water immersion (HWI)	• Pre-exercise HWI reduced decline in muscle strength, soreness, and microvascular function	• Thermal discomfort, nausea, and dizziness • Waste level HWI can potentially mitigate thermal discomfort while still increasing body temperature
Cheng et al., 2017[12]	Superficial heat therapy (water-perfusing garment at 38°C) vs cryotherapy (ice-chilled water-perfusing garment)	• Heat therapy exposure 2 hours postendurance exercise better improved fatigue resistance	
Kim et al., 2019[13]	Superficial heat therapy (water-perfusing garment at 54-55°C for 90 min)	• Heat therapy postexercise increased fatigue resistance and promoted the tissue expression of proangiogenic factors • No impact on the overall recovery profile of muscle strength	
Solsona et al., 2023[14]	HWI vs cold-water immersion (CWI)	• Between high-intensity training sessions, CWI can hinder performance outcomes compared with HWI • HWI had no significant effect on recovery	
Kuhlenhoelter et al., 2016[15]	Superficial heat therapy (water-perfusing garment at 48°C for 90 min)	• Induced vascular growth of skeletal muscle • May aid in recovery efforts by recapillarizing the muscle	

(continued)

Table 1. Continued

Author, Year	Modality Studied	Benefits	Risks/Complications
Hafen et al., 2018[16]	Deep heat therapy (diathermy)	• With repeat exposure, mild heat stress induced by pulsed shortwave diathermy established mitochondrial adaptation in skeletal muscle	
Ihsan et al., 2023[17]	Superficial heat therapy (heating pad)	• Localized heat therapy did not confer a strong enough stimulus for long-term muscle adaptations • Localized heat therapy may require a more potent stimulus to achieve substantial clinical benefit	
Labidi et al., 2021[18]	Superficial heat therapy (heating pad)	• Superficial heating did not provide a potent enough stimulus to induce muscle adaptation	

may provide sufficient increases in skeletal muscle temperature that allow for long-term angiogenic benefit.[15] However, one major risk associated with whole- body thermotherapy stems from the considerable thermal discomfort with elevated core body temperatures and the risk placed on certain populations who are contraindicated to whole body heat stress.[3,13] Overall, definitive evidence regarding the underlying efficacy of thermotherapy is lacking, thus highlighting the need for more targeted studies to provide clearer guidelines on the best practices for using heat therapy in injury prevention and recovery.

Cold Modalities

Methods

The literature review focused on assessing the effectiveness of cold treatment on injury prevention and recovery. A comprehensive search was conducted in PubMed and Cochrane databases using the search terms (“cold therapy” or “hydrotherapy” or “cold water immersion”) and (“recovery” or “injury prevention”). Clinical trials and randomized controlled trials were evaluated for relevance. Studies were included if they met the following criteria: (1) peer-reviewed original research articles, (2) studies involving human participants, and (3) studies that were published within the past 10 years. Exclusion criteria were (1) non-English publications, (2) studies published earlier than 2014, and (3) review articles, editorials, and case reports. Initially, titles and abstracts were screened to assess relevance, followed by a full-text assessment of potentially pertinent studies. Data extracted included study design, sample size, treatment type, and follow-up duration. Ultimately, 15 clinical trials and randomized controlled trials met the inclusion criteria for the review (Fig 2 and Table 2).[14,19-32]

Results

The therapeutic use of cold, known as cryotherapy, is historically the most popular treatment for acute musculoskeletal injury or fatigue. The use of therapeutic hypothermia and cold water bathing has been present for thousands of years, but cold therapy has most recently been adopted by athletes in an attempt to attenuate the negative effects of strenuous exercise on future performance.[19] Postexercise cold therapy is widely accepted for its perceived benefits in both subjective and objective recovery measurements, such as

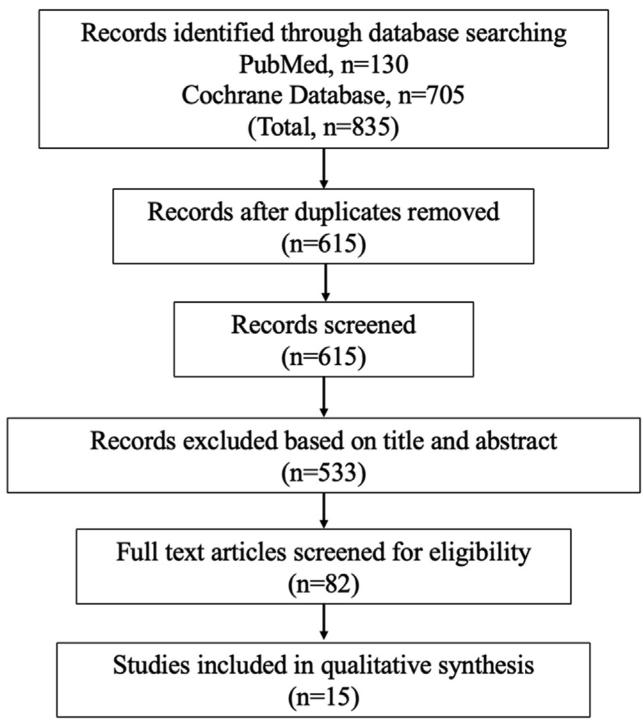

Fig 2. Flow chart of data availability for cold modalities.

Table 2. Literature Reporting on Cold Modalities

Author, Year	Modality Studied	Benefits	Risks/Complications
Wilson et al., 2018[19]	Cold water immersion (CWI), whole-body cryotherapy (WBC)	• WBC limited stress response symptoms and muscle soreness	• WBC was harmful for recovery of muscle function compared with CWI • Both groups were detrimental in comparison with the placebo
Hohenauer et al., 2020[20]	CWI, partial-body cryotherapy (PBC)	• CWI was more effective for recovery of stretch-shortening cycle movements than isometric strength recovery	• PBC and CWI reduced SmO_2 following the exercise-induced muscle damage protocol compared with baseline by ~15%
Hohenauer et al., 2018[21]	CWI, PBC		• CWI decreased muscle oxygen saturation, cutaneous vascular conductance, mean skin temperature, and local skin temperature
Stearns et al., 2018[22]	CWI	• CWI had no detrimental effects on recovery	
Machado et al., 2017[23]	CWI	• CWI groups acted more efficiently for soreness and muscle function	
de Freitas et al., 2019[24]	CWI	• CWI attenuated muscle edema across the training week	• Players experienced discomfort caused by the cold
Peake et al., 2017[25]	CWI, active recovery (AR)		• CWI is no more effective than active recovery for reducing inflammation or cellular stress in muscle
Adamczyk et al., 2016[26]	CWI, ice massage	• There was a clear decrease in the pain experienced in the ice massage and CWI groups	
Wilson et al., 2019[27]	CWI, WBC	• Neither cryotherapy' intervention was more effective than a placebo at limiting decrements in muscle function, perturbations in perceptual responses or increased inflammation	
Siqueira et al., 2018[28]	CWI	• There were lower rates of delayed-onset muscle soreness (DOMS) in the CWI group	• The CWI group felt "slightly uncomfortable" during the cooling procedures
Solsona et al., 2023[14]	CWI, hot water immersion (HWI), AR		• Mean power output was possibly negatively impacted by CWI compared with HWI or AR
Roberts et al., 2015[29]	CWI, AR	• CWI reduced hemodynamics and tissue temperature, helped to maintain muscle strength after resistance exercise, and prevented decrease in maximal isometric strength	
Roberts et al., 2014[30]	CWI, AR	• CWI reduced muscle temperature, muscle soreness and swelling, venous O_2 saturation, and plasma myoglobin concentration	
Sánchez-Ureña et al., 2017[31]	CWI	• CWI reduced the signs of fatigue and for specifically delaying the onset of DOMS	
Ferreira-Junior et al., 2015[32]	PBC	• PBC resulted in a quicker recovery of muscle strength and relieved pain 72 h after damaging exercise	

Table 3. Clinical Indications and Comparison Between Hot and Cold Modalities

Clinical Indications	Modality	
	Hot	Cold
Blood flow modulation	x (vasodilation)	x (vasoconstriction)
Muscle relaxation	x	x
Pain reliever/analgesic	x (alleviates muscle tension by increasing temperature)	x (numbing affected area)
Acute context		x
Delayed/chronic context	x	

reducing muscle soreness and improving functional recovery.[21] Ultimately, the use of cryotherapy is thought to decrease exercise-induced muscle damage and DOMS.[20,26] The proposed physiological mechanism by which cold exposure helps decrease the negative effects of strenuous exercise are related to its vasoconstrictive effects, leading to reduced inflammation and tissue metabolism, decreased cardiac output, and analgesia, as well as various neuromuscular and hormonal changes.[20] Common methods include whole-body cryotherapy, partial-body cryotherapy, and cold-water immersion (CWI).[20,23,26] Despite its widespread use among athletes, evidence supporting the efficacy of cryotherapy in influencing inflammation and muscle recovery remains limited.[20,25]

Although research on cold therapy yields varying conclusions, several consistent themes emerge. One of the major benefits of cold therapy, implemented in the form of CWI, is a decrease in muscle swelling after completion of strenuous exercise.[24,28,30] Measured primarily through thigh circumference, it was found that an increase throughout training was attenuated by the application of CWI, signifying the ability of the cold treatment to reduce muscle edema.[24] Reducing edema can contribute to injury prevention by improving tissue function, enhancing joint stability, and lending to a faster recovery. Another recurring benefit observed across studies involving whole-body cryotherapy, partial-body cryotherapy, and CWI is the efficient alleviation of DOMS.[19,20,23,26,31] The application of cold, in any form, was commonly seen to limit the stress response symptoms of exercise, primarily reducing the signs of fatigue and restoring function in the affected muscle groups.[19,20,23,26,31] On top of reducing edema and DOMS, cold therapy has been found to result in a quicker recovery of muscle strength after resistance exercise.[29,32] Conversely, risks associated with cryotherapy include decreased muscle oxygen saturation as the result of vasoconstriction, potentially impairing muscle function and increasing injury risk if prolonged.[20,21] Some studies report mixed outcomes regarding muscle strength and performance recovery postcryotherapy, with instances of reduced power output and knee extension torque.[14,19,24] Other complications, such as discomfort from extreme cold and occasional stress responses in muscles, were noted, although these were generally manageable.[19,28] Overall, conclusive evidence supporting the superiority of cryotherapy over other recovery methods remains limited.[19,22-25,27] It is noted that effects of cryotherapy can sometimes be attributed to the placebo effect or athlete preference, but ultimately if using this treatment responsibly, there will be no severe deleterious effects.[19,23,27] In studies that did find significant results, cold therapy was seen to decrease DOMS and help resolve global or generalized muscle injury or fatigue.[20,26] Further research is necessary to determine the full scope of cryotherapy's effectiveness in injury prevention and recovery protocols.

Discussion

Both hot and cold therapy are widely recognized and implemented in the clinic for their effectiveness in the management and prevention of musculoskeletal injuries, with each modality having similarities and differences in terms of overall benefit, application, and timing. Deciding between which thermal modality to implement will often depend on the circumstances of the individual. One of the primary similarities in benefits between these 2 therapeutic modalities is their ability to modulate blood flow, reduce muscle spasm, and maintain an analgesic effect—albeit via different mechanisms of action—which are all important contributing factors for injury prevention and recovery. For therapeutic use as a pain reliever, cold therapy's mechanism of action involves numbing the affected area, thus reducing the sensation of pain, whereas hot therapy primarily takes advantage of increases in tissue temperatures that could alleviate muscle tension and therefore reduce discomfort that comes with injury. Both hot and cold therapies can rectify muscle spasms that may be associated with injury, with cold therapy doing so through diminished nerve activity whereas heat therapy's vasodilatory effects allow counteractive muscle relaxation. Lastly, both therapies address inflammation by controlling blood flow through the affected areas. Cryotherapy reduces inflammation through its vasoconstrictive effects, whereas thermotherapy aids in inflammatory control through vasodilation, ultimately promoting blood circulation that will

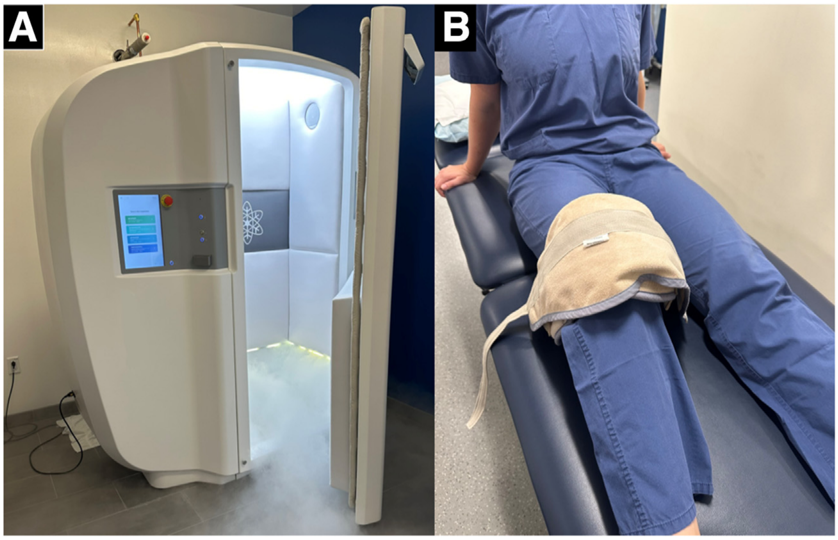

Fig 3. (A) Example of cryotherapy chamber. (B) Example of thermal conduction/heat pack on a right knee.

help clear any inflammatory byproducts out of the injured areas while also allowing for delivery of oxygen and nutrients for healing.

The major differences between hot and cold therapies lie in their distinct application and timing strategies, which directly influence their effectiveness as a treatment modality in recovery and injury prevention (Table 3). Cryotherapy—whether using ice packs, cold baths, or cryo-chambers—is most effective when used in an acute context, often immediately after an injury occurs to reduce any swelling, inflammation, and pain (Fig 3). The prompt application of cold therapy allows for faster recovery by minimizing tissue damage. Thus, cold therapy is best used for both treating acute injuries and preventing overuse injuries through prompt resolution of inflammation after an intense physical activity. In contrast, thermotherapy—using certain modalities such as hot packs, warm baths, or sauna—is generally most effective if used after the acute phase of inflammation or when peak DOMS has subsided (Fig 3). By applying heat, patients can counteract the muscle stiffness and tension pre- and postexercise to allow for a better range of motion and increased joint flexibility for performing movement. For this reason, heat therapy is typically used for the treatment of chronic injuries and for use passively as a warm-up either prior to engaging in activity or during a post-exercise recovery period.

Conclusions

In sum, both cold and hot therapy play similar but unique roles in injury prevention and recovery. The key to effective use of either depends on understanding the nature of the injury as well as the appropriate timing of therapeutic application. By leveraging the unique mechanisms of each modality, athletes can optimize their recovery process and reduce the risk of future injury.

Disclosures

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: E.G.M. reports board membership and co-author for *Arthroscopy* and speaker for Arthrex. All other authors (K.L.V., D.P.L., J.L.M.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Logan CA, Asnis PD, Provencher MT. The role of therapeutic modalities in surgical and nonsurgical management of orthopaedic injuries. *J Am Acad Orthop Surg* 2017;25:556-568.
2. Heiss R, Lutter C, Freiwald J, et al. Advances in delayed-onset muscle soreness (DOMS)—part II: Treatment and prevention. *Sportverletz Sportschaden* 2019;33:21-29.
3. Hotfiel T, Mayer I, Huettel M, et al. Accelerating recovery from exercise-induced muscle injuries in triathletes: Considerations for Olympic distance races. *Sports Basel Switz* 2019;7:143.
4. Chaillou T, Treigyte V, Mosely S, Brazaitis M, Venckunas T, Cheng AJ. Functional impact of post-exercise cooling and heating on recovery and training adaptations: Application to resistance, endurance, and sprint exercise. *Sports Med Open* 2022;8:37.
5. McGorm H, Roberts LA, Coombes JS, Peake JM. Turning up the heat: An evaluation of the evidence for heating to promote exercise recovery, muscle rehabilitation and adaptation. *Sports Med* 2018;48:1311-1328.
6. Rodrigues P, Trajano GS, Wharton L, Minett GM. Effects of passive heating intervention on muscle hypertrophy and neuromuscular function: A preliminary systematic review with meta-analysis. *J Therm Biol* 2020;93:102684.

7. Malanga GA, Yan N, Stark J. Mechanisms and efficacy of heat and cold therapies for musculoskeletal injury. *Postgrad Med* 2015;127:57-65.
8. Jackman JS, Bell PG, Van Someren K, et al. Effect of hot water immersion on acute physiological responses following resistance exercise. *Front Physiol* 2023;14:1213733.
9. Freiwald J, Magni A, Fanlo-Mazas P, et al. A role for superficial heat therapy in the management of non-specific, mild-to-moderate low back pain in current clinical practice: A narrative review. *Life Basel Switz* 2021;11:780.
10. Petrofsky J, Berk L, Bains G, Khowailed IA, Lee H, Laymon M. The efficacy of sustained heat treatment on delayed-onset muscle soreness. *Clin J Sport Med* 2017;27:329-337.
11. Sabapathy M, Tan F, Al Hussein S, et al. Effect of heat preconditioning on recovery following exercise-induced muscle damage. *Curr Res Physiol* 2021;4:155-162.
12. Cheng AJ, Willis SJ, Zinner C, et al. Post-exercise recovery of contractile function and endurance in humans and mice is accelerated by heating and slowed by cooling skeletal muscle. *J Physiol* 2017;595:7413-7426.
13. Kim K, Kuang S, Song Q, Gavin TP, Roseguini BT. Impact of heat therapy on recovery after eccentric exercise in humans. *J Appl Physiol Bethesda Md* 1985 2019;126:965-976.
14. Solsona R, Méline T, Borrani F, et al. Active recovery vs hot- or cold-water immersion for repeated sprint ability after a strenuous exercise training session in elite skaters. *J Sports Sci* 2023;41:1126-1135.
15. Kuhlenhoelter AM, Kim K, Neff D, et al. Heat therapy promotes the expression of angiogenic regulators in human skeletal muscle. *Am J Physiol Regul Integr Comp Physiol* 2016;311:R377-R391.
16. Hafen PS, Preece CN, Sorensen JR, Hancock CR, Hyldahl RD. Repeated exposure to heat stress induces mitochondrial adaptation in human skeletal muscle. *J Appl Physiol (1985)* 2018;125:1447-1455.
17. Ihsan M, Labidi M, Racinais S. Skeletal muscle oxidative adaptations following localized heat therapy. *Eur J Appl Physiol* 2023;123:1629-1635.
18. Labidi M, Ihsan M, Behan FP, et al. Six weeks of localized heat therapy does not affect muscle mass, strength and contractile properties in healthy active humans. *Eur J Appl Physiol* 2021;121:573-582.
19. Wilson LJ, Cockburn E, Paice K, et al. Recovery following a marathon: A comparison of cold water immersion, whole body cryotherapy and a placebo control. *Eur J Appl Physiol* 2018;118:153-163.
20. Hohenauer E, Costello JT, Deliens T, Clarys P, Stoop R, Clijsen R. Partial-body cryotherapy (−135°C) and cold-water immersion (10°C) after muscle damage in females. *Scand J Med Sci Sports* 2020;30:485-495.
21. Hohenauer E, Costello JT, Stoop R, et al. Cold-water or partial-body cryotherapy? Comparison of physiological responses and recovery following muscle damage. *Scand J Med Sci Sports* 2018;28:1252-1262.
22. Stearns RL, Nolan JK, Huggins RA, et al. Influence of cold-water immersion on recovery of elite triathletes following the ironman world championship. *J Sci Med Sport* 2018;21:846-851.
23. Machado AF, Almeida AC, Micheletti JK, et al. Dosages of cold-water immersion post exercise on functional and clinical responses: A randomized controlled trial. *Scand J Med Sci Sports* 2017;27:1356-1363.
24. de Freitas VH, Ramos SP, Bara-Filho MG, et al. Effect of cold water immersion performed on successive days on physical performance, muscle damage, and inflammatory, hormonal, and oxidative stress markers in volleyball players. *J Strength Cond Res* 2019;33:502.
25. Peake JM, Roberts LA, Figueiredo VC, et al. The effects of cold water immersion and active recovery on inflammation and cell stress responses in human skeletal muscle after resistance exercise. *J Physiol* 2017;595:695-711.
26. Adamczyk JG, Krasowska I, Boguszewski D, Reaburn P. The use of thermal imaging to assess the effectiveness of ice massage and cold-water immersion as methods for supporting post-exercise recovery. *J Therm Biol* 2016;60:20-25.
27. Wilson LJ, Dimitriou L, Hills FA, Gondek MB, Cockburn E. Whole body cryotherapy, cold water immersion, or a placebo following resistance exercise: A case of mind over matter? *Eur J Appl Physiol* 2019;119:135-147.
28. Siqueira AF, Vieira A, Bottaro M, et al. Multiple cold-water immersions attenuate muscle damage but not alter systemic inflammation and muscle function recovery: A parallel randomized controlled trial. *Sci Rep* 2018;8:10961.
29. Roberts LA, Muthalib M, Stanley J, et al. Effects of cold water immersion and active recovery on hemodynamics and recovery of muscle strength following resistance exercise. *Am J Physiol Regul Integr Comp Physiol* 2015;309:R389-R398.
30. Roberts LA, Nosaka K, Coombes JS, Peake JM. Cold water immersion enhances recovery of submaximal muscle function after resistance exercise. *Am J Physiol Regul Integr Comp Physiol* 2014;307:R998-R1008.
31. Sánchez-Ureña B, Martínez-Guardado I, Crespo C, et al. The use of continuous vs. intermittent cold water immersion as a recovery method in basketball players after training: A randomized controlled trial. *Phys Sportsmed* 2017;45:134-139.
32. Ferreira-Junior JB, Bottaro M, Vieira A, et al. One session of partial-body cryotherapy (−110 °C) improves muscle damage recovery. *Scand J Med Sci Sports* 2015;25:e524-e530.