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REVIEW PAPER

The Contemporary Use of Cooling Modalities in the Recovery From Sport Injury

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ABSTRACT

The therapeutic application of any modality that removes heat from the body and results in a decrease in tissue temperature may come under the umbrella term of 'cryotherapy'. Commonly used in sport for injury, rehabilitation, and recovery for readiness to perform, the typical rationale for its use is a reduction in perception of pain, or muscle soreness among other physiological responses. To facilitate the recovery process from sports injury, cryotherapeutic modalities are often applied with the intention to positively control and affect metabolic and inflammatory processes, with the aim of aiding in the healing process, not preventing it altogether. That said, debates concerning the use of cryotherapy within early stages of an injury are prevalent in recent literature. Although, this is predominantly due to a lack of understanding of the multifaceted responses that underpin its beneficial use within a sporting context. Consequently, optimal cooling protocols for the recovery of sport injury are limited, despite supporting evidence for its use. Yet it is known that modalities and protocols differ in the responses they can achieve.

Recent applied research (Alexander et al., 2021; Alexander et al, 2021a) has demonstrated that several variables affect the optimisation of cooling protocols for injury recovery including, although not limited to the thermodynamic properties of cooling modes, dose exposure, compression adjunct, phase change and markers of performance. Adaptations to these variables have shown to affect biomechanical, biochemical, physiological and psychological responses synchronously. Therefore, we cannot consider the impact of cryotherapy on one of these response without the other when devising optimal applications for sport injury recovery. Consequently, for cryotherapy to be effective as a treatment modality in the use of sport injury, its ability to reduce tissue temperature within a safe therapeutic range combined with practitioner decision-making around application timing and modality choice is key. Several advancements in cooling technologies and protocols from our work and others have been developed to offer a better understanding of the multifaceted response to cryotherapy for sport injury recovery. Furthermore, to maximise the effectiveness of its use within the applied setting, our research continues to investigate the individualisation of cryotherapeutic protocols in consideration of the underlying mechanisms to optimally affect the physiological, biomechanical, biochemical and psychological responses most appropriately within elite sport populations. The aim of this short review is however to provide a contemporary critical discussion on the current approaches of cooling modalities in the recovery from injury within a sporting context.

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Introduction

Often utilised in the management of sport injury recovery, cryotherapy modalities can be an integral contribution to the positive functional return to competitive activity. Historically, cryotherapy has gained attention as an efficient way of providing analgesia and managing tissue damage occurring because of the inflammatory response (Kwiecien and McHugh, 2021). Characteristics of an inflammatory response to musculoskeletal soft tissue trauma presents with pain, oedema, increased blood flow and heat (Rigby and Dye, 2017). Incidentally, the withdrawal of heat is the principal purpose of cryotherapy applications (Kwiecien & McHugh, 2021), and fundamental to the benefits of this modality (Allan et al, 2022; Alexander et al 2021a). Cryotherapy modalities and protocols, however, differ significantly in the physiological, biomechanical, biochemical and psychological responses they initiate (Alexander et al, 2021a). The most traditional form of cryotherapy acknowledged is ice and in the 1960's became recognised and recommended for its application and treatment of musculoskeletal injuries (Grant, 1964; Hayden, 1964). Current day practices, however, encompass an abundance of modalities including wetted ice, gel packs, cryo-vests, cryo-compressive devices, and targeted or circumferential cooling, to name but a few. In sport, its use can be rationalised based on the intended aim (Bleakley et al, 2004; Alexander et al 2021a), not exclusive to injury management (Galiuto, 2016), rehabilitation (Bleakley & Hopkins, 2010), post-exercise recovery (Du Pont et al, 2017; Alexander et al, 2021a) or for performance readiness purposes (Alexander et al, 2021a).

Recent debates that question whether *'to ice or not to ice',* in the early management of sports injuries are platitudes that we should consider outdated perhaps, despite their prevalence across recent social media. That said, uncertainty and misunderstanding still exists at medical or performance practitioner/team level when considering how to optimise cooling applications for the management of sport injury. Confusion is often derived from the limited literature available that reflects multifaceted responses that underpin its use within a sporting context. Similarly, barriers to the translation of knowledge into applied practices are reported (Long and Jutte 2020), and therefore owing to the conflicting understanding around optimal cryotherapeutic protocols for sports injury (Alexander et al, 2021b). Its application should be used in context and to aid in the control of inflammation, not to prevent it altogether and applied specifically to the athlete's individual presentation. Ultimately these debates support the need for further clarity and understanding on how we can and should be optimising the application of cryotherapy applicable to the presentation of the athlete to provide the most advantageous benefits.

The purpose of this review therefore is to provide a contemporary overview of current use of cryotherapy in the management of recovery from injury for the context of its application within sport.

Tissue Injury & Healing

During exercise or injury, the damage of myofilament structure defines the processes that transpire from injury to muscles and are initiated rapidly, occurring in several stages (Huard et al, 2002; Järvinen et al., 2005; Tidball, 2011; Lieber, 2018; Kwiecien and McHugh, 2021). The natural inflammatory response occurs following the bleeding phase of an initial injury, followed by several catabolic events that aim to return the tissue to pre-injury function (Kwiecien and McHugh, 2021). A complex and dynamic process is presented with clarity by Watson (2014), summarising tissue healing through a regeneration and repair process. A common way to describe the entire process is through 4 phases: *Bleeding, Inflammation, Proliferation* and *Remodelling* (Watson, 2014). The time-course of these phases can be briefly described from bleeding (hours) with the rapid onset overlap of the inflammatory (1-3 days), and proliferation phases (24-48 hours to 2-3 weeks post injury) which is heavily dependent on the vascularity of the tissue (i.e., peak proliferation production takes longer within less vascularised tissues), and finally remodelling (from 2-3 weeks post injury lasting months) (Watson, 2014). In summary, these broad stages of tissue repair overlap each other, and the duration of phases vary dependent on the nature and severity of the sports injury and tissue type (i.e., muscle vs ligament), and consequently the understanding of such process is important for

The understanding around the effects of cooling on metabolism and inflammation is summarised in a recent systematic review (Kweicien and McHugh, 2021) suggesting the application of cryotherapy can help diminish the magnitude of secondary tissue hypoxia (Long and Jutte, 2020) within and adjacent to the site of injury. That said, the evidence to support this originates from animal models (Kweicien and McHugh, 2021) and challenges exist with transference of this knowledge to humans, specifically when considering the differences in muscle metabolism (Kweicien and McHugh, 2021). The inflammatory response to injury is an essential part of the tissue repair process (Watson, 2014). Consequently, the application of cryotherapy modalities within this phase should be used within the correct context to support the initiation of positive physiological responses. This may be achieved through the aim of controlling inflammation most effectively, reduce pain (Long and Jutte, 2020) and synchronously supporting the principles of mechanotransduction for optimal tissue loading in injury rehabilitation (Khan and Scott, 2009). Studies agree that cryotherapy can enhance regenerative processes during recovery from injury (Järvinen et al. 2005; Dykstra et al. 2009) through the decrease of any further proliferation following the initial tissue damage (Knight 1995; Merrick 2002; Enwemeka et al., 2002; Bleakley et al., 2012a; Ihsan et al., 2013), or secondary tissue damage (Knight, 1995; Merrick et al. 1999; Knight et al. 2000; Long and Jutte, 2020). The challenge as a practitioner is identifying the most appropriate combination of cooling protocol and modality choice, alongside optimal timing to achieve this. Mechanisms in which cryotherapy modalities and protocols can be most effectively applied throughout the processes of regeneration and repair are becoming better understood within the evidence base, and consequently may help to maximise the return to functionality of an athlete post injury if transpired into practice successfully.

Developments in Cryotherapeutic Modalities, Practical Applications and Research

Since around the 1960's an evolution in the interest of cryotherapy has grown extensively for its use in practice and unsurprisingly research outputs. The propensity of cryotherapeutic modality use for sporting injuries in practice was historically considered unfounded by the evidence base (Hawkins, 2016), suggesting insufficient or lacking in evidential explanation for its use at the time (Bleakley et al, 2004; Hubbard and Denegar, 2004). Since then, some of our research examples have focused on understanding mode, dose, temperature and duration response of cryotherapeutic applications (Alexander et al, 2019; 2020; 2023). Current day understanding of the role of cryotherapy in sport injury management still demonstrates different perspectives with conflicting arguments and literature on either side often failing to acknowledge the importance of context. Evidently there are multifactorial variables to firstly understand and consequently be able to consider when aiming to decipher what may be the optimum cryotherapy application for sports injury, with individual human responses to cooling being at the forefront of consideration (Alexander et al, 2021a).

It is considered for a cryotherapeutic modality to be effective and safe, a rapid reduction in skin surface temperature (T_{sk}) and the ability to maintain these reduced temperatures over a pertinent period, without causing damage to tissue is essential (Breslin et al, 2015). To induce beneficial physiological effects, reductions in T_{sk} of at least 5–15°C is outlined in traditional PRICE guidelines (ACPSM - Bleakley et al, 2011), with absolute T_{sk} below 12°C required to induce analgesia (Bleakley and Hopkins, 2010) and absolute therapeutic range identified as between 10-15°C for deeper physiological changes to ensue (Bleakley and Hopkins, 2010; Bleakley et al, 2011). Thermoregulatory responses are initiated through the skin, due to a lack of thermal receptors within muscle tissue. Yet, the magnitude of intramuscular temp reduction is imperative for positive physiological changes to ensue. A quadratic relationship however between T_{sk} and intramuscular temperature is known, put simply as skin rewarms, deeper musculature continues to cool for a period (Kennett et al., 2007). Practitioners therefore should be mindful of this relationship when undertaking local cooling and consider modality choice to achieve desired outcomes. This however is only one consideration and variable that results in capricious responses through protocol/mode adaptation.

It is established that different thermodynamics exist when comparing cryotherapeutic modalities, and the efficiency of thermal gradient between muscle and mode of cooling influences the decrease in muscle tissue temperature (Merrick et al, 2003). Also known as phase change capability (Merrick et al., 2003; Dykstra et al, 2009). As to which cooling modality is 'best' for injury management tends to demonstrate agreement for crushed or wetted ice in earlier literature (Kennet et al, 2007; Dykstra et al, 2009), determined by their efficient phase change ability to reduce T_{sk} to within optimum therapeutic ranges for physiological effects to ensue. There are several developments in cryotherapeutic modality now available, yet a distinct lack of literature which explores this through invasive/direct measurement, hence the exponential use of thermography in determining the efficiency of cryotherapeutic modalities (Alexander & Rhodes, 2020). Furthermore, the adjunct of compression applied in synchronisation with cooling is known to increase the magnitude of cooling (Alexander et al., 2020) and subcutaneous adipose tissue levels and athlete characteristics (Alexander et al, 2019) are inversely correlated to the magnitude of muscle temperature change in response to local cooling (Myer et al, 2001; Otte et al, 2002). In summary, practitioners and researchers should acknowledge that several variables affect tissue response to local cooling. Consequently, this impacts the ability to decipher what therapeutic approach may be best to ensure the desired physiological responses occur in the context of sport injury presentation and management.

General protocols for the application of cooling for sports injury management often follow the original Ice, Compression and Elevation (ICE), and Rest, Ice, Compression and Elevation (RICE) guidelines (Bleakley et al, 2012b), applied to limit secondary tissue injury (Long and Jutte, 2020), which evolved to; Protection, Rest, Ice, Compression and Elevation (PRICE) (ACPSM, Bleakley et al, 2011). An influx of interest noted since 2011 investigate elements of the 'PRICE' acronym, utilised within treatment paradigms (Bleakley et al, 2012b), with the aim to provide further pathophysiological rationale (Ramos et al, 2016) and clinical effectiveness for PRICE components with relevance to practice. Further clarification by Jutte and Long (2020) highlights the usefulness of cryotherapeutic adjunct to therapeutic rehabilitation, beyond the post-acute stages. Consequently, progression of the protocol acronym to 'POLICE' (Bleakley et al, 2012b) corresponding to Protection, Optimal Loading, Ice, Compression and Elevation, represents the concept and importance of optimal loading in respect of mechanotransduction principles through appropriate mechanotherapy techniques (Khan and Scott, 2009), which complement the original PRICE guidelines (ACPSM, Bleakley et al, 2011; 2012a). This approach supports a contemporary view to enhance how, when and why local cooling applications may be successfully implemented within acute injury management or rehabilitation. Conversely, when considering immediate 'on-pitch/side-line/half-time' injury management, practitioners should be mindful of the effects found on knee joint repositioning and dynamic stability suggesting a heightened injury risk if returning to competitive play following a 20-minute ice exposure (Alexander et al, 2016; Alexander et al, 2028). Again, we suggest context and modification of protocol should be considered here to negate the potential ramifications in this scenario. Previously, the introduction of POLICE guidelines by Bleakley et al, (2012b) further emphasised the lack of comprehension that exists surrounding optimal cryotherapy protocols to support the management of musculoskeletal sports injury. The authors stressed the intention was to also generate new areas of investigation from the proposal of POLICE (Bleakley et al, 2012b). As a result of further investigations, contemporary dialogues suggest that treatment parameters should be based on the intention of outcome (Long and Jutte, 2020; Alexander et al, 2021a). For example, minimising the risk of secondary injury of deeper structures vs providing analgesia may require different durations or modes of applications to meet the intended therapeutic aim. For example, if analgesia is the predominant aim of treatment, Jutte and Long, (2020) suggest that the need to reduce deeper tissue structures is minimal and therefore may not warrant the revision of the cooling application to consider the influence of adipose tissue levels. Overall, what these discussions highlight is the need for continued contemporary research to investigate such parameters with the notion of identifying the role of cooling modalities through

rigorous enquiry. This would help determine the most optimum cryotherapy application protocols for use within sports injury management contexts.

Conversely, the most recent debate that questions whether we should be using ice (cooling) at all, within the acute stages of an injury (Dubois and Esculier, 2020), presents the acronym of, 'PEACE and LOVE'. This approach encompasses the management of both acute and subacute to chronic stages of healing of soft tissue injury, with the underpinning message to avoid cryotherapy (as an anti-inflammatory approach) during the acute stage (Dubois and Esculier, 2020). The authors argument to avoid cooling is based on the disruption of the inflammation process of angiogenesis and revascularisation thought to be caused by cryotherapy, ultimately suggesting that this could lead to a negative effect on repair of tissue and redundant synthesis of collagen (Singh et al, 2017). That said, the article appears to criticise the modality with only a limited body of evidence underpinning it and in response a critical debate was presented by Long and Jutte (2020) refuting the argument by Dubois and Esculier (2020). Many studies that try to decipher how we could most optimally use cryotherapeutic modalities better within this phase often do not support cryotherapy (Long and Jutte, 2020) and fail to consider the variables that could be adapted more beneficially for the positive control of inflammation and pain during injury recovery management which would be beneficial in a sporting context. We suggest the question here isn't black and white as to 'ice or not' and eradicate it completely from sports injury management. Instead, as practitioners, we should be asking how we can optimise the application of cryotherapy in any given context to support sport injury recovery, whilst respecting the body's natural processes to control healing more effectively. This requires thorough understanding, further exploration and initiation of applied studies that practically contribute to the contemporary evidence base for this therapeutic modality.

Although recent literature has extended the knowledge around optimising cryotherapeutic protocols for sports injury recovery, the 'context' of application again may be missing from these investigations in respect to the most optimum modality choice. Additionally, our group identify a gap in applied evidence that considers multiple variables and multifaceted responses to cryotherapy in study design or the investigation of contemporary modalities. Consequently, this is important to understand as variables are unlikely to be affected in isolation. Moreover, there is little research that explores the effectiveness of cryotherapeutic applications through parameters which are relevant to the high-performance sport environment (Alexander et al, 2021a). Consequently, some of our work has investigated several iterations of cryotherapeutic modalities in such environments exploring protocols in unison and comparatively for the functional recovery profiles of hamstrings in professional football, for example (Alexander et al., 2020; 2019). Collectively findings identify that significant discrepancies when comparing modalities and protocol adaptations in the ability to optimally reduce tissue temperature, provide consistent contact between modality and skin for efficient phase change to occur, rewarming durations, impact of compression adjunct and desired outcomes of application. Finally, the challenges to current guidelines highlighted in recent debate only strengthen the rationale for further studies that reflect the use of cryotherapy for injury within the sports environment.

Practical Implications

The context of cryotherapeutic application is important with consideration around aim and intended outcome. In practical terms what this means is that rather than dismiss the use of cryotherapy altogether for acute sports injury management, practitioners need to consider the context, influencing variables, timing, and modality choice most effectively in combination to implement them most optimally into practical applications to maximise the beneficial responses. Cooling protocols for the recovery of sports injury need to be adapted to the individual presentation of the athlete and consider previously published work from us and others that investigates this within an athletic population (Alexander et al, 2021a). The transference of that knowledge into practice however, even within elite level environments, is still limited.

Summary

Whilst debate may continue around the use of

cryotherapy within the acute inflammatory stages of an injury, practitioners should be mindful of how useful cryotherapy modalities can be when an understanding of how they can be applied to support the injury context and intended outcomes are considered. The optimal loading of tissue structures during the recovery from sports injury is required with 'mechanotransductive' principles underpinning the rationale for this. Cryotherapy when applied in the correct context throughout various stages of the healing process can be considered imperative to help control inflammation positively. As a result, this adjunct may provide an important opportunity for optimal loading within safe parameters to occur supporting the functional return to sport more effectively than without. Practitioners should consider current inaccurate dialogue regarding cryotherapeutic modalities, yet we acknowledge that further quality research would be beneficial especially in a sporting context. In summary, therapeutically this modality can be a successful adjunct to the principles of mechanotherapy in the management and recovery of sport injury during several phases of healing when applied complimentary to the desired therapeutic outcomes.

References

1. Alexander, J., Allan, D. R., & Rhodes, D. D. (2021). Cryotherapy in sport: A warm reception for the translation of evidence into applied practice. *Research in Sports Medicine*, *30*(4), 458-461. https://doi.org/10.1080/15438627.2021.1899920
2. Alexander, J., Carling, C., & Rhodes, D. (2022). Utilisation of performance markers to establish the effectiveness of cold-water immersion as a recovery modality in elite football. *Biology of Sport*, *39*(1), 19-29. https://doi.org/10.5114/biolsport.2021.103570
3. Alexander, J., Mawene, Y., Alexanders, J., Jeffery, J., & Rhodes, D. (2023). The effects of wetted ice on dynamic stability over a Rewarming period. *Central European Journal of Sport Sciences and Medicine*, *41*, 13-23. https://doi.org/10.18276/cej.2023.1-02
4. Alexander, J., & Rhodes, D. (2020). Thermography for defining efficiency of cryotherapy modalities in sport. *Temperature*, *8*(2), 105-107. https://doi.org/10.1080/23328940.2020.1819517
5. Alexander, J., Greenhalgh, O., and Rhodes, D. (2020). Physiological Parameters in Response to Levels of Pressure during Contemporary Cryo-Compressive Applications Implications for Protocol Development. *J Athletic Enhance. 9*(1), 1-6. Physiological Parameters in Response to Levels of Pressure during Contemporary CryoCompressive Applications Implications for Protocol Development | SciTechnol
6. Alexander, J., Rhodes, D. D., Birdsall, D., & Selfe, J. (2020). Comparison of cryotherapy modality application over the anterior thigh across Rugby union positions; A crossover randomized controlled trial. *International Journal of Sports Physical Therapy*, *15*(2), 210-220. https://doi.org/10.26603/ijspt20200210
7. Alexander, J., Richards, J., Attah, O., Cheema, S., Snook, J., Wisdell, C., May, K., & Selfe, J. (2018). Delayed effects of a 20-min crushed ice application on knee joint position sense assessed by a functional task during a re-warming period. *Gait & Posture*, *62*, 173-178. https://doi.org/10.1016/j.gaitpost.2018.03.015
8. Alexander, J., Selfe, J., Oliver, B., Mee, D., Carter, A., Scott, M., Richards, J., & May, K. (2016). An exploratory study into the effects of a 20-minute crushed ice application on knee joint position sense during a small knee bend. *Physical Therapy in Sport*, *18*, 21-26. https://doi.org/10.1016/j.ptsp.2015.06.004
9. Alexander, J., Selfe, J., Greenhalgh, O., & Rhodes, D. (2021). Cryotherapy and compression in sports injury management: A scoping review. *International Journal of Therapy and Rehabilitation*, *28*(10), 1-19. https://doi.org/10.12968/ijtr.2020.0141
10. Allan, R., Akin, B., Sinclair, J., Hurst, H., Alexander, J., Malone, J. J., Naylor, A., Mawhinney, C., Gregson, W., & Ihsan, M. (2021). Athlete, coach and practitioner knowledge and perceptions of post-exercise cold-water immersion for recovery: A qualitative and quantitative exploration. *Sport Sciences for Health*, *18*(3), 699-713. https://doi.org/10.1007/s11332-021-00839-3
11. Allan, R., Malone, J., Alexander, J., Vorajee, S., Ihsan, M., Gregson, W., Kwiecien, S., &

Mawhinney, C. (2022). Cold for centuries: A brief history of cryotherapies to improve health, injury and post-exercise recovery. *European Journal of Applied Physiology*, *122*(5), 1153-1162. https://doi.org/10.1007/s00421-022-04915-5

12. Bleakley, C., McDonough, S., & MacAuley, D. (2004). The use of ice in the treatment of acute soft-tissue injury. *The American Journal of Sports Medicine*, *32*(1), 251-261. https://doi.org/10.1177/0363546503260757
13. Bleakley, C. M., Glasgow, P., & Webb, M. J. (2011). Cooling an acute muscle injury: Can basic scientific theory translate into the clinical setting? *British Journal of Sports Medicine*, *46*(4), 296-298. https://doi.org/10.1136/bjsm.2011.086116
14. Bleakley, C. M., Glasgow, P., & MacAuley, D. C. (2012). PRICE needs updating, should we call the POLICE? *British Journal of Sports Medicine*, *46*(4), 220-221. https://doi.org/10.1136/bjsports-2011-090297
15. Bleakley, C. M., & Hopkins, J. T. (2010). Is it possible to achieve optimal levels of tissue cooling in cryotherapy? *Physical Therapy Reviews*, *15*(4), 344-350. https://doi.org/10.1179/174328810x12786297204873
16. Bleakley, CM., Glasgow, PD., Philips, P., Hanna, L., Callaghan, MJ., Davison, GW., Hopkins, TJ., and Delahunt, E. (2011). For the Association of Chartered Physiotherapists in Sports and Exercise Medicine (ACPSM). Guidelines on the Management of Acute Soft Tissue Injury Using Protection Rest Ice Compression and Elevation. London: ACPSM, 15–21.
17. Breslin, M., Lam, P., & Murrell, G. A. (2015). Acute effects of cold therapy on knee skin surface temperature: Gel pack versus ice bag. *BMJ Open Sport & Exercise Medicine*, *1*(1), e000037. https://doi.org/10.1136/bmjsem-2015-000037
18. Dubois, B., & Esculier, J. (2019). Soft-tissue injuries simply need PEACE and LOVE. *British Journal of Sports Medicine*, *54*(2), 72-73. https://doi.org/10.1136/bjsports-2019-101253
19. DuPont, W. H., Hardesty, V. H., Barnhart, E. C., Meuris, B. J., & Kraemer, W. J. (2017). The effects of cryo-compression therapy on recovery from an acute bout of resistance exercise. *Medicine & Science in Sports & Exercise*, *49*(5S), 682. https://doi.org/10.1249/01.mss.0000518801.59947.9c
20. Dykstra, J. H., Hill, H. M., Miller, M. G., Cheatham, C. C., Michael, T. J., & Baker, R. J. (2009). Comparisons of cubed ice, crushed ice, and wetted ice on intramuscular and surface temperature changes. *Journal of Athletic Training*, *44*(2), 136-141. https://doi.org/10.4085/1062-6050-44.2.136
21. Enwemeka, C. S., Allen, C., Avila, P., Bina, J., Konrade, J., & Munns, S. (2002). Soft tissue thermodynamics before, during, and after cold pack therapy. *Medicine & Science in Sports & Exercise*, *34*(1), 45-50. https://doi.org/10.1097/00005768-200201000-00008
22. Galiuto, L. (2016). The Use of Cryotherapy in Acute Sports Injuries. *Ann Sports Med Res. 3*(2): 1060.
23. Grant, AE. (1964). Massage with ice (cryokinetics) in the treatment of painful conditions of the musculoskeletal system. *Archives of Physical Medical Rehabilitation* 45:233–238.
24. Hayden, CA. (1964) Cryokinetics in an early treatment program. *Physical Therapy 44*:990–993.
25. Hawkins, J. (2016). Is the clinical use of ice still relevant? *Experimental Physiology 101*(7): 789-789.
26. Huard, J., Li, Y., & Fu, F. H. (2002). Muscle injuries and repair. *The Journal of Bone and Joint Surgery-American Volume*, *84*(5), 822-832. https://doi.org/10.2106/00004623-200205000-00022
27. Ihsan, M., Watson, G., Lipski, M., & Abbiss, C. R. (2013). Influence of Postexercise cooling on muscle oxygenation and blood volume changes. *Medicine & Science in Sports & Exercise*, *45*(5), 876-882. https://doi.org/10.1249/mss.0b013e31827e13a2
28. Järvinen, T. A., Järvinen, T. L., Kääriäinen, M., Kalimo, H., & Järvinen, M. (2005). Muscle injuries. *The American Journal of Sports Medicine*, *33*(5), 745-764. https://doi.org/10.1177/0363546505274714
29. Kennet, J., Hardaker, N., Hobbs, S., Selfe, J. (2007). Cooling efficiency of 4 common cryotherapeutic agents. *Journal of Athletic Training 42*(3):343.
30. Khan, K. M., & Scott, A. (2009). Mechanotherapy: How physical therapists' prescription of

exercise promotes tissue repair. *British Journal of Sports Medicine*, *43*(4), 247-252. https://doi.org/10.1136/bjsm.2008.054239

31. Knight KL (1995) Cryotherapy in sport injury management. Human Kinetics.
32. Knight, K. L., Brucker, J. B., Stoneman, P. D., & Rubley, M. D. (2000). Muscle injury management with cryotherapy. *Athletic Therapy Today*, *5*(4), 26-30. https://doi.org/10.1123/att.5.4.26
33. Kwiecien, S. Y., & McHugh, M. P. (2021). The cold truth: The role of cryotherapy in the treatment of injury and recovery from exercise. *European Journal of Applied Physiology*, *121*(8), 2125-2142. https://doi.org/10.1007/s00421-021-04683-8
34. Lieber, R. L. (2018). Biomechanical response of skeletal muscle to eccentric contractions. *Journal of Sport and Health Science*, *7*(3), 294-309. https://doi.org/10.1016/j.jshs.2018.06.005
35. Long, B. C., & Jutte, L. S. (2020). 21st century attacks on cryotherapy in sports health care—Clinician beware. *Athletic Training & Sports Health Care*, *12*(3), 99-101. https://doi.org/10.3928/19425864-20200401-02
36. Merrick, MA. (2002). Secondary injury after musculoskeletal trauma: a review and update. *Journal of Athletic Training 37*(2):209–217.
37. Merrick, M. A., & McBrier, N. M. (2010). Progression of secondary injury after musculoskeletal trauma—A window of opportunity? *Journal of Sport Rehabilitation*, *19*(4), 380-388. https://doi.org/10.1123/jsr.19.4.380
38. Rigby, J. H., & Dye, S. B. (2017). Effectiveness of various cryotherapy systems at decreasing ankle skin temperatures and applying compression. *International Journal of Athletic Therapy and Training*, *22*(6), 32-39. https://doi.org/10.1123/ijatt.2016-0079
39. Singh, D. P., Barani Lonbani, Z., Woodruff, M. A., Parker, T. J., Steck, R., & Peake, J. M. (2017). Effects of topical icing on inflammation, angiogenesis, Revascularization, and Myofiber regeneration in skeletal muscle following contusion injury. *Frontiers in Physiology*, *8*. https://doi.org/10.3389/fphys.2017.00093
40. Tidball, J. G. (2011). Mechanisms of muscle injury, repair, and regeneration. *Comprehensive Physiology*, 2029-2062. https://doi.org/10.1002/cphy.c100092
41. Vieira Ramos, G., Pinheiro, C. M., Messa, S. P., Delfino, G. B., Marqueti, R. D., Salvini, T. D., & Durigan, J. L. (2016). Cryotherapy reduces inflammatory response without altering muscle regeneration process and Extracellular matrix remodeling of rat muscle. *Scientific Reports*, *6*(1). https://doi.org/10.1038/srep18525
42. Watson, T. (2006). Tissue repair: the current state of the art / Soft Tissue Repair and Healing Review. Sportex medicine.