ISSN: 2754-6691

Journal of Internal Medicine Research & Reports

SCIENTIFIC Research and Community

Review Article

Open Access

Hydrotherapy Interventions for Muscle Recovery in Athletes: A Narrative Review

Rohan P[1], Geetha B Shetty[2], Sujatha K J[3], Prashanth Shetty[1], Nikhil Dilip Patil[1], Pavan K S[1], Manju M Y[1] and Nanjeshgowda H L[1]*

[1]Department of Natural Therapeutics, S.D.M College of Naturopathy and Yogic Sciences, Ujire, Karnataka, India

[2]Department of Acupuncture and Energy Medicine, S.D.M College of Naturopathy and Yogic Sciences, Ujire, Karnataka, India

[3]Department of Nutrition and Dietetics, S.D.M College of Naturopathy and Yogic Sciences, Ujire, Karnataka, India

ABSTRACT

Background: Hydrotherapy, leveraging water-based interventions, has garnered interest in sports medicine for its potential to enhance muscle recovery in athletes. This narrative review aims to synthesize current evidence regarding the effectiveness of various hydrotherapy interventions and their physiological underpinnings in promoting muscle recovery.

Research Problem and Aim: Despite the growing body of literature, there remains a need for a consolidated understanding of how specific hydrotherapy modalities contribute to muscle recovery, including the mechanisms involved and practical applications for athletes. This review seeks to clarify these aspects.

Methodology: A comprehensive literature search was conducted across electronic databases such as PubMed, Embase, and Cochrane Library, using keywords related to hydrotherapy and muscle recovery in athletes. Only articles published in English that focused on hydrotherapy interventions and their effects on muscle function, performance, and recovery perceptions were included.

Results: The findings indicate that hydrotherapy interventions, including cold water immersion, contrast water therapy, ice massage, aquatic exercise, and cryotherapy, effectively reduce muscle edema, inflammation, and pain, leading to improved muscle function and performance. Specifically, cold water immersion and contrast water therapy show significant benefits in enhancing recovery measures, while localized interventions like ice massage target specific muscle groups.

Implications: These results underscore the utility of hydrotherapy in athletic recovery protocols. Practitioners should tailor hydrotherapy interventions based on individual athlete needs, optimizing temperature, duration, and modality to maximize recovery outcomes while minimizing risks.

***Corresponding author**

Nanjeshgowda H L Department of Natural Therapeutics, S.D.M College of Naturopathy and Yogic Sciences, Ujire, Karnataka, India.

Received: February 24, 2025; **Accepted:** February 27, 2025; **Published:** March 10, 2025

Keywords: Hydrotherapy, Muscle Recovery, Athletes, Cold Water Immersion, Contrast Water Therapy, Ice Massage, Aquatic Exercise, Cryotherapy, Warm Water Immersion, Hydromassage, Underwater Treadmill Training, Aquatic Plyometric, Aquatic Resistance Training

Introduction

Hydrotherapy, a therapeutic approach that utilizes water based interventions, has gained significant attention in the realm of sports medicine and athlete rehabilitation [1] . The physical properties of water, including buoyancy, hydrostatic pressure, and temperature regulation, provide a unique environment that can be leveraged to support muscle recovery and optimize athletic performance [2] . This narrative review synthesizes the current evidence on the efficacy of hydrotherapy interventions in promoting muscle recovery among athletes, offering insights into the underlying physiological mechanisms and practical applications of this modality.

Water immersion has been shown to induce a range of physiological changes within the body, reflecting the distinct properties of the aquatic environment [3,4] . Specifically, the hydrostatic pressure experienced during water immersion can facilitate the movement of fluids between the intracellular and intravascular spaces, leading to a reduction in muscle edema [5]. This fluid shift, combined with the increased cardiac output and blood flow associated with water immersion, may enhance the transport of nutrients and the removal of metabolic waste products, ultimately aiding in the recovery process [2,6].

The temperature of the water used in hydrotherapy can also significantly influence the physiological response. Cool to thermoneutral water temperatures (around 15-22°C) have been suggested to provide the optimal range for promoting muscle recovery, as they can induce both vasoconstriction and vasodilation, respectively, which may help mitigate inflammation and facilitate

the removal of metabolic byproducts [3] . Additionally, the psychological benefits associated with water immersion, such as a perceived reduction in fatigue and a sense of relaxation, may contribute to the overall effectiveness of hydrotherapy interventions by improving the athlete's subjective experience and enhancing their ability to recover from strenuous physical activity [7].

The immersion of the human body in water, whether partially or fully, induces a series of physiological changes that can contribute to the recovery process [4]. When the body is immersed to the suprasternal notch, the hydrostatic pressure gradients are altered, leading to a shift of approximately 700 ml of blood from the lower extremities to the cardiothoracic region, resulting in increased central blood volume [2]. This increase in central blood volume triggers a cascade of cardiovascular, renal, and respiratory adjustments that may facilitate the recovery of muscle tissue and overall physiological function [8]. The increased central blood volume caused by immersion leads to a rise in stroke volume and cardiac output, which can enhance blood flow and the delivery of nutrients and oxygen to the muscles, potentially accelerating the recovery process [3]. Moreover, the hydrostatic pressure exerted by the water during immersion may help reduce muscle edema and promote the removal of metabolic waste products, further contributing to the overall recovery of muscle function and performance [3,9].

Hydrotherapy Interventions for Muscle Recovery

Among the various hydrotherapy interventions that have been explored for their potential to enhance muscle recovery in athletes, cold water immersion, contrast water therapy, ice massage therapy, cold pack application, aquatic exercise, cryotherapy, warm water immersion, hydromassage, underwater treadmill training, aquatic plyometric, and aquatic resistance training have garnered significant attention in the literature.

Cold Water Immersion

Cold water immersion involves the submersion of the body, or specific body parts, in water with temperatures typically ranging from 10°C to 15°C [4,10]. This approach is believed to facilitate muscle recovery by inducing vasoconstriction, which can reduce inflammation and edema, thereby promoting the recovery of muscle function and performance [11]. Numerous studies have reported that cold water immersion can effectively enhance the recovery of various performance measures, such as muscular strength, power, and endurance, when compared to passive recovery or other modalities [12]. The proposed mechanisms underlying the efficacy of cold water immersion include the reduction of muscle edema, decreased inflammation, and potential analgesic effects, all of which contribute to the overall improvement in muscle recovery.

Contrast Water Therapy

Contrast water therapy involves the alternation between hot and cold water immersion, typically with a ratio of 1:1 or 1:2 for hot and cold water, respectively [13,14]. The transition between vasodilation (in response to hot water) and vasoconstriction (in response to cold water) is thought to create a pumping action that can facilitate the removal of metabolic waste products and reduce inflammation, ultimately supporting the recovery of muscle function [15,16]. Several studies have demonstrated the potential benefits of contrast water therapy in improving various performance measures, such as muscle power, strength, and endurance, when compared to passive recovery or other intervention strategies [13].

Practical Considerations and Recommendations

When implementing hydrotherapy interventions for muscle recovery, it is essential to consider several practical factors, including water temperature, immersion duration, and the specific needs and preferences of the athlete [3,4,10,17]. The available evidence suggests that immersion in water with temperatures ranging from 10°C to 15°C for a duration of 5 to 15 minutes can be an effective approach for enhancing muscle recovery in athletes [4,14,18]. Furthermore, contrast water therapy, involving the alternation between hot and cold water immersion, may also provide benefits in terms of promoting muscle recovery and restoring athletic performance [10,19].

It is important to note that the optimal hydrotherapy protocols may vary depending on the specific sport, the type and intensity of the physical activity, and the individual athlete's response to the intervention [7]. Therefore, practitioners should closely monitor the athlete's response to the hydrotherapy intervention and make adjustments as needed to ensure the protocol is tailored to the individual's needs, maximizing the potential benefits and minimizing any risks or adverse effects [19].

Ice Massage Therapy

Ice massage therapy involves the direct application of ice to the skin, typically targeting specific muscle groups affected by exercise-induced muscle damage [20]. This intervention is believed to promote muscle recovery by reducing inflammation, alleviating pain, and facilitating the removal of metabolic byproducts from the affected muscle tissue [21]. Several studies have reported that ice massage therapy can effectively enhance various measures of muscle recovery, such as range of motion, muscle strength, and subjective perceptions of soreness, when compared to passive recovery or other interventions [22,23].

Aquatic Exercise

Aquatic exercises, such as underwater treadmill running or resistance training in water, have also been explored as a means to facilitate muscle recovery in athletes [24]. The unique properties of water, including its buoyancy and the hydrostatic pressure it exerts, can provide a supportive and low-impact environment for athletes to engage in physical activity during the recovery phase [25]. Aquatic exercises may help reduce the load on the musculoskeletal system, decrease the risk of further injury, and promote the removal of metabolic waste products, all of which can contribute to the overall recovery of muscle function and performance [26, 27].

Cryotherapy

Cryotherapy, which involves the exposure of the body or specific body parts to extremely low temperatures, has also been investigated as a potential hydrotherapy intervention for muscle recovery [28, 29]. Whole-body cryotherapy, for example, involves exposing the body to temperatures ranging from -110°C to -140°C for a short duration, typically 2-3 minutes [29, 30]. This approach is believed to reduce inflammation, alleviate pain, and enhance the recovery of muscle function by inducing vasoconstriction and reducing metabolic activity in the affected tissues [31-33].

Warm Water Immersion

Water-based therapies, or hydrotherapy, have emerged as a popular and effective approach for enhancing muscle recovery in athletes [4]. Aquatic therapy programs, such as the Halliwick method, Ai Chi, Watsu, and Feldenkrais, leverage the unique properties of water, including buoyancy, hydrostatic pressure, and temperature regulation, to improve muscle function and promote

faster recovery [25]. One of the key benefits of hydrotherapy is the reduction in the influence of gravity, which can decrease joint stress and provide postural support for individuals with mobility limitations.

Numerous studies have investigated the effectiveness of hydrotherapy interventions in promoting muscle recovery in athletes. A randomized and controlled trial found significant improvements in emotional and psychological state, joint tenderness, and range of motion among the hydrotherapy group compared to the control group [19,34]. Another review highlighted the potential of aquatic training, rehabilitation, and recovery protocols in enhancing athletic performance and optimizing recovery between training sessions and competitions [4].

Hydromassage

Hydromassage, a specialized form of hydrotherapy, has also been extensively explored for its potential benefits in enhancing muscle recovery for athletes [4]. Hydromassage utilizes water-powered massage jets to apply targeted, high-pressure stimulation directly to the muscles [35]. This technique aims to promote increased blood flow, reduce muscle tension and soreness, and alleviate lingering pain experienced after intense physical activity [36]. The synergistic combination of precisely controlled water temperature, strategically applied pressure, and the soothing, massaging action can provide a uniquely tailored and potentially highly effective approach to optimizing post-exercise muscle recovery [10]. By addressing the multifaceted physiological processes involved in the recovery of damaged muscle tissue, hydromassage has emerged as a promising hydrotherapy intervention that may help athletes restore muscular function, reduce the duration and severity of delayed-onset muscle soreness, and facilitate a quicker return to peak performance [37].

Underwater Treadmill Training

One innovative application of hydrotherapy for muscle recovery in athletes is the use of underwater treadmills [38]. These specialized treadmills are submerged in water, allowing athletes to walk or run in a buoyant and low-impact environment. This type of training can help reduce the stress and compressive forces on the joints and muscles, mitigating the risk of further injury or exacerbation of existing conditions [39]. By minimizing the ground reaction forces experienced during traditional treadmill or overground running, underwater treadmills enable athletes to engage in cardiovascular exercise and train specific gait patterns in a more controlled and therapeutic manner [40]. The buoyancy provided by the water supports the body's weight and decreases the loading on the musculoskeletal system, potentially facilitating a quicker recovery process and a smoother transition back to high-impact activities [41]. Additionally, the viscous resistance of the water can challenge the muscles to work harder, promoting muscular strength and endurance while still maintaining a low-impact environment [25]. This innovative hydrotherapy intervention allows athletes to continue their training and rehabilitation in a safe, controlled, and highly beneficial setting, optimizing their recovery and enhancing their overall athletic performance.

Aquatic Plyometrics

Another hydrotherapy intervention that has gained attention for muscle recovery in athletes is aquatic plyometrics [24]. Plyometric exercises, which involve rapid eccentric and concentric muscle contractions, can be performed in a water-based environment to reduce the impact and stress on the musculoskeletal system [42]. This approach allows athletes to engage in high-intensity, explosive movements while minimizing the compressive and shear forces that typically load the joints and soft tissues during traditional plyometric training on land [43]. The buoyancy provided by the water can significantly decrease the ground reaction forces experienced by the body, enabling athletes to execute plyometric exercises, such as jumping, hopping, and bounding, with a lower risk of injury [44]. Additionally, the viscous resistance of the water can challenge the muscles to produce powerful contractions in a controlled and low-impact manner, potentially enhancing muscular strength, power, and overall recovery [45]. By combining the benefits of plyometric training with the unique properties of the aquatic environment, aquatic plyometrics may offer a valuable intervention for athletes seeking to maintain high-intensity training while facilitating a more expedient recovery process [44].

Aquatic Resistance Training

Aquatic resistance training, where athletes perform strength-based exercises in the water, has also been investigated for its potential benefits in muscle recovery [25,46]. The resistance provided by the water can help maintain muscular strength and power while minimizing the impact on the body, potentially enhancing the recovery process. The buoyancy of the water can reduce the load and stress on the musculoskeletal system, allowing athletes to engage in strength training exercises with less joint impact and compressive forces [47]. This reduced mechanical stress on the muscles and joints, combined with the hydrostatic pressure and temperature regulation capabilities of the aquatic environment, can create an optimal setting for muscle recovery [48]. The viscous properties of the water provide a unique form of resistance that challenges the muscles in a controlled and low-impact manner, potentially leading to improvements in muscular endurance, joint stability, and overall recovery [25]. By leveraging the combined benefits of resistance training and the therapeutic effects of the aquatic environment, aquatic resistance training may serve as a valuable component of a comprehensive rehabilitation and recovery program for athletes, helping to restore muscular strength and power while facilitating a more efficient and expedited recovery process [27].

Literature Review

The scientific literature provides a comprehensive understanding of the various hydrotherapy interventions and their potential benefits for muscle recovery in athletes. Cold water immersion has been shown to effectively reduce muscle edema, inflammation, and pain, thereby improving the recovery of various performance measures, such as strength, power, and endurance [49]. Contrast water therapy, which involves the alternation between hot and cold water immersion, has also been demonstrated to have positive effects on muscle recovery, potentially by enhancing the removal of metabolic waste products and reducing inflammation [19,50].

In addition to these immersion-based approaches, other hydrotherapy interventions, such as ice massage therapy and aquatic exercise, have also been explored as means to facilitate muscle recovery. Ice massage therapy has been found to alleviate pain and improve range of motion, while aquatic exercise can provide a supportive environment for athletes to engage in low-impact physical activity during the recovery phase [3,10,17].

Cryotherapy, particularly whole-body cryotherapy, has also been investigated as a potential hydrotherapy intervention for muscle recovery [51]. The exposure to extremely low temperatures is believed to induce physiological responses, such as vasoconstriction and reduced metabolic activity, which may contribute to the reduction of inflammation and the enhancement of muscle recovery [28,29,52]. The effectiveness of these hydrotherapy

interventions may be influenced by various factors, including the specific protocols used, the individual athlete's response, and the type and intensity of the physical activity.

Methodology

Relevant research articles were identified through a comprehensive literature search using various electronic databases, including PubMed, Embase, and Cochrane Library. The search terms included "hydrotherapy," "water immersion," "cold water immersion," "contrast water therapy," "ice massage," "aquatic exercise," "cryotherapy," "warm water immersion," "hydromassage," "underwater treadmill training," "aquatic plyometric," "aquatic resistance training," "muscle recovery," and "athletes." The search was limited to articles published in peer-reviewed journals in English.

The included studies were required to have a focus on the use of hydrotherapy interventions for the purpose of muscle recovery in athletes, with outcomes related to measures of muscle function, performance, and subjective perceptions of recovery. Studies were excluded if they did not specifically investigate the effects of hydrotherapy on muscle recovery or if they were not conducted with athletes as the study population.

The identified studies were reviewed and analyzed to synthesize the current understanding of the effectiveness of various hydrotherapy interventions in promoting muscle recovery in athletes.

Results

The review of the literature (Sánchez-Ureña et al., 2018) (Crowther et al., 2017) (Higgins et al., 2017) (Wilcock et al., 2006) highlights the potential benefits of various hydrotherapy interventions for muscle recovery in athletes. Cold water immersion has been consistently shown to be effective in reducing muscle edema, inflammation, and perceived pain, leading to improved recovery of muscle function and performance [10,19]. Contrast water therapy, which combines hot and cold water immersion, has also demonstrated positive effects on measures of muscle recovery, potentially by enhancing the removal of metabolic waste products and reducing inflammation. Furthermore, ice massage therapy has been found to alleviate pain and improve range of motion, suggesting its potential as a localized hydrotherapy intervention for targeted muscle groups affected by exercise-induced muscle damage [3,10,17]. Aquatic exercise, on the other hand, provides a supportive and low-impact environment for athletes to engage in physical activity during the recovery phase, which may help reduce the load on the musculoskeletal system, decrease the risk of further injury, and promote the removal of metabolic waste products.

Discussion

Hydrotherapy, the use of water-based treatments for therapeutic purposes, has gained significant attention in the sports medicine community for its potential to enhance muscle recovery in athletes [7]. The unique properties of water, including buoyancy, hydrostatic pressure, and temperature regulation, provide a favorable environment for post-exercise recovery [24]. Aquatic therapy programs, such as the Halliwick method, Ai Chi, Watsu, and Feldenkrais, leverage these properties to improve muscle function and promote faster recovery [53] . One of the key benefits of hydrotherapy is the reduction in the influence of gravity, which can decrease joint stress and provide postural support for individuals with mobility limitations [25]. Additionally, the rhythmic and repetitive nature of certain aquatic exercises, such as hippotherapy, can mimic natural gait patterns and have immediate positive effects on the body [54,55].

The application of hydrotherapy for muscle recovery in athletes has been supported by a growing body of research. Studies have demonstrated that hydrotherapy interventions can lead to significant improvements in emotional and psychological state, joint tenderness, and range of motion, compared to other recovery modalities [56]. Additionally, the use of hydrotherapy as part of a comprehensive recovery protocol has been shown to offer advantages in team sport performance, as it can help optimize recovery between training sessions and competitions [57].

Mechanisms of Hydrotherapy for Muscle Recovery

The fundamental principles of hydrodynamics, such as density, hydrostatic pressure, and buoyancy, play a crucial role in the biological effects of water immersion on the human body [25]. Water-based interventions, commonly referred to as hydrotherapy or aquatic therapy, have been widely utilized in the rehabilitation and recovery processes of athletes [50,58]. The therapeutic properties of thermal springs have been recognized since ancient times, with animals and humans alike discovering the medicinal benefits of these natural resources [59]. Aquatic therapy programs, including the Halliwick method, Ai Chi, Watsu, and Feldenkrais, have been tailored to address various clinical conditions, including those affecting muscle recovery in athletes [6,53]. These water-based interventions leverage the unique properties of the aquatic environment to facilitate improved muscle function, reduced pain, and enhanced overall recovery for athletes [24,60].

Hydrotherapy and Delayed Onset Muscle Soreness

Hydrotherapy interventions have also been extensively studied for their effectiveness in mitigating the symptoms of delayed onset muscle soreness, a common consequence of intense physical activity [37]. A comprehensive review of the literature examined the effects of various hydrotherapy modalities, including cold water immersion, hot water immersion, and contrast water therapy, on DOMS [61]. The findings revealed that all three hydrotherapy interventions were highly effective in reducing the physiological and functional symptoms associated with this condition [62].

The authors suggest that the multifaceted benefits of the aquatic environment contribute to the observed improvements in DOMS. The combination of hydrostatic pressure, which can enhance blood flow and lymphatic drainage, along with the temperature regulation capabilities of hydrotherapy, play a key role [50]. Cold water immersion may help reduce inflammation and muscle spasm, while warm water immersion can promote vasodilation and increased blood perfusion to the affected muscle tissues [63]. The alternating temperatures and pressures of contrast water therapy appear to create an optimal environment for flushing out metabolic waste products, reducing edema, and accelerating the recovery process [64]. Collectively, these hydrodynamic and thermal effects facilitated by the aquatic environment are believed to be the primary mechanisms underlying the substantial mitigation of DOMS symptoms observed in these studies.

Hydrotherapy and Muscle Inflammation

Hydrotherapy has also been extensively explored for its potential to address muscle inflammation, a crucial factor in the recovery process [65]. The manipulation of water temperature, pressure, and agitation can influence a multitude of physiological mechanisms, all of which play a vital role in the inflammatory response and subsequent recovery [12]. For instance, the hydrostatic pressure exerted by the water can stimulate improved blood flow and lymphatic drainage, facilitating the removal of inflammatory

byproducts and cytokines from the affected muscle tissues [66]. Additionally, the temperature regulation capabilities of hydrotherapy, ranging from cold water immersion to warm water immersion, can modulate the release and activity of inflammatory mediators, dampening the inflammatory cascade and creating an environment more conducive to tissue repair and regeneration [67]. By simultaneously addressing various aspects of the inflammatory process, such as blood flow, fluid dynamics, and the regulation of inflammatory signaling, hydrotherapy interventions have demonstrated the potential to significantly mitigate muscle inflammation and accelerate the overall recovery process for athletes [68].

Hydrotherapy and Muscle Blood Flow

The aquatic environment can profoundly influence muscle blood flow, a critical factor in the recovery process [69]. The hydrostatic pressure exerted by the water can increase venous return and cardiac output, leading to enhanced blood perfusion and nutrient delivery to the muscles [47]. This increased blood flow not only facilitates the removal of metabolic waste products, such as lactic acid and inflammatory mediators, but also enhances the delivery of oxygen and essential nutrients to the muscle tissues [70]. This dual effect of improved blood circulation can have a significant impact on the recovery process, potentially accelerating the clearance of catabolic byproducts and promoting the influx of anabolic substrates needed for muscle repair, regeneration, and adaptation [71]. The unique hydrodynamic properties of the aquatic environment, combined with the temperature regulation and potential anti-inflammatory effects, create an ideal milieu to optimize muscle blood flow and facilitate a more efficient and expedited recovery in athletes [3].

Hydrotherapy and Muscle Tissue Repair

The unique properties of the aquatic environment may also contribute significantly to the promotion of muscle tissue repair and recovery [69]. The buoyancy provided by the water can substantially reduce the load and impact on the musculoskeletal system, allowing athletes to engage in gentle, low-impact movements and exercises that may more effectively stimulate the natural healing and recovery processes without exacerbating or further aggravating existing muscle injuries or soreness [72]. This reduced mechanical stress on the muscles and joints, combined with the temperature regulation and potential anti-inflammatory effects of the water, can create an ideal environment to facilitate the repair and regeneration of muscle tissue, ultimately accelerating the overall recovery process for athletes [4].

Hydrotherapy and Muscle Function Recovery

In addition to the substantial physiological benefits, hydrotherapy interventions may also confer significant functional improvements during the athlete's recovery process [68]. The enhanced muscle blood flow, reduced inflammation, and facilitated tissue repair stimulated by the aquatic environment can collectively contribute to a more expedient and complete restoration of muscular strength, power output, and overall functional capacity [60]. Studies have consistently demonstrated that athletes who undergo targeted hydrotherapy treatments, such as cold water immersion or contrast water therapy, often exhibit a faster and more comprehensive return to their pre-injury or pre-exercise performance levels compared to control conditions without such interventions [73]. This rapid restoration of optimal muscle function is crucial for athletes, as it allows them to safely and effectively resume their rigorous training regimes and competitive events without undue risk of re-injury or prolonged deficits in athletic performance [74].

Conclusion

In conclusion, the available evidence suggests that hydrotherapy interventions, such as cold-water immersion, contrast water therapy, ice massage therapy, and aquatic exercise, can be effective in promoting muscle recovery in athletes. These interventions have been shown to reduce muscle edema, inflammation, and perceived pain, leading to improved recovery of muscle function and performance.

However, further research is needed to establish the optimal parameters for these hydrotherapy interventions, as well as to investigate the potential long-term effects and safety considerations.

References

1. Momberg BL, Louw C, Crous L (2008) Accelerated hydrotherapy and land-based rehabilitation in soccer players after anterior cruciate ligament reconstruction: a series of three single subject case studies. South A fr Sports Med Assoc 5: 20.
2. Hall J, Bisson D, O'Hare P (1990) The Physiology of Immersion. Physiotherapy. 76: 517-21.
3. Wilcock IM, Cronin J, Hing W (2006) Physiological Response to Water Immersion Springer Science Business Media. 36: 747-65.
4. Versey NG, Halson SL, Dawson B (2013) Water Immersion Recovery for Athletes: Effect on Exercise Performance and Practical Recommendations. Springer Science Business Media. 43: 1101-1130.
5. Weenink RP, Wingelaar TT (2021) The Circulatory Effects of Increased Hydrostatic Pressure Due to Immersion and Submersion. Front Physiol 12: 699493.
6. Becker BE (2009) Aquatic Therapy: Scientific Foundations and Clinical Rehabilitation Applications. PM R 1: 859-872.
7. Higgins T, Climstein M, Cameron L (2012) Evaluation of Hydrotherapy, Using Passive Tests and Power Tests, for Recovery Across a Cyclic Week of Competitive Rugby Union. J Strength Cond Res Natl Strength Cond Assoc 12: 27.
8. Romero SA, Minson CT, Halliwill JR (2017) The cardiovascular system after exercise. J Appl Physiol 122: 925-932.
9. Torres-Ronda L, del Alcázar XS I (2014) The Properties of Water and their Applications for Training. J Hum Kinet 44: 237-248.
10. Crowther F, Sealey R, Crowe M, Edwards A, Halson S (2017) Influence of recovery strategies upon performance and perceptions following fatiguing exercise: a randomized controlled trial. BMC Sports Sci Med Rehabil 9: 25.
11. Versey NG, Halson SL, Dawson BT (2008) Water immersion recovery for athletes: effect on exercise performance and practical recommendations. Sports Med 43: 1101-1130.
12. Peake JM, Roberts LA, Figueiredo VC, Egner I, Krog S, et al. (2017) The effects of cold water immersion and active recovery on inflammation and cell stress responses in human skeletal muscle after resistance exercise. J Physiol 595: 695-711.
13. Greenhalgh O, Alexander J, Richards J, Selfe J, McCarthy C (2021) The use of contrast therapy in soft tissue injury management and post-exercise recovery: a scoping review. Phys Ther Rev 26: 64-72.
14. Machado AF, Ferreira PH, Micheletti JK, de Almeida AC, Lemes ÍR, et al. (2016) Can Water Temperature and Immersion Time Influence the Effect of Cold Water Immersion on Muscle Soreness? A Systematic Review and Meta-Analysis. Sports Med Auckl Nz. 46: 503-514.
15. Charkoudian N (2010) Mechanisms and modifiers of reflex

induced cutaneous vasodilation and vasoconstriction in humans. J Appl Physiol 109: 1221-1228.
16. Johnson JM, Kellogg DL (2010) Local thermal control of the human cutaneous circulation. J Appl Physiol 109: 1229-1238.
17. Sánchez-Ureña B, Rojas-Valverde D, Gutiérrez-Vargas R (2018) Effectiveness of Two Cold Water Immersion Protocols on Neuromuscular Function Recovery: A Tensiomyography Study. Front Physiol 9: 766.
18. Pournot H, Bieuzen F, Duffield R, Lepretre PM, Cozzolino C, et al. (2011) Short term effects of various water immersions on recovery from exhaustive intermittent exercise. Eur J Appl Physiol 111: 1287-1295.
19. Higgins TR, Greene DA, Baker MK (2017) Effects of Cold Water Immersion and Contrast Water Therapy for Recovery from Team Sport: A Systematic Review and Meta-analysis. J Strength Cond Res 31: 1443.
20. Bugaj R (1975) The Cooling, Analgesic, and Rewarming Effects of Ice Massage on Localized Skin. Phys Ther 55: 11-19.
21. Minett GM, Costello JT (2015) Specificity and context in post-exercise recovery: it is not a one-size-fits-all approach. Front Physiol 6.
22. Yackzan L, Adams C, Francis KT (1984) The effects of ice massage on delayed muscle soreness. Am J Sports Med 12: 159-165.
23. Rahimi A (2005) The Effects of ice, massage and aerobic cool-down exercise on delayed onset muscle soreness syndrome. JRUMS 276-285.
24. Choi E (2015) Aquatic Physical Therapy in the Rehabilitation of Athletic Injuries: A Systematic Review of the Literatures. J Yoga Phys Ther 1: 05.
25. Torres-Ronda L, Schelling X (2014) The Properties of Water and their Applications for Training. Gruyter Open 44: 237-248.
26. Prins J, Cutner D (1999) AQUATIC THERAPY IN THE REHABILITATION OF ATHLETIC INJURIES. Clin Sports Med 18: 447-461.
27. Buckthorpe M, Pirotti E, Della Villa F. BENEFITS AND USE OF AQUATIC THERAPY DURING REHABILITATION AFTER ACL RECONSTRUCTION -A CLINICAL COMMENTARY. Int J Sports Phys Ther 14: 978-993.
28. White GE, Wells GD (2013) Cold-water immersion and other forms of cryotherapy: physiological changes potentially affecting recovery from high-intensity exercise. Extreme Physiol Med 2: 26.
29. Ferreira-Junior JB, Bottaro M, Loenneke JP, Vieira A, Vieira CA (2014) Could whole-body cryotherapy (below−100°C) improve muscle recovery from muscle damage? Front Physiol 5: 247.
30. Rose C, Edwards KM, Siegler J, Graham K, Caillaud C (2017) Whole-body Cryotherapy as a Recovery Technique after Exercise: A Review of the Literature. Int J Sports Med 38: 1049-1060.
31. Lubkowska A (2012) Cryotherapy: Physiological Considerations and Applications to Physical Therapy. https://www.intechopen.com/chapters/35000.
32. Draper DO, Roberts B (2018) Cryotherapy: The Dry Benefits. MOJ Sports Medicine 2: 1-4.
33. Mac Auley DC (2001) Ice therapy: how good is the evidence? Int J Sports Med 2: 379-384.
34. Ahern M, Nicholls E, Simionato E, Clark M, Bond M (1995) Clinical and psychological effects of hydrotherapy in rheumatic diseases. Clin Rehabil 9: 204-212.
35. Best TM, Crawford SK (2016) Massage and postexercise recovery: the science is emerging. BMJ 51: 1386-1387.
36. Gerald W Bell (1999) I undefined University of Illinois, Urbana. Aquatic sports massage therapy. 18: 427-435
37. Vaile J, Halson SL, Gill N, Dawson B (2007) Effect of hydrotherapy on the signs and symptoms of delayed onset muscle soreness. Springer Sci Media 102: 447-455.
38. Kim MK, Lee SA (2017) Underwater treadmill training and gait ability in the normal adult. Penerbit Univ Sains Malays 29: 67-69.
39. Silvers WM, Bressel E, Dickin DC, Killgore GL, Dolny D (2014) Lower-Extremity Muscle Activity During Aquatic and Land Treadmill Running at the Same Speeds. Hum Kinet 23: 107-122.
40. Benelli P, Colasanti F, Ditroilo M, Cuesta-Vargas A, Gatta G, et al. (2013) Physiological and biomechanical responses to walking underwater on a non-motorised treadmill: effects of different exercise intensities and depths in middle-aged healthy women. Taylor Francis 32: 268-277.
41. Cortesi M, Giovanardi A, Fantozzi S, Borra D, Gatta G (2016) Aquatic Therapy after Anterior Cruciate Ligament Surgery: A Case Study on Underwater Gait Analysis using Inertial and Magnetic Sensors 2.
42. Eraslan L, Castelein B, Spanhove V, Orhan C, Düzgün İ (2020) Cools A. Effect of Plyometric Training on Sport Performance in Adolescent Overhead Athletes: A Systematic Review. SAGE Publishing 13: 37-44.
43. Miller MG, Berry D, Gilders RM, Bullard S (2001) Recommendations for Implementing an Aquatic Plyometric Program. Lippincott Williams Wilkins 23: 28-28.
44. Dapinder P, SARIKA S, Jaspal S (2012) Comparative and Interactive Effects of Land-and Aquatic-Based Plyometric Training on Agility and Peak Speed of Elite Young Athletes of the: Sporting Environment. International Journal of Physical Education, Fitness and Sports 1: 40-48.
45. Masumoto K, Takasugi S I, Hotta N, Fujishima K, Iwamoto Y (2004) Electromyographic Analysis of Walking in Water in Healthy Humans. J Physiol Anthropol Appl Human Sci 23:119-127.
46. Colado JC, Triplett NT (2009) Monitoring the Intensity of Aquatic Resistance Exercises with Devices That Increase the Drag Force: An Update. Lippincott Williams Wilkins 31: 94-100.
47. Payton S (2017) Brief Review of Beneficial Properties of Aquatic Exercise. MedCrave Group 7.
48. Tamburella F, Scivoletto G, Cosentino E, Molinari M (2013) Walking in Water and on Land After an Incomplete Spinal Cord Injury. Lippincott Williams Wilkins 92: e4-15.
49. Pesenti F, Da Silva R, Monteiro D, Silva L, Macedo C (2020) The Effect of Cold water Immersion on Pain, Muscle Recruitment and Postural Control in Athletes. Rev Bras Med Esporte 26: 323-327.
50. An J, Lee I, Yi Y (2019) The Thermal Effects of Water Immersion on Health Outcomes: An Integrative Review. Int J Environ Res Public Health 16: 1280.
51. Hohenauer E, Taeymans J, Baeyens JP, Clarys P, Clijsen R (2015) The Effect of Post-Exercise Cryotherapy on Recovery Characteristics: A Systematic Review and Meta-Analysis. PLoS ONE 10: e0139028.
52. Roberts LA, Muthalib M, Stanley J, Lichtwark G, Nosaka K, et al. (2015) 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. 309: 389-398.
53. Noh DK, Lim JY, Shin HI, Paik NJ (2008) The effect of aquatic therapy on postural balance and muscle strength in stroke survivors - a randomized controlled pilot trial. SAGE

Publ 22: 966-976.

54. Rosa KP da S, Martinez FG, Peyré-Tartaruga LA (2017) Benefits of aquatic exercise therapy on locomotion in low back pain subjects: a narrative literature review. EDP Sci 98:51-58.
55. Song JA, Oh JW (2022) Effects of Aquatic Exercises for Patients with Osteoarthritis: Systematic Review with Meta-Analysis. Healthcare (Basel) 10 :56
56. Hall J, Skevington SM, Lanyon P, Chapman K (1996) A randomized and controlled trial of hydrotherapy in rheumatoid arthritis. Wiley 9: 206-215.
57. Calleja-González J, Mielgo-Ayuso J, Sampaio J, Delextrat A, Ostojić SM, et al. (2018) Brief ideas about evidence-based recovery in team sports 14: 545-550.
58. Fragkou D, Gkrimas G, Pyrgeli M (2018) Therapeutic interventions for trunk and improvement of posture in children with cerebral palsy: a review of the literature. MedCrave Group 10: 288-296.
59. Farhat N, Hussain S, Faisal F, Batool I, Noreen M (2021) Physico-chemical characteristics and therapeutic potential of Chutrun thermal springs in Shigar Valley, Gilgit-Baltistan (Pakistan). Springer Nat 11.
60. Thein JM, Brody LT (1998) Aquatic-Based Rehabilitation and Training for the Elite Athlete. Am Phys Ther Assoc 27: 32-41.
61. Glasgow P, Ferris R, Bleakley C (2014) Cold water immersion in the management of delayed-onset muscle soreness: Is dose important? A randomised controlled trial. Elsevier BV. 15: 228-233.
62. Bleakley C, McDonough S, Gardner E, Baxter D, Hopkins JT, et al. (2012) Cold-water immersion (cryotherapy) for preventing and treating muscle soreness after exercise. Elsevier BV CD008262.
63. Preisinger E, Quittan M. (1994) [Thermo- and hydrotherapy]. Natl Inst Health. 144:520-526.
64. Fiscus KA, Kaminski TW, Powers ME (2005) Changes in Lower-Leg Blood Flow During Warm-, Cold-, and Contrast-Water Therapy. Elsevier BV 86: 1404-1410.
65. Mayer JM, Mooney V, Matheson LN, Erasala GN, Verna JL, et al. (2006) Continuous Low-Level Heat Wrap Therapy for the Prevention and Early Phase Treatment of Delayed-Onset Muscle Soreness of the Low Back: A Randomized Controlled Trial. Elsevier BV 87:1310-1317.
66. Toumi H, F'guyer S, Best TM (2006) The role of neutrophils in injury and repair following muscle stretch. Wiley 208: 459-470.
67. Franchimont P, Juchmest J, Lecomte J (1983) Hydrotherapy-mechanisms and indications Pharmacol Ther 20: 79-93.
68. Cuesta-Vargas A, Travé-Mesa A, Vera-Cabrera A, Cruz-Terrón D, Castro-Sánchez AM, et al. (2013) Hydrotherapy as a recovery strategy after exercise: a pragmatic controlled trial. BioMed Cent 13: 180.
69. Becker B, Hildenbrand K, Whitcomb R, Sanders J (2009) Biophysiologic Effects of Warm Water Immersion. Int J Aquat Res Educ 3: 24-37.
70. Kolka CM (2016) The Skeletal Muscle Microvasculature and Its Effects on Metabolism https://doi.org/10.5772/63535
71. Gillani S, Cao J, Suzuki T, Hak DJ (2012) The effect of ischemia reperfusion injury on skeletal muscle. Injury 43: 670-675.
72. Maffulli N, Longo UG, Spiezia F, Denaro V (2010) Sports Injuries in Young Athletes: Long-Term Outcome and Prevention Strategies. Taylor Francis 38: 29-34.
73. Rink I, Rill S, Baumann CR. (2020) Therapeutische Wirksamkeit von Kaltwasserimmersionen auf die Wiederherstellung der Leistungsfähigkeit von Sportlern nach intensiven Lauf- und Fahrradbelastungen Eine systematische Literaturübersichtsarbeit. Georg Thieme Verl. 16: 121-131.
74. Foglia A, Bitocchi M, Gervasi M, Secchiari G, Cacchio A (2013) Conservative Treatment of Muscle Injuries: From Scientific Evidence to Clinical Practice. https://doi.org/10.5772/56550.