CRYOTHERAPY: ONE OF THE POSSIBILITIES OF MUSCLE RECOVERY AFTER TRAUMATIC INJURIES

Abstract. Muscle injuries are increasingly common in today's active lifestyles, necessitating effective recovery methods. Cryotherapy's effectiveness lies in its ability to reduce inflammation, provide pain relief, and accelerate the recovery process. Cryotherapy, employing cold for therapeutic benefits, has gained popularity for its potential to enhance muscle recovery. This article provides a thorough examination of cryotherapy as a promising method for restoring muscle function.
after traumatic injuries. Analyzing recent research and publications, the review explores the principles of cryotherapy, its impact on the recovery process, and the increasing popularity of this modality in rehabilitation. The analysis covers various cryotherapy methods, including cryo-chambers, local cold application, and immersion in cold water, highlighting their effectiveness, comfort, and safety. The review delves into the physiological principles of cryotherapy, emphasizing its role in reducing inflammation, alleviating pain, accelerating the recovery process, promoting tissue healing, and controlling swelling. It also addresses potential limitations and risks associated with cryotherapy, such as the risk of hypothermia, emphasizing the need for caution and individualized approaches. The article incorporates findings from recent studies, examining the impact of cryotherapy on dynamic postural stability, physiological and biomechanical performance in athletes, and its application in specific scenarios like post-surgical interventions and injuries resulting from physical activities. Furthermore, the review discusses the contraindications of whole-body cryotherapy (WBC) and underscores the importance of conducting cryotherapy in controlled conditions. In conclusion, this comprehensive review underscores the significant potential of cryotherapy in muscle recovery after injuries, providing valuable insights into its applications, effectiveness, and considerations for individualized treatment plans. The article aims to contribute to a deeper understanding of cryotherapy and its role in the evolving landscape of rehabilitation strategies for diverse patient populations.

**Keywords:** cryotherapy, muscle damage, treatment, recovery, rehabilitation, cryotherapy methods.

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КРИОТЕРАПІЯ: ОДНА З МОЖЛИВОСТЕЙ ВІДНОВЛЕННЯ М'ЯЗІВ ПІСЛЯ ТРАВМАТИЧНИХ УШКОДЖЕНЬ

Анотація. Травми м'язів стають все більш поширенним явищем у сучасному активному способі життя, що вимагає ефективних методів відновлення. Ефективність кріотерапії полягає в її здатності зменшувати запалення, знеболювати та прискорювати процес відновлення. Кріотерапія, що використовує холод з лікувальною метою, набула популярності завдяки своєму потенціалу для покращення відновлення м'язів. У цій статті представлено ґрунтовний огляд кріотерапії як перспективного методу відновлення функцій м'язів після травматичних ушкоджень. Аналізуючи останні дослідження та публікації, в огляді розглядаються принципи кріотерапії, її вплив на процес відновлення та зростаючу популярність цього методу в реабілітації. Аналіз охоплює різні методи кріотерапії, включаючи кріокамери, локальне застосування холоду та занурення в холодну воду, підкреслюючи їхню ефективність, комфорт та безпеку. Огляд заглиблюється у фізіологічні принципи кріотерапії, підкреслюючи її роль у зменшенні запалення, полегшені болю, прискоренні процесу одужання, сприянні загоєнню тканин і контролі набряків. У ній також розглядаються потенційні обмеження та ризики, пов'язані з кріотерапією, такі як ризик переохолодження, підкреслюються ефективність, комфорт та безпеку. Огляд заглиблюється у фізіологічні принципи кріотерапії, підкреслюючи її роль у зменшенні запалення, полегшені болю, прискоренні процесу одужання, сприянні загоєнню тканин і контролі набряків. У ній також розглядаються потенційні обмеження та ризики, пов'язані з кріотерапією, такі як ризик переохолодження, підкреслюються необхідність обережності та індивідуального підходу. Статті включає результати нещодавніх досліджень, що вивчають вплив кріотерапії на динамічну стабільність постави, фізіологічні та біомеханічні показники спортсменів, а також її застосування в конкретних сценаріях, таких як післяопераційні втручання та травми, отримані внаслідок фізичних навантажень. Крім того, в огляді обговорюються протипоказання до
Kręotapieja wscio gola (WBC) i podkreśla się wadliwości prowadienia kręotapieja w kontrolowanych umowach. Na zakończenie, cei wsebiczny ogląd podkreśla znaczy potencjał kręotapieja u wodnionem mięścyczkowi próżiau tram, nadając cruzin informacj a proj za stosowania, efektywność a mięcienia wydjo individuálnych planów lićowania. Czci ma na met spriyü gióshōmu roczumieńiu kręotapieja a jej rol w ewolucji strategii reabilitacji dla riznych grup pacjentów.

Kłucywe słowa: kręotapieja, uszkodzenia m’ęźcib, lićowania, wiedzenia, reabilitacja, metody kręotapieja.

Statement of the problem. In the contemporary landscape of active lifestyles, the prevalence of muscle injuries has become an inherent aspect of various human activities, stemming from accidents, overexertion, or unforeseen circumstances [1]. These injuries often result in significant damage, necessitating effective and reliable recovery strategies. Science already knows methods of treating traumatic muscle injuries, such as physiotherapy and rehabilitation, pharmacotherapy, platelet-rich plasma injections, laser therapy, ultrasound therapy, and the use of mesenchymal stem cells [2,3,4]. Amid the array of available approaches, cryotherapy, harnessing the therapeutic potential of cold, has emerged as an innovative and increasingly popular method for muscle recovery. The multifaceted nature of muscle injuries demands comprehensive interventions that extend beyond conventional methodologies. Cryotherapy presents itself as a promising avenue, offering rapid pain relief, substantial effects on inflammation reduction, and overall enhancement of the injured muscle's condition [5]. However, the integration of cryotherapy into mainstream rehabilitation practices requires a nuanced understanding of its mechanisms, applications, and potential considerations. Understanding cryotherapy's benefits and limitations is pivotal, especially in light of recent studies that highlight both positive and potentially adverse effects on dynamic postural stability and physiological performance in athletes. Moreover, the safety considerations and contraindications associated with cryotherapy, particularly in the context of whole-body cryotherapy, warrant meticulous examination to ensure its responsible and effective application [6]. In essence, this review seeks to address the overarching problem of optimizing muscle recovery after traumatic injuries through cryotherapy. By critically assessing its principles, applications, safety considerations, and real-world impact, this exploration aims to contribute to a deeper understanding of cryotherapy's role in the evolving landscape of rehabilitation strategies and its potential as a mainstream approach to muscle health.

Analysis of the latest research and publications. The purpose of this article is to thoroughly review cryotherapy as an effective method of restoring muscle function after traumatic injuries. The analysis will cover the main literature data, the principles of cryotherapy, its impact on the recovery process and scientifically
proven results of successful application. We will try to identify the advantages of this method and understand how it can become a necessary link in an integrated approach to the rehabilitation of patients after muscle injuries.

The aim of this article is to analyse the literature and gain a deeper understanding of what cryotherapy is and its new perspectives in the field of muscle health.

Presentation of the main material.

Cryotherapy is a method that uses low temperatures to achieve a therapeutic effect. The article by Kwiecien S. and McHugh M. (2021) states that cryotherapy is a physical intervention to treat injuries and facilitate recovery from physical activity. Typically, ice is used to treat musculoskeletal injuries, while cold water immersion or full-body cryotherapy is used to recover from physical activity. In humans, the main benefit of traditional cryotherapy is to relieve pain after injury or reduce soreness after exercise. In recent developments, a new approach has been successfully applied, involving cooling with a phase change material (PCM) at a temperature of 15 °C for 3-6 hours after exercise. Although prolonged use of cryotherapy during resistance training can reduce the anabolic effect of training, recovery with PhMF does not disrupt acute adaptation. Consequently, cryotherapy is recommended after training when rapid recovery is critical between exercises, unlike in conventional training. Therefore, in order to reduce the escalation of secondary tissue damage that occurs several hours after an injury or intense physical activity, it is necessary to apply cryotherapy liberally in the first hours after the onset of structural damage [7].

The paper by Patel, K et al. (2019) indicates that during exercise, muscle activity generates oxidants within cells that are released into the intercellular space through membrane ruptures, which often occur during physical activity. These released oxidants contribute to additional membrane damage, which leads to an increase in the concentration of reactive oxygen species in the intracellular space. This surge in reactive oxygen species triggers a local inflammatory response that leads to muscle damage. Whole-body cryotherapy (WBC) is proposed to reduce pain and injury after sports events by reducing catabolic muscle activity [8].

A controlled trial by Fullam, K. et al. (2015) aimed to evaluate the direct effect of 15 minutes of ankle cryotherapy on dynamic postural stability in 29 elite-level male college athletes. The participants were tested using the Star Excursion balance test in different directions before and after cryotherapy. The results showed a significant decrease in performance in all directions after cryotherapy, indicating a negative impact on dynamic postural stability. There were no significant changes in the kinematics of the hip, knee and ankle joints, but there was a marked decrease in the average speed of the centre of pressure trajectory after cryotherapy. Hence, the study suggests that ankle cryotherapy may have a negative impact on dynamic postural stability immediately after application [9].
Jill Alexander et al. (2021) investigated the immediate effects of Game Ready® cryotherapy on physiological and biomechanical performance in elite men's academy football players following a gruelling training session during a competitive season. Twenty participants were randomised to undergo cryotherapy (Game Ready®) or passive recovery. Measurements included counter-movement jump (CMJ), isometric adductor muscle strength (IAS), hamstring flexibility (HF) and skin surface temperature (Tsk). The results show a significant decrease in the jump versus movement scores immediately after cryotherapy, but not during passive recovery. No significant effects were observed for IAS or HF. Skin surface temperature decreased significantly with cryotherapy, aligning with therapeutic ranges. The study suggests that although cryotherapy may reduce immediate performance, its use should take into account specific recovery requirements, adapting individually to optimise the athlete's readiness for further training or competition [10].

The paper by J. L. Moeller et al. (1997) described a case highlighting an unusual complication of distal hamstring icing - cryotherapy-induced generalised peroneal nerve palsy in a 22-year-old football player. After 20 minutes of ice application, the patient experienced foot drop and sensory changes in the lower leg and foot. In contrast to previously described cases with nerve damage to the fibular neck due to lateral icing of the knee joint or circular icing of the hip, this case involved icing of the distal hamstring, which caused more proximal nerve damage. The patient achieved full clinical neurological recovery over the following year. This highlights the need for caution, even with common methods such as ice, especially in individuals with low body fat or when ice is applied to areas with less subcutaneous tissue protection for the nerves [11].

An investigation by Kevin C. Miller et al. (2015) aimed to assess the impact of wearing a full American football uniform during cold-water immersion (CWI) on the time required to cool rectal temperature (Trec) from 39.5°C to 38.0°C and to determine its effect on post-immersion Trec recovery. Eighteen physically active men participated in the study, wearing either a control uniform or a full football uniform during CWI. The results showed that participants wearing the full uniform experienced a faster cooling time to reach 38.0°C compared to the control uniform. The study suggests that, contrary to concerns, immersing football athletes with hyperthermia in a full uniform during CWI does not negatively impact body-core cooling and does not cause greater post-immersion hypothermic afterdrop [12].

The main principles of cryotherapy are as follows:
- Reducing inflammation, as cold leads to vasoconstriction, reducing the penetration of blood and lymph into the injured area. This helps to reduce inflammation and eliminate swelling that may accompany, which is typical in muscle injuries [13].
- Pain relief, as low temperatures can have an analgesic effect because they block the transmission of pain signals. This allows patients to experience less discomfort and pain during recovery, which facilitates the rehabilitation process [14].
- Accelerate the recovery process as cold helps to constrict blood vessels, improves lymphatic drainage and lowers tissue temperature. This leads to a decrease in metabolic activity in damaged cells, which can help repair and prevent further damage [15].

- Tissue healing, as cryotherapy helps to improve blood circulation at the site of injury, which in turn supports faster tissue healing and reduces the risk of scarring [16].

- Control of swelling, as lowering the temperature in the area of injury helps to limit the expansion of blood vessels and lymphatic vessels, preventing excessive swelling [17].

In general, cryotherapy creates an optimal environment for the rapid and effective recovery of muscle tissue, helping to reduce pain, inflammation and restore normal muscle function.

Cryotherapy in rehabilitation is used to improve muscle function and accelerate recovery from injury or exertion. There are several main methods of implementing cryotherapy in rehabilitation programmes, such as cryo-chambers, local application of cold to the injured area, and immersion in cold water [18].

*Cryo-chambers* are special rooms in which a patient is exposed to low temperatures for a short time. This method allows the patient's entire body to be wrapped in cold, rapidly reducing body temperature. This approach is effective in reducing inflammation, improving blood circulation and providing anaesthetic effect [19].

*Local application of cold*, this method involves applying cold directly to the damaged muscle or joint area. This can be done with the help of cold compresses, gels, aerosols or special cryo-gels. Local application of cold allows you to precisely target a specific area, reducing swelling and relieving muscle pain [20].

*When immersed in cold water*, it is possible to notice the immersion of the body or a specific part of it in cold water. Immersion in cold water can help to reduce body temperature and the area of injury, as well as stimulate healthy blood circulation. It can also induce a "shock" response, which helps to reduce inflammation [21].

A comparison of the effectiveness, comfort and safety of these methods is presented in Table 1

<table>
<thead>
<tr>
<th>Methods</th>
<th>Effectiveness</th>
<th>Comfort and safety</th>
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<tbody>
<tr>
<td>Cryo-chambers</td>
<td>Fast and generally effective, but may require special equipment.</td>
<td>May not be comfortable for those with cellular or agliophobia.</td>
</tr>
<tr>
<td>Local cold application</td>
<td>Effective for specific areas, can be used easily at home</td>
<td>Provides precise control and ease of use.</td>
</tr>
<tr>
<td>Immersion in cold water</td>
<td>Effectiveness depends on water depth and temperature</td>
<td>Caution is advised as prolonged contact with cold water can cause hypothermia.</td>
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Limitations and potential risks include the fact that the use of cryo-chambers or specialised devices may require expensive equipment and special conditions, which may not always be available to all patients. In addition, prolonged exposure to cold conditions can lead to hypothermia, which can be dangerous to health. This should be treated with caution, especially when using cold applications on your own. It should be remembered that there are patients who may experience discomfort from exposure to cold or have individual sensitivity to low temperatures [22,23].

There are a number of cases where the use of cryotherapy in rehabilitation has led to successful results in restoring muscle function after injuries and facilitated a faster return to full activity. In the paper by Tricia J. Hubbard et al. (2004) evaluated four randomised, controlled clinical trials examining the effectiveness of cryotherapy in accelerating return to activity, found some promising trends but raised concerns about the overall quality of the studies. Although studies show that cryotherapy, especially if started immediately after an injury, can help speed up the return to work or sports activities, their shortcomings highlight the need for more rigorous research in this area. One of the main problems is the low quality of research, as reflected in the PEDro scores. Insufficient detail in the statistical analysis, uneven distribution of subjects between groups, and variations in the types of work or sport to which patients returned contribute to methodological problems. In addition, studies demonstrate a lack of uniformity in the definition and measurement of return to participation, which further complicates the evaluation of cryotherapy in this context [24].

Cryotherapy has been used in rehabilitation to aid in muscle recovery after injuries and exercise [7]. While traditional cryotherapy methods, such as ice, have been effective in reducing pain and soreness, evidence in humans is lacking due to inadequate duration of application. However, the novel application of cooling with phase change material (PCM) has shown success in rapid recovery following exercise.

The catalyst for the surge in interest in cryomedicine was once a watershed moment when Cristiano Ronaldo, a prominent Portuguese footballer, shared his experience of cryotherapy on social media. This case not only drew public attention to cryotherapy, but also triggered a wave of its use among athletes, especially in football and tennis. Athletes regularly expose their bodies to intense physical activity during training and competition, which leads to muscle fatigue and microtrauma. Reduced inflammation and improved blood circulation contribute to faster recovery, potentially minimising downtime between training and competition. In addition, the positive effects of cryotherapy on muscle pain and overall performance make it an attractive complement to traditional rehabilitation methods. [25,26].

Numerous elite athletes, including basketball icons LeBron James and Stephen Curry, consider cryotherapy an essential component of their postgame recovery regimen [27]. The practice extends beyond the realm of sports, gaining
popularity among A-list celebrities like actresses Jennifer Aniston and Demi Moore, singer Alicia Keys, and actor Will Smith. These prominent figures have embraced cryotherapy for its acclaimed advantages, which encompass not only reducing inflammation and expediting muscle recovery post-exercise but also enhancing sleep quality and alleviating stress [28].

Whole-body cryotherapy (WBC) stands out as the favored form of cryotherapy in the celebrity sphere, attracting considerable attention [29]. This technique involves entering a chamber that envelops the entire body up to the neck, with temperatures ranging between minus 110 degrees Celsius (minus 166 degrees Fahrenheit) and minus 140 degrees Celsius. The extreme cold is achieved through the use of either liquid nitrogen, rendering this method relatively expensive. Despite the cost, the allure of WBC persists among celebrities, who value its immersive and intense approach to leveraging the purported benefits of cryotherapy.

In a review, Ingrid Hultenheim Klintberg and Maria Eh Larsson (2021) systematically assessed the evidence for the use of cryotherapy in patients with musculoskeletal conditions, including surgical procedures, acute pain or injury, and long-term pain or dysfunction. The search covered the period from January 2000 to January 2018 (updated in June 2019), including systematic reviews (SRs) and randomised controlled trials (RCTs). Eight SRs and 50 RCTs were included out of 6,027 papers. The analysis showed moderate evidence (GRADE III) for the effectiveness of cryotherapy in surgical procedures, with benefits in pain reduction, improved range of motion (ROM), patient satisfaction, and minimal side effects. For acute pain or injury, as well as long-term pain or dysfunction, cryotherapy demonstrated positive effects, but with more results characterised by low strength of evidence (GRADE II). The overall conclusion of this paper is that cryotherapy is safe and well-tolerated for musculoskeletal injuries and dysfunctions, hinting at potentially increasing efficacy with more advanced forms of cryotherapy. The call for future research emphasises the evaluation of critical factors such as time, cooling temperature, dose (time) and frequency [30]. For example, after knee arthroscopy, the application of cold can help to restore joint and muscle function more quickly. Also, people who have been injured as a result of physical activity or fitness training can use cryotherapy to relieve pain and speed up recovery [31].

It is important to note that the success of cryotherapy depends on many factors, including the type of injury, the individual patient's characteristics and the correct choice of cryotherapy method [32]. In many cases, combining cryotherapy with other rehabilitation methods can lead to the best results.

It is also important to keep in mind the contraindications of cryomedicine. As a therapeutic intervention in the medical field, whole-body cryotherapy (WBC) follows strict guidelines and indications to ensure its safe use [33,34]. Today, the recognised contraindications for WBC include cryoglobulinemia, cold intolerance, Raynaud's disease, hypothyroidism, acute respiratory diseases and cardiovascular
diseases (including unstable angina and NYHA stage III and IV heart failure). In addition, contraindications include purulent gangrenous skin lesions, sympathetic nervous system neuropathy, local blood flow disorders, cachexia, hypothermia, claustrophobia, and mental disorders that may interfere with patient cooperation during treatment.

It is important to emphasise that when conducted in appropriate and controlled conditions, OST is considered a safe procedure. Scientific studies have provided evidence of its harmless effects on lung function and heart function. It should be noted that, although WBC is generally well tolerated, patients with pre-existing cardiovascular disease should be cautious, as a very small, clinically insignificant increase in systolic blood pressure has been reported. This underlines the importance of taking into account the individual characteristics of people with specific health problems when considering the use of whole body cryotherapy.

**Conclusions.** Cryotherapy, known for its ability to use cold to improve physical condition and tissue repair, is a promising method in the rehabilitation of patients with muscle injuries. Based on the analysis of scientific data and practical experience, several conclusions can be drawn:

1. Cryotherapy demonstrates great effectiveness in reducing inflammation and pain in affected tissues. Reducing the production of pro-inflammatory mediators and blocking pain helps patients to restore muscle function faster.
2. Cryotherapy effectively controls swelling, promotes vasoconstriction and subsequent dilation, improving blood supply to the affected tissues and supporting rapid recovery.
3. Cryotherapy not only provides pain relief by blocking the transmission of pain signals, but can also be easily used in various forms, such as cryo-chambers, local cold application or immersion in cold water.
4. It is important to take into account the individual characteristics of each patient and the specific conditions of the injury when choosing a cryotherapy method. Caution in the application of cold and consideration of potential risks, such as hypothermia, are essential.

All of these aspects confirm that cryotherapy has significant potential in restoring muscle function after injury and can be an important component of a comprehensive rehabilitation programme for different categories of patients. However, it is important to take into account the individual characteristics and circumstances of each case to maximise the positive effects of cryotherapy.

**Prospects for further research**

Further research could explore optimal cryotherapy protocols, including the ideal duration, frequency, and temperature settings for various types of muscle injuries. This could lead to personalized cryotherapy regimens tailored to individual patient needs and specific injury characteristics.

**Conflict of interest**
The authors declare no conflict of interest.

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