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GENERAL REVIEW

Whole-body cryotherapy in orthopaedics: current concepts

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Abstract

The use of whole-body cryotherapy (WBC) for musculoskeletal ailments is growing. WBC, involving brief exposure to extremely low temperatures, is increasingly used for its analgesic, anti-inflammatory, and antioxidant effects. The paper examines the physiological impacts of WBC on cardiovascular, musculoskeletal, hematologic, hormonal, and metabolic systems. Specific orthopaedic applications discussed include its role in the management of fractures, osteoarthritis, osteonecrosis of the femoral head, osteomyelitis, adhesive capsulitis, tendinopathies, rheumatic pathologies, chronic pain syndromes, and fibromyalgia. The study also highlights the benefits and drawbacks of WBC, including its potential to improve athletic performance, recovery, mood, and well-being, while noting risks like frostbite and impaired muscle strength. Clinical evidence from various studies is evaluated, revealing a spectrum of outcomes. For instance, WBC shows promise in enhancing bone health in athletes and providing relief in osteoarthritis and fibromyalgia patients. However, evidence for its efficacy in conditions like chronic pain syndromes and osteomyelitis is less robust. The paper underscores the need for further research to establish standardised protocols and understand long-term effects. While WBC offers significant benefits in orthopaedics, understanding its limitations and potential risks is crucial for its safe and effective clinical application.

Keywords Whole-body cryotherapy · Orthopaedics · Musculoskeletal conditions · Rheumatic pathologies

Introduction

Cryotherapy has long been employed as a method to alleviate chronic pain, leveraging its convenience, cost-effectiveness, and simplicity. Its application can be localised (using ice packs) or generalised (employing partial or whole-body cryotherapy, WBC), tailored to the specific pain site [1]. In WBC, the body is briefly exposed to extremely low temperatures. WBC, encompassing both ice baths and cold air chambers, has been extensively studied for its effects on recovery in athletes. Cold-water immersion for 5–15 min at 10–15 °C appears effective in enhancing recovery [2]. In cold air chamber cryotherapy, a controlled setting, such as a cryo chamber or cryo cabin, whose temperatures can vary from − 100 to − 195 °C, is used for a brief (2–3 min) exposure to extremely cold air. To avoid potential skin scorching and necrosis, it is essential to remove all body sweat before entering the chamber [3, 4]. The schematic representation of

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the whole-body cryotherapy chamber is depicted in Fig. 1. The main objective of this study is to comprehensively examine and analyse the existing body of literature about specific orthopaedic conditions as mentioned in Fig. 2.

Physiological effects of WBC

A comprehensive review of the literature underscores the multifaceted impacts of WBC on cardiovascular, inflammatory, musculoskeletal, hematologic, hormonal, and metabolic parameters as mentioned in Fig. 3.

The anti-inflammatory effects of WBC have been a focus of investigation. According to research, WBC can modify interleukin levels, particularly those of IL-6. Even though results regarding the impact of WBC on IL-6 have varied as a result of different exercise methods, a single WBC session raises IL-6 concentration while repeated sessions bring it back to the normal level. In addition, the steady induction of the anti-inflammatory response, manifested by elevated IL-10 and IL-1Ra and decreased IL-1, highlights the promise of WBC as a therapeutic approach for treating inflammation-related disorders [4–6].

In the context of musculoskeletal effects, WBC's ability to mitigate muscle damage and promote recovery has been explored. It has been investigated if WBC can reduce muscle damage and encourage healing in the setting of musculoskeletal consequences. Oxidants produced by exercise-induced muscle injury play a role in inflammation and subsequent muscle damage. By reducing inflammation, WBC may counteract this process by lowering catabolic muscle activity. WBC may minimise muscle injury because it lowers serum levels of lactic dehydrogenase and creatine kinase. Additionally, WBC may encourage bone formation over resorption by changing the equilibrium of bone metabolism through elevated osteoprotegerin levels, improving bone density and health [5, 6]. WBC has a modest effect on cardiac electrical conduction since it only minimally impacts ECG intervals like the PR, QT, and QTc intervals. However, a significant rise in mean heart rate has been noticed after WBC sessions, which may be related to a sympathetic response brought on by the cold. This slight systolic blood pressure elevation and increased heart rate are both typically within normal norms. However, uncommon supraventricular ectopic beats have occasionally been detected, highlighting the significance of monitoring cardiovascular alterations during WBC [7].

Hematologic alterations in WBC include haemolysis-triggered erythropoietin release as seen by temporary drops in haemoglobin, erythrocyte count, and haematocrit followed by increases in erythropoietin levels. Hormonally, WBC raises norepinephrine due to cold-induced sympathetic response, potentially acting as a hormonal stimulant. Positive effects on lipid metabolism are indicated by WBC-induced lipid profile changes, which include decreased triglycerides, raised HDL cholesterol, and decreased LDL cholesterol [4, 5]. The pros and cons of WBC in humans are tabulated in Table 1.

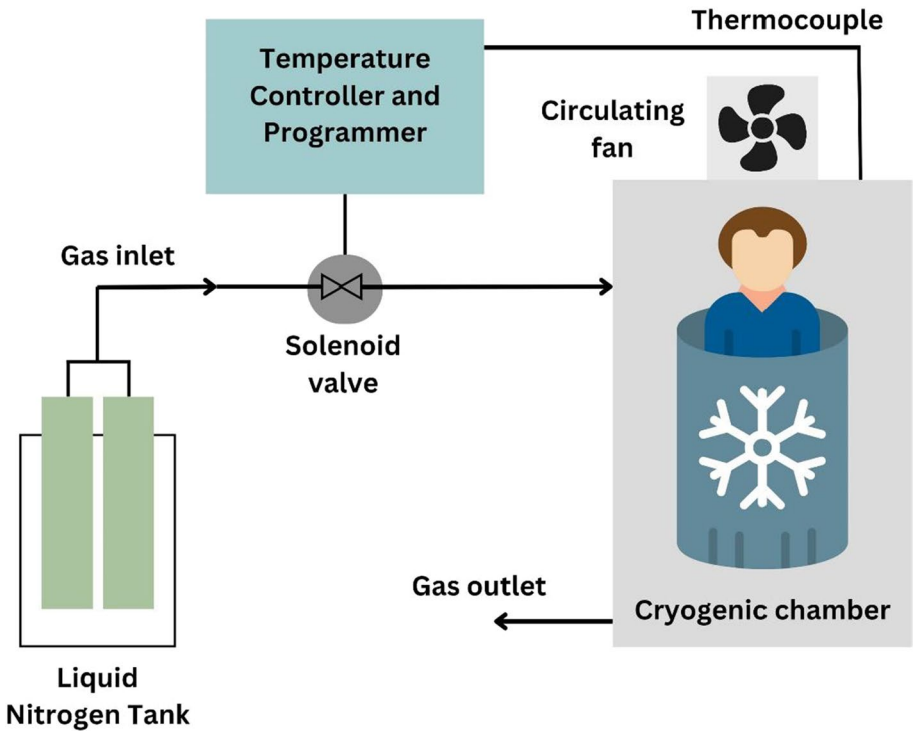


Fig. 1 Schematic representation of whole-body cryotherapy chambers (Created with Biorender.com)

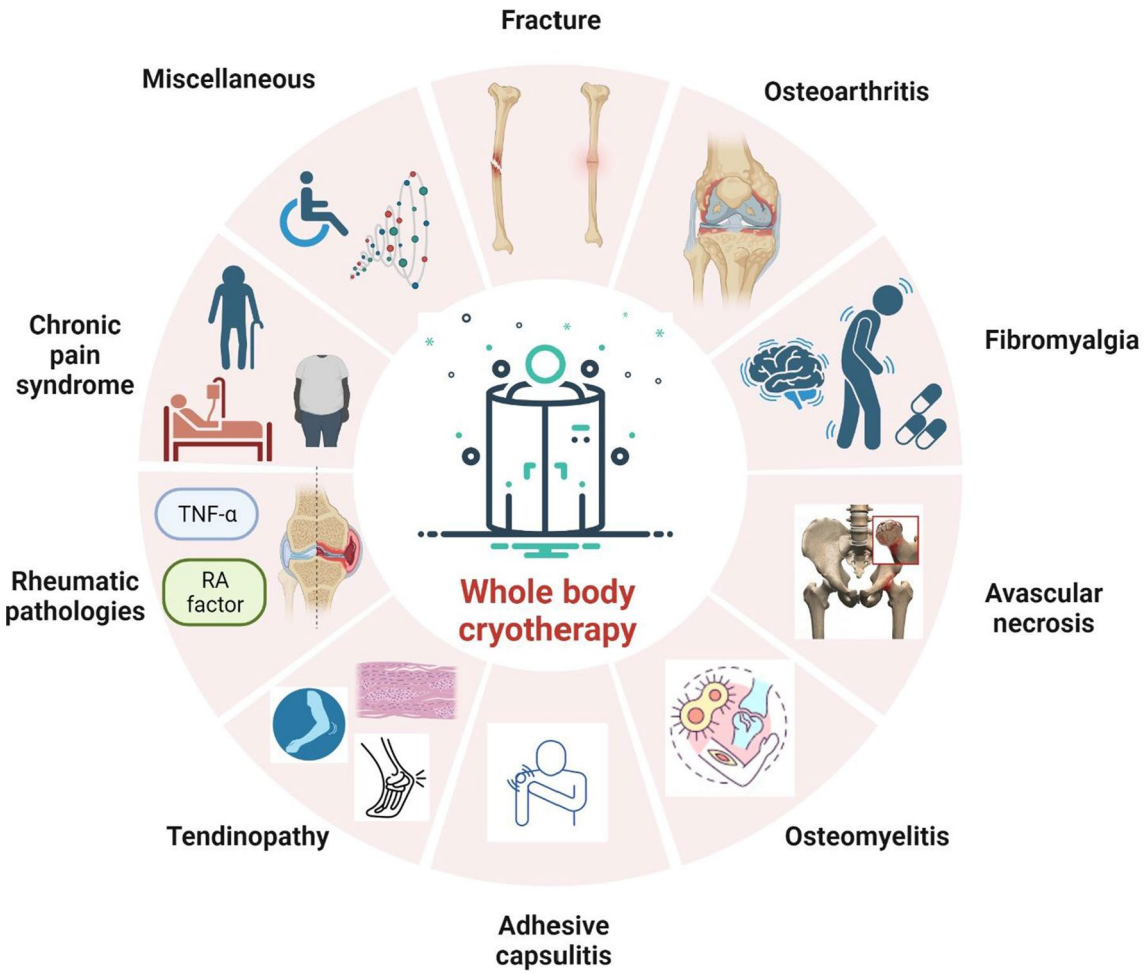


Fig. 2 Evidence of whole-body cryotherapy in musculoskeletal disorders (created with Biorender.com)

Clinical applications of WBC in orthopaedics

Fractures

To pinpoint the beneficial benefits of WBC on athletes' musculoskeletal systems, particularly bone remodelling, Galliera et al. undertook a study examining the changes in the osteoimmunological biomarkers OPG, RANKL, and RANK after WBC treatment in male rugby players from the Italian National team. The results revealed a considerable rise in OPG levels, pointing to a positive osteogenic impact brought on by WBC [8]. Leegwater et al. utilised numerical simulations to examine the effects of cryotherapy on patients with postoperative hip fractures, to measure the deep tissue temperature and to assess how well it worked as an analgesic for pain coming from soft tissues. Trochanter (11–27 °C), mid-femur (11–24 °C), and distal femur (10–16 °C) skin temperature measurements revealed significant variation. In cachectic patients, the predicted temperature decrease may have possibly extended to the bone to a depth of 3 cm. However, there was no connection between pain and temperature reduction, indicating that cryotherapy-induced analgesia likely comes from the skin rather than from muscle or bone pain alleviation [9].

Cryotherapy and contrast baths both significantly improved hand function after distal wrist fractures, according to a study comparing their effectiveness in lowering oedema and boosting hand function after wrist fractures. Statistics indicated that both techniques improved symptoms. The results did not support the initial null hypothesis, which suggested that cryotherapy was more effective than contrast baths. Contrast baths are just as efficient as cryotherapy at reducing swelling and improving hand function after distal wrist fractures. However, it is necessary to conduct more research to determine how WBC affects bone metabolism and fracture healing.

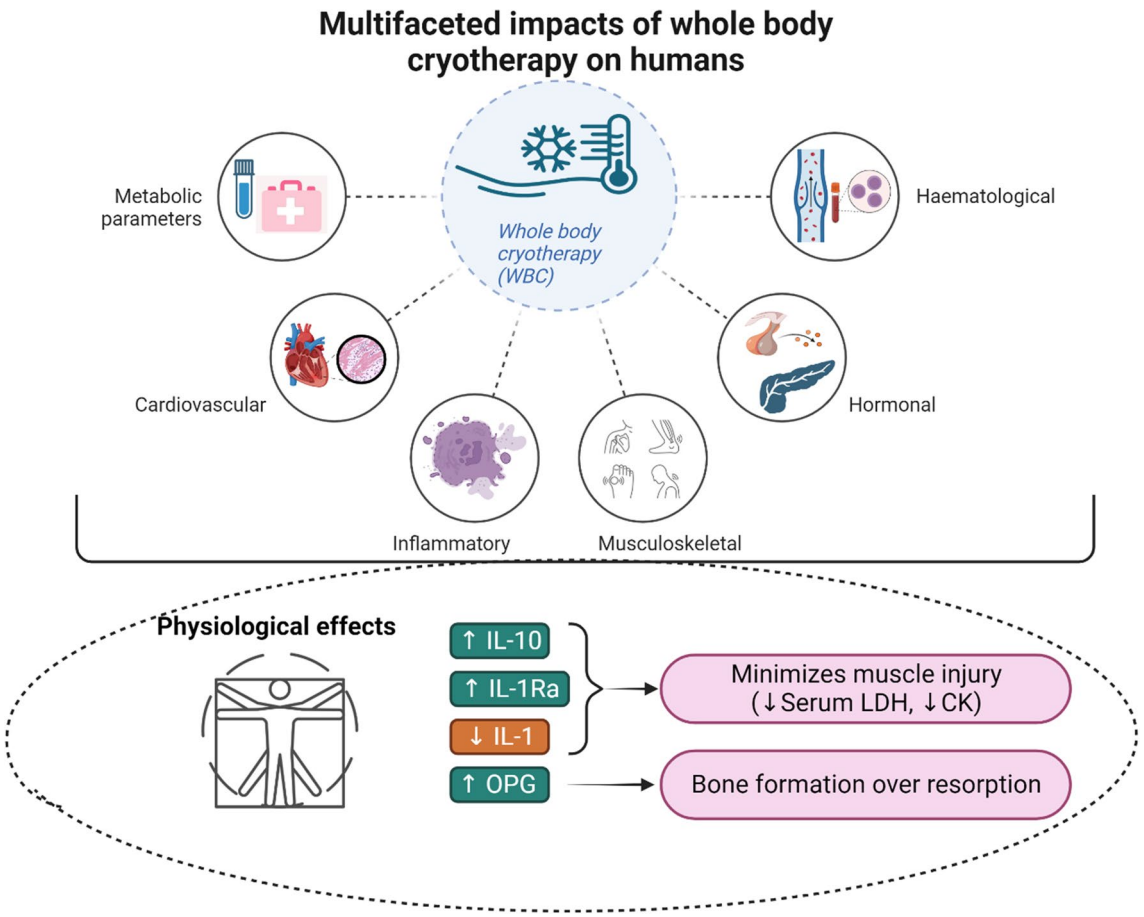


Fig. 3 Physiological effects of whole-body cryotherapy on humans (created with Biorender.com)

Table 1 WBC in orthopaedics

Merits/demerits	Category	Mechanism	Clinical implications
Pros	Anti-Inflammatory, Analgesic, Antioxidant Effects	Vasoconstriction in peripheral tissues reduces inflammation; modulation of pain receptors	Beneficial for chronic inflammatory conditions like rheumatoid arthritis, post-surgery recovery
	Athletic Performance, Recovery, Muscle Soreness	Vasoconstriction and re-warming process remove waste products from muscle tissues	May benefit athletes and individuals in intense physical activity for quicker recovery
	Enhancement of mood, well-being, quality of life	Stimulation of endorphin release	May benefit individuals with mood disorders or those seeking enhanced well-being
Cons	Adverse reactions: frostbite, skin burns	Exposure to extreme cold temperatures can cause skin and tissue damage	Higher risk for individuals with sensitive skin or specific medical conditions
	Impairment of muscle strength, power, endurance	Vasoconstriction may limit blood flow to muscle tissues	Conflicting outcomes for athletes and individuals seeking muscle strength and endurance
	Psychological Stress, Anxiety, Discomfort	Extreme cold can induce stress response	Not recommended for individuals with pre-existing psychological conditions

Osteoarthritis

Osteoarthritis (OA) of the knee is a prevalent and expensive ailment which prompts non-pharmacological pain management techniques. Through vasoconstriction, cryotherapy, which is frequently used for alleviating pain, swelling, and inflammation, alters muscle impact, tissue metabolism, and oxygen uptake. Cryotherapy's possible effects on an osteoarthritic model could be examined to provide useful clinical knowledge. While some guidelines recommend using cryotherapy to treat OA, others stress the need for more research. In a mouse model of acute knee arthritis, decreased joint swelling, discomfort, and inflammation along with enhanced balance and motor control were observed. Acetylcholine is released when parasympathetic neurons are activated by cryotherapy, which may suppress the NF-kB pathway and decrease pro-inflammatory cytokines [10]. Chruściak et al. evaluated the effect of WBC on 50 OA patients [11]. After a 10-day cold treatment cycle, 78% of patients reported noticeable improvement, 18% had improved, and only 4% had no change [11]. WBC significantly reduced the frequency and severity of pain, which resulted in less analgesic medication use. The course of treatment increased the range of physical activity and had a favourable impact on the general well-being of the patient [11]. In contrast, in another study, the control group received sham packs filled with sand while the experimental group received cryotherapy using ice packs with compression on the knee. The effects of knee osteoarthritis patients' quality of life and physical function were not affected by short-term cryotherapy, according to the results. The authors classified the evidence supporting cryotherapy's ability to effectively treat pain, knee stiffness, range of motion, and physical function as low-level using the GRADE approach. According to the study's findings, cryotherapy did not outperform a sham procedure in relieving pain or improving function and quality of life [12].

Osteonecrosis of the femoral head

The role of cryotherapy in mitigating conditions like femoral head osteonecrosis (ONFH) has been investigated through innovative methods such as the MRI-guided argon helium cryotherapy system. Lacunae rates in the experimental group surpassed the control group's at 4, 8, and 12 weeks post-surgery [13]. Li et al. introduced a novel device for osteonecrosis of the femoral head (ONFH) which offered the possibility of osteonecrosis repair and the restoration of the femoral head blood flow. The experimental group received a scaffold that was anastomosed with the pre-existing hip blood arteries and incorporated with vascular bundles. Animal tests supported the feasibility. Histological examination and micro-CT demonstrated increased bone growth in the experimental group. Vascular bundles that were implanted exhibited the potential to branch, improving blood flow and bone recovery. More evidence is necessary to establish the reliability of this innovative technique. Potential limb blood flow interruption and damage to the saphenous nerve are a couple of surgical consequences. Research in the future may examine vascular anastomosis alternatives like arterial looping and transplanted vessel choices like saphenous vein transplantation [14]. Further investigation into cryotherapy's potential impact on ONFH is required to pave the way for better treatment strategies and outcomes.

Osteomyelitis

There is currently insufficient in-depth research on the potential of cryotherapy for osteomyelitis. In a case study, the use of cryosurgery and bioactive glass in the treatment of ulna osteomyelitis in a 17-year-old patient was highlighted, offering evidence of the effectiveness of this strategy [15].

Adhesive capsulitis

The emerging technique of WBC has the potential to improve range of motion (ROM) and ease discomfort, but more research is needed to determine whether it is effective in treating adhesive capsulitis (AC). WBC is believed to provide analgesic and anti-inflammatory properties through increasing b-endorphin levels and decreasing nerve conduction. While the usefulness of WBC has been examined in a variety of settings, its use in AC remains unexplored. Thirty patients with shoulder adhesive capsulitis were split into two groups for a randomised controlled experiment. While the other group received only physical therapy and mobilisation, one group received passive joint mobilisation, physical therapy modalities, and WBC. Both groups showed considerable improvement, but the WBC group made more advancements than the other two, demonstrating its promise for treating AC [5, 16].

Tendinopathies

The effectiveness of ultrasound therapy alone versus ultrasound therapy combined with cryotherapy for the treatment of Achilles tendinopathy was evaluated and compared by Agostini et al. Notably, in all assessments that were done, both groups showed a considerable improvement over time. When compared to the ultrasound-only group, the group receiving both ultrasound and cryotherapy showed better pain reduction and increased function at 15 days. Both groups showed independent progress over time. A statistically significant difference between values assessed after 60 days was discovered by subsequent post hoc analysis. For individuals with tendinopathies,

combining the two treatments at the same time is promising because it may maximise their combined therapeutic effects [17]. Romero-Morales et al. compared eccentric exercise (EE) with vibration training and EE paired with cryotherapy to better understand chronic mid-portion Achilles tendinopathy (AT). Both techniques increased tendon thickness and cross-sectional area, according to ultrasound measurements conducted over 12 weeks, with the EE vibration group demonstrating a statistically significant increase in cross-sectional area. He looked into the impact of abdominal muscles on Achilles tendinopathy therapy in another study. For 12 weeks, participants underwent either EE with vibration or EE with cryotherapy. While inter-rectus distance was reduced in both groups, the rectus anterior muscle thickness was significantly increased in the EE vibration group. Cryotherapy may be used to treat tendinopathy, according to these studies, but further research is necessary to draw firm conclusions [18, 19].

Rheumatic pathologies

One such method used in the rehabilitation of rheumatoid arthritis (RA) patients is WBC. Its efficacy is still up for question, nevertheless, as few studies are comparing systemic and local cryotherapy and limited research contrasting WBC with other treatment options. Gizinska et al. included 19 patients receiving traditional rehabilitation (TR) and 25 patients receiving WBC. Over a 50-m distance, both groups showed comparable reductions in pain, disease activity, fatigue, walking duration, and step count. The TR group had better HAQ results. Notably, IL-6 and TNF-α levels were significantly lowered in both groups. Regardless of the precise method, a 2-week rehabilitation programme benefits RA patients [20]. The 2016 ASAS-EULAR guidelines suggest treating ankylosing spondylitis (AS) with a mix of non-pharmacological and pharmaceutical treatments. By lowering oxidative stress, enhancing lipid profiles, promoting spinal mobility, and reducing pain, WBC has shown promise in treating rheumatic disorders, including AS. In a recent study, Stanek et al. compared the effects of exercise alone (ET group) against exercise plus WBC on endothelial inflammation in AS patients. Inflammatory markers (hs-CRP, sP-Selectin, sVCAM-1, and neopterin) were significantly lower in the WBC group than in the ET group. Following treatment, both groups showed decreased levels of oxidative stress indicators (LHP, lipofuscin, and PON-1 activity), with the WBC group showing higher decreases. WBC may be a therapy option because it appears to have a favourable impact on endothelial parameters in AS patients [21].

Chronic pain syndromes

Cryotherapy offers a low-risk, easy-to-administer treatment option for managing chronic pain, with potential advantages for a variety of chronic conditions. Numerous researchers have demonstrated the effectiveness of cryotherapy in the treatment of chronic pain, including randomised controlled trials and prospective analyses. Applications of localised and non-local cryotherapy show promise in reducing chronic pain associated with rheumatic and degenerative diseases. Notably, cryotherapy demonstrates safety, with few documented negative effects. However, the currently available information has some drawbacks, such as non-standardised studies, variations in cryotherapy practice, and sporadically missing control groups in some studies. Patients' self-reported pain and disability metrics, such as the Pain Numerical Rating Scale (PNRS), Oswestry Disability Index (OSI), and Roland Morris Questionnaire (RMQ), were gathered throughout each session of a quasi-experimental trial designed to examine the effects of WBC on pain, disability, and serum inflammatory markers in patients with chronic low back pain (LBP). The results showed a significant decline in PNRS, OSI, and RMQ scores from the first to the last sessions, indicating lessened pain and disability. Surprisingly, PNRS began to noticeably diminish after just four WBC treatments. A decrease in the pro-inflammatory marker IL-2 and an increase in the anti-inflammatory marker IL-10 were also seen in the study's findings, along with changes in other serum inflammatory markers [22]. WBC showed a significant analgesic benefit in individuals with trapezius myofascial pain syndrome. Patients noticed a significant pain reduction right away following each WBC session, starting with the initial one. Starting from the sixth session, the difference in pain intensity as measured by the visual analogue scale (VAS) and algometry at trigger sites (TPs) became statistically significant. Notably, during the length of the trial, no notable changes in the concentrations of inflammatory or anti-inflammatory substances were seen. WBC is a useful analgesic strategy for treating myofascial pain conditions in the trapezius muscle [23].

Fibromyalgia

In recent years, WBC has gained attention as a potential therapeutic approach for addressing the multifaceted challenges of fibromyalgia (FM), reducing pain and exhaustion while improving the quality of life for FM patients. Interleukin (IL-)1, IL-6, TNF, and IL-10 are among the cytokines that are out of balance in FM. Klemm et al. [24] reported that WBC lowers IL-1 and TNF-a levels. After 3- and 6-month sessions, the study found a decrease in pain and disease activity. Three months after the end of treatment, however, there have been no persistent clinical advantages

[24]. WBC causes vasoconstriction and thermogenesis as a result of activating cold receptors in the hypothalamus' thermoregulatory centre. Noradrenaline is released as a result, and the sympathetic nervous system is activated. Minimal side effects from a large number of WBC sessions point to the possibility of multi-treatment procedures [25]. A randomised controlled trial involving 24 fibromyalgia (FMS) patients was carried out. Elevan of them underwent 10 sessions of WBC in addition to receiving conventional care, while the other 13 were placed in the control group. In comparison with the control group, the cryotherapy group showed a notable improvement in health-reported quality of life that persisted for at least a month after the intervention [26].

Miscellaneous

WBC is a medical physical treatment widely used in sports medicine for recovery from injuries and after-season recovery. It has been shown to have anti-inflammatory, anti-analgesic, and antioxidant effects, and can also be used as a preventive strategy against exercise-induced inflammation and soreness. By mitigating inflammatory responses, WBC potentially alleviates pain and soreness, facilitating swift recovery for athletes [4, 5]. WBC may have some benefits in reducing muscle soreness and tiredness following exercise, according to a study examining how it affects post-exercise muscular discomfort in adults [27]. WBC therapies administered within an hour may be better than delayed treatments for the restoration of muscle strength [28]. Sports professionals can cautiously use repeated WBC to aid in recovery after exercise without unduly worrying about the athletes' fitness improvements or long-term performance, especially during training stages which are more concerned with developing overall strength than explosive power [29].

Complications and contraindications of WBC

It is important to be aware of the contraindications which may limit the use of this technique. Individuals suffering from illnesses including cryoglobulinemia, cold intolerance, Raynaud disease, and hypothyroidism should use WBC with caution. As with acute respiratory disorders, cardiovascular diseases (especially unstable angina pectoris and cardiac failure in stages III and IV according to NYHA), uncontrolled hypertension, sensory neuropathies, or purulent-gangrenous cutaneous lesions, WBC is not recommended for people with these conditions. Another contraindication is sympathetic nervous system neuropathies, which impair the ability to modulate peripheral vascular vasoconstriction/dilation. Additionally, claustrophobia, cachexia, past cold injuries, and local blood flow problems need to be taken into account [4, 5, 30]. Cryotherapy has a relatively low-risk profile, with most problems coming from patient misunderstanding or overuse [2, 31]. It can lead to various complications, including skin rashes, frostbite, perniosis, and damage to the peripheral nerves [6, 32, 33]. The greatest risk of consequences, including nitrogen asphyxiation and loss of consciousness, occurs when WBC is used in nitrogen gas chambers. Prevention involves avoiding direct skin contact, limiting exposure time, and patient education. It is essential to provide comprehensive counselling and close supervision to orthopaedic patients receiving cryotherapy to reduce these hazards [2, 5].

Quality of recommendations

The existing literature supports various levels of evidence [34] for the use of WBC in treating musculoskeletal disorders, as summarised in Table 2 and Fig. 4.

In an evaluation of the existing levels of scientific evidence supporting various musculoskeletal disorders, the conditions can be categorised into tiers based on the robustness of the evidence. Disorders such as fractures, osteoarthritis, fibromyalgia, adhesive capsulitis, and tendinopathy demonstrate strong scientific evidence (Levels 1–3), thereby justifying the continuation of current therapeutic approaches and clinical guidelines. Conversely, conditions like osteonecrosis of the femoral head and osteomyelitis present moderate levels of evidence (Levels 4–6), indicating the need for additional rigorous studies to solidify their respective clinical management paradigms. Rheumatological conditions, which fall into a moderate evidence tier with a Level 4 rating, show promise and could potentially benefit from targeted research to elevate them to a higher evidence level. Most critically, chronic pain syndromes manifest a conspicuously limited foundation of scientific evidence (Level 7), thus identifying them as a high-priority target for future

Table 2 Hierarchical quality of evidence supporting WBC utilisation in orthopaedics

Rank	Musculoskeletal ailment	Quality of recommendation	References
1	Fractures	2	[35]
2	Osteonecrosis of femoral head	6	[13, 14]
3	Osteomyelitis	6	[15]
4	Osteoarthritis	2	[12]
5	Fibromyalgia	2	[26]
6	Adhesive capsulitis	2	[16]
7	Tendinopathy	2	[18, 19]
8	Chronic pain syndromes	7	[22]
9	Rheumatological conditions	4	[20]

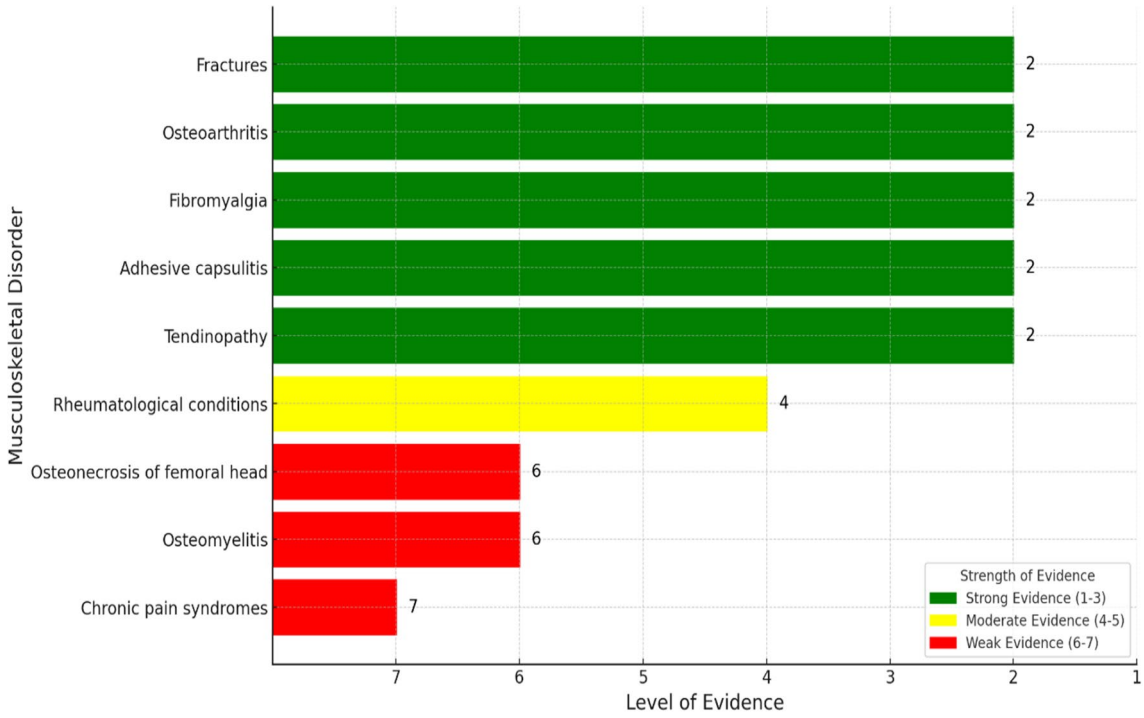


Fig. 4 Hierarchical quality of evidence supporting WBC utilisation in orthopaedics

research initiatives. The delineation of disorders based on the strength of scientific evidence can serve as a valuable framework for prioritising research endeavours and resource allocation in both clinical and academic settings.

Future prospective

Future strategies for using WBC in orthopaedics should prioritise thorough research to establish its safety and efficacy in specific patient populations. Additional research is necessary to determine the potential benefits of WBC in elderly, non-professional athletes and people who do not participate in athletic activities, ensuring its suitability for a range of age groups [7]. Further investigation should focus on how the anti-inflammatory properties of WBC may synergistically improve athletes' performance when incorporated into training regimens [4]. Furthermore, the possibility of WBC enhancing sleep patterns and general quality of life in specific orthopaedic disorders presents a line of inquiry [26]. Long-term effects, standardisation of protocols, and studies on other chronic pain syndromes should also be focal points of future research [1]. WBC and cold water immersion (CWI) could be compared to reveal the differential effects on inflammatory markers, blood flow, and muscle swelling, allowing for a better in-depth understanding of their uses in orthopaedic therapy [28].

Conclusions

WBC has become an appealing modality of adjunctive treatment in various musculoskeletal disorders by demonstrating the potential to reduce pain, speed up recovery, and generally enhance patients' quality of life. While WBC has produced promising outcomes in several trials, it is important to be aware of its restrictions, limitations, and potential consequences to use it safely and effectively in clinical practice. Standardisation of protocols, comparison with other modalities, and long-term effects should be looked into as WBC research develops to confirm its efficacy with certainty.

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Declarations

Conflict of interest The authors declare that they have any competing interests in this article.

Ethical approval This study complies with ethical standards.

Consent to participate Not applicable.

Consent for publication Not applicable.

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