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Cryotherapy for the Management of Chronic Musculoskeletal Conditions: A Clinical Assessment of Pain and Function

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Abstract

Background: Chronic pain, defined as pain persisting or recurring for more than three months, affects an estimated 13.5% to 47% of the general population, with chronic musculoskeletal pain prevalence ranging from 11.4% to 24%. Given the high and rising prevalence of musculoskeletal pain, driven by demographic trends, there is an urgent need for effective interventions, particularly in rehabilitation care settings.

Materials and Methods: Twenty patients with chronic musculoskeletal conditions participated in a treatment program consisting of 10 cold-air cryotherapy sessions. The effectiveness of the therapy was evaluated by assessing changes in pain, range of motion, and physical function using the Western Ontario and McMaster Universities Arthritis Index (WOMAC) before and after treatment.

Results: All assessed parameters showed statistically significant improvements. Pain, measured using the Visual Analog Scale, decreased by 42.9%, while range of motion increased by 15.23%. The WOMAC questionnaire indicated improvements of 34.68% in pain, 40.26% in stiffness, and 24.87% in physical function.

Conclusions: Cold-air cryotherapy demonstrates potential as an effective treatment for various chronic musculoskeletal conditions. Its efficacy, ease of application, affordability, and transportability make it a promising alternative not only for acute edematous injuries but also for chronic pain management.

Keywords: Cold therapy; Cold-air cryotherapy; Chronic pain; Musculoskeletal disorders; Osteoarthritis

Introduction

Musculoskeletal disorders impact an estimated 1.71 billion people worldwide, often leading to chronic pain, restricted movement and fine motor function, and decreased social engagement. The incidence of these conditions, along with their related functional impairments, is rising swiftly due to an aging population and overall demographic expansion. Importantly, musculoskeletal disorders constitute the primary driver of rehabilitation demands globally, with nearly two-thirds of adults requiring rehabilitative services due to these conditions. In addition to their physical effects, musculoskeletal disorders frequently occur alongside other non-communicable diseases, including cardiovascular conditions, thereby increasing the likelihood of further health complications. Furthermore, individuals living with musculoskeletal disorders face a heightened susceptibility to mental health challenges [1].

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Pain is a central symptom of musculoskeletal disorders, substantially contributing to functional impairment and serving as a key indicator of disease severity, activity, and prognosis [2]. Chronic pain, defined as pain persisting or recurring for more than three months, affects an estimated 13.5% to 47% of the general population, with chronic musculoskeletal pain prevalence ranging from 11.4% to 24% [3]. Given the high and rising prevalence of musculoskeletal pain, driven by demographic trends, there is an urgent need for effective interventions, particularly in rehabilitation care settings [1].

Non-pharmacological interventions, including exercise, heat and cold applications, massage, transcutaneous electrical nerve stimulation (TENS), and the use of assistive devices or orthotics, play a crucial role in managing chronic pain. These approaches can be employed individually or in conjunction with appropriate pharmacological treatments. A unifying characteristic of these physical therapies is their ability to regulate physical energy by either introducing or extracting it from the body. For instance, heat therapy increases thermal energy, cold therapy reduces it, and massage delivers both mechanical and thermal stimulation. The modulation of energy levels induces a range of physiological responses at the cellular, tissue, and systemic levels, influencing metabolic activity, membrane permeability, tissue flexibility, circulation, and neural activity in both the peripheral and central nervous systems. Among emerging therapeutic strategies for musculoskeletal conditions, cold therapy via cold-air cryotherapy devices has recently gained attention for its potential benefits [4].

The rehabilitative effects of cold therapy have been known since the time of ancient Greece, when it was applied in the form of water therapy [5]. Over the years, the effects of cold on changing the rate of tissue metabolism, local vasoconstriction, and reduction of edema, inflammation, and nerve conduction velocity have been demonstrated [6]. Despite considerable progress in the field of cold therapy, application through water immersion and topical cooling remains popular [7]. The application of ice through ice bags or gel packs brings the advantages of easy availability, transportability and fast local application, but is limited by the thermal capacity of the packs, which heat up relatively quickly. The modern method of whole-body cryotherapy chambers exposes individuals to cold air below -195°C for a short period of time [8]. This method has gained acceptance in the professional athlete community due to its effectiveness in tissue regeneration, but due to its availability and expensive operation, it has limitations in immediate post-injury application. Newly developed modalities represent cryotherapy devices working on the principle of cold air or liquid nitrogen, enabling immediate and rapid application of cold to the affected area [5]. They are relatively portable, with low operating costs (especially the cold-air variant) enabling immediate and effective application of very low temperatures. The very latest version is a device delivering combined cold and compression therapy through special sleeves enabling manually undemanding application. This method has been proven to be able to achieve exceptionally low temperatures across the treated area [9].

Clinical evidence is relatively extensive from the point of view of cold therapy, but it may be insufficient in terms of individual modalities and technologies. The benefit of local cryotherapy has been demonstrated for inflammatory rheumatic diseases and for post-operative pain control in patients recovering from knee and shoulder surgery [10-13]. Cold-water immersion showed a positive effect on muscle soreness after exercise [14,15]. However, there is a lack of research on the benefits of device cryotherapy for chronic musculoskeletal conditions causing long-term pain and limitations in daily activities.

This research aims to evaluate the effectiveness of cold-air cryotherapy in improving pain, range of motion and physical function in patients with chronic musculoskeletal conditions.

Materials and Methods

The study was conducted as part of routine rehabilitation care at a private clinic from June 2024 to January 2025. Patients with chronic extremity disorders causing pain and disability for more than three months and meeting the criteria for treatment with a cryotherapy device (BTL Industries Ltd.) were included. Exclusion criteria comprised Raynaud's disease, cold hypersensitivity (cold urticaria), open wounds (including burns), cardiovascular and circulatory disorders, skin sensitivity impairments, advanced diabetes mellitus, spinal cord injury, acrocyanosis, vascular inflammation, systemic lupus erythematosus, cold-induced bronchospasm, hematological disorders affecting coagulation, decompensated hypertension, acute unstable fractures in the treatment area, clinical signs or risk factors for deep vein thrombosis or embolism, and conditions where increased venous or lymphatic return was contraindicated. The study adhered to the ethical principles of the Declaration of Helsinki (1964) and its subsequent amendments.

As this was a pilot study, the sample size could not be determined based on prior research. Therefore, a minimum of 20 participants was selected.

The treatment protocol consisted of 10 cryotherapy sessions, administered three times per week for 10–15 minutes each. Depending on the disorder's location and severity, cold therapy was applied manually using a hose and interchangeable nozzles. The device allowed customization of treatment parameters, including duration, airflow intensity (levels 1–9), and mode (continuous or pulsed). To optimize cooling efficiency, the device and accessories were pre-cooled before each session.

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Pain, range of motion and self-evaluated physical function assessment was conducted before the first and after the final session. Patients rated their pain using the Visual Analog Scale (VAS), a 10-point scale where 0 represents "no pain" and 10 indicates "worst possible pain". Flexion range of motion was measured by the treating therapist using a standard goniometer. Additionally, functional outcomes were evaluated using the Western Ontario and McMaster Universities Arthritis Index (WOMAC), a 24-item questionnaire assessing pain, stiffness, and physical function. Each item was rated on a difficulty scale from 0 ("None") to 4 ("Extremely"), with the total score expressed as a percentage of the maximum possible score of 96.

Data analysis and statistical evaluation were performed using a custom script in Matlab (MatLab R2010b, MathWorks, Inc., Natick, MA, USA). The Shapiro-Wilk test confirmed normal data distribution, allowing for the use of a paired t-test for statistical comparisons. A p-value of <0.05 was considered statistically significant.

Results

A total of twenty patients diagnosed with different chronic musculoskeletal disorders successfully completed the full study protocol. The majority were older adults experiencing common chronic joint conditions, such as osteoarthritis and arthrosis (Table 1).

Despite the advanced age of the participants and the chronic nature of their conditions, the study program resulted in statistically significant improvements across all assessed parameters (Table 2). The most notable progress was observed in pain reduction, as measured by the Visual Analogue Scale (VAS), with a decrease exceeding 42%, as illustrated in Figure 1. While the increase in range of motion also reached statistical significance, its magnitude was less pronounced compared to other measured outcomes, a trend further confirmed by graphical data representation (Figure 2). Within the WOMAC questionnaire, the greatest improvement was recorded in stiffness, followed by pain and physical function (Figure 3), with an overall enhancement approaching 35%.

Table 1: Baseline characteristics of patients, diagnosed conditions, and affected body regions.

Characteristic		Indication		Body Part	
Age	61.75 ± 15.03	Osteoarthritis	9 (45%)	Knee	11 (55%)
Gender	Male: 8 (40%)	Arthrosis	4 (20%)	Hip	3 (15%)
	Female: 12 (60%)	Lateral epicondylitis	2 (10%)	Ankle	2 (10%)
Affected Side	Right: 14 (70%)	Muscle injury	3 (15%)	Shoulder	2 (10%)
	Left: 6 (30%)	Tendinopathy	2 (10%)	Elbow	2 (10%)

Table 2: Outcome measures obtained prior to the initiation and after completion of the treatment program, average achieved difference across all participants (Diff), its percentage representation (% Diff) and P value evaluated by paired T-test. P values below 0.05 were considered statistically significant.

	Before	After	Diff	% Diff	P (<0.05)
Pain (VAS)	6.13 ± 1.55	3.50 ± 1.50	2.63 ± 1.11	42.9	<0.001
ROM (°)	87.65 ± 31.69	101.00 ± 27.98	-13.35 ± 8.22	-15.23	<0.001
WOMAC					
	Before	**After**	**Diff**	**% Diff**	**P (<0.05)**
Pain	6.20 ± 2.82	4.05 ± 2.95	2.15 ± 1.90	34.68	<0.001
Stiffness	3.85 ± 1.79	2.30 ± 1.34	1.55 ± 1.23	40.26	<0.001
Physical function	19.50 ± 12.08	14.65 ± 9.40	7.50 ± 4.36	24.87	<0.001
Total	32.05 ± 13.99	21.00 ± 11.91	11.05 ± 6.29	34.48	<0.001

VAS: Visual Analog Scale; ROM: Range of Motion; WOMAC: Western Ontario and McMaster Universities Arthritis Index

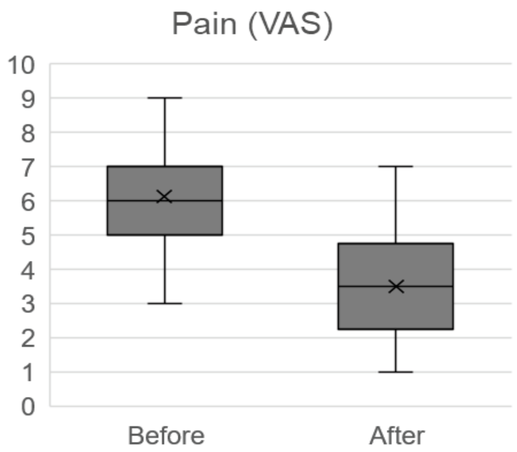

Figure 1: Box plot graph visualizing VAS data. The box represents the interquartile range (IQR), with the horizontal line indicating the median. Whiskers extend to the minimum and maximum values. The cross mark (×) denotes the mean.

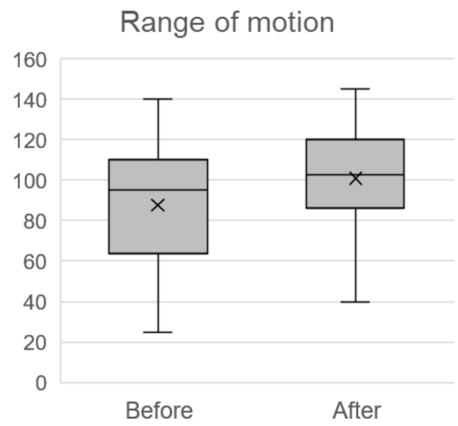

Figure 2: Box plot depicting flexion range of motion data for different joints. The box indicates the interquartile range (IQR), with the horizontal line representing the median. Whiskers extend to the minimum and maximum values, while the cross mark (×) denotes the mean.

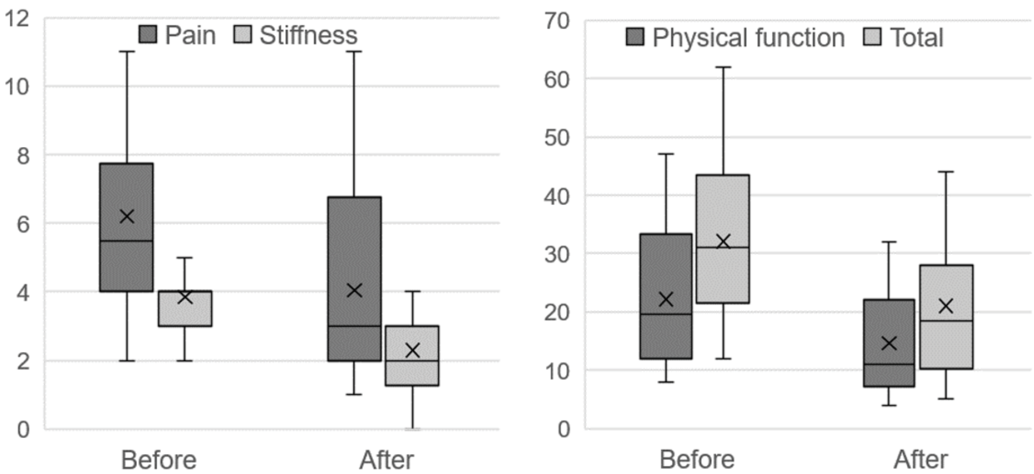

Figure 3: Box plots showing the progression of WOMAC domains over the study period. The box represents the interquartile range (IQR), with the horizontal line indicating the median. Whiskers extend to the minimum and maximum values, while the cross mark (×) denotes the mean.

Discussion

Although the analgesic effects of cold on musculoskeletal pain have long been recognized, they are primarily linked to acute traumatic injuries. A common example is the management of acute ankle sprains within the framework of rest, ice, compression, and elevation (RICE) therapy [16]. While effective acute pain treatment is crucial in preventing its progression to chronic pain, it is often overlooked, contributing to the high prevalence of chronic pain [3,16]. As a result, the potential role of cold therapy in managing chronic musculoskeletal pain has become an area of growing research interest.

Recent research has shown a beneficial effect of cold-air cryotherapy on pain, range of motion, and physical function in patients with chronic musculoskeletal conditions. This is the first study to investigate the impact of device local cryotherapy on such outcomes. Previous studies have primarily examined whole-body cryotherapy, with results consistent with those found in the present study, particularly in terms of pain relief. Whole-body cryotherapy has been shown to reduce pain by 1.08 - 2.48 cm on the VAS scale, depending on the protocol, which aligns with the 2.63 cm improvement observed in this study [17-21]. Additionally, the study revealed a positive effect on the chronic condition, as assessed by the BASDAI score [21-24]. Unfortunately, a direct comparison cannot be made due to differences in methodology, particularly as the WOMAC score was used in this study. Similarly, a comparison of improvements in range of motion is not feasible.

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A theoretical explanation of the mechanism of action can further help support the validity of the obtained results. Cold therapy alleviates chronic musculoskeletal pain through multiple mechanisms. It decreases the activity of nociceptors and the neural pathways involved in pain transmission. Additionally, cold exposure induces vasoconstriction, reducing blood flow to the affected area and consequently limiting the delivery of inflammatory mediators, including prostaglandins, which are involved in the sensitization of pain pathways. This reduction in local tissue metabolic activity further minimizes the impact of depolarizing and sensitizing agents. Cold therapy also inhibits muscle spasms and produces local anesthetic and anti-inflammatory effects by cooling the tissues. These combined actions help reduce both pain and inflammation, improving patient outcomes in chronic musculoskeletal pain management [4,9].

The results must be interpreted within the context of several study limitations, primarily due to its pilot design. A major limitation is the absence of a control group, which would have allowed for comparisons between improvements in patients receiving treatment and those without intervention. This shortcoming is somewhat mitigated by the chronic nature of the conditions studied, where spontaneous improvement was not anticipated. Another limitation of this study is the absence of a sufficiently long follow-up period to evaluate the duration of the clinical effect. Without an extended follow-up, it is not possible to determine with certainty whether the observed results will persist beyond the completion of the treatment program. Additionally, the small, heterogeneous sample of subjects with various musculoskeletal disorders presents an opportunity for improvement in future research. A larger, more homogenous cohort with specific musculoskeletal indications would allow for a more robust evaluation of the effects of cold-air cryotherapy. Expanding the study to include objective movement quality indicators, such as basic walking tests, would also enhance the reliability of the findings.

Despite these limitations, the pilot study successfully fulfilled its objective of exploring treatment options for patients with chronic musculoskeletal conditions. Given the high prevalence of musculoskeletal pain and the underestimation of its treatment, the number of individuals with chronic issues continues to rise [16]. Device cold-air cryotherapy offers a relatively affordable, effective, and efficient alternative to whole-body cryotherapy, providing therapists with a practical tool for incorporating cold therapy into routine care.

Conclusions

Research has highlighted the potential of the cold-air cryotherapy device in alleviating symptoms in patients with chronic musculoskeletal conditions. Statistically significant improvements in pain, range of motion, stiffness, and physical function demonstrate that cold therapy is an effective modality, not just for acute edematous injuries but also for chronic conditions. The relatively new cold-air cryotherapy device shows promise in treating a range of painful conditions, owing to its efficacy, ease of application, cost-effectiveness, and transportability.

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