The influence of circulating cold water cryotherapy with or without intermittent pneumatic compression on shoulder joint position sense (JPS) in recreationally active adults: a randomized crossover trial

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INTRODUCTION

Cryotherapy, a technique aimed at lowering tissue temperatures by extracting heat from the body, has been widely employed in the treatment of acute musculoskeletal injuries. It is believed to reduce tissue temperature, metabolism, nerve conduction speed, inflammation, pain, swelling, circulation, stiffness, muscle spasm, and symptoms of delayed-onset muscle soreness, helping athletes return to play by alleviating pain and swelling.

Nevertheless, beyond superficial skin cooling, there is a significant dearth of compelling scientific support for its effectiveness. Some studies indicate that decreasing skin temperature to around 13.6°C is necessary for an analgesic effect, but this may simultaneously slow nerve conduction[1]. This cooling process might potentially elevate the risk of injury by impairing nerve conduction velocity, muscle force production, and proprioception. Despite the importance of proprioception for sports performance and injury prevention, the impact of cryotherapy on it remains uncertain.

Several methods have been employed to assess proprioception, with joint position sense (JPS) being the most common. However, inconsistencies in testing methods and cryotherapy application make it challenging to consolidate data. Some studies have demonstrated negative effects on proprioception due to cryotherapy, particularly in the shoulder joint, which is vital for dynamic stability. Proprioception, particularly JPS, relies on mechanoreceptors found in muscle and tendon structures, possibly not reached by superficial cryotherapy techniques, thus explaining inconclusive results.

Despite one study showing decreased JPS following cryotherapy[2], there is a lack of research employing continuous circulating cold water, which could provide a more consistent and deeper cooling effect. Moreover, many studies are small and at risk of bias, lacking pre-registration and sample size calculations, possibly introducing biases. No pre-registered studies have investigated the impact of continuous circulating cold water cryotherapy, often combined with pneumatic compression, on shoulder proprioception.

Therefore, this study aims to determine whether continuous circulating cold water cryotherapy with or without compression affects shoulder JPS.

METHODS

The trial protocol was pre-registered on the open science framework (https://osf.io/8vmna/), registration doi 10.17605/OSF.IO/RW5DZ

Starting in December 2019, we recruited healthy, recreationally active adults through announcements on our university's virtual learning platform (MS Teams) and by word of mouth. Participants with recent upper limb injuries (within the last 6 months), cold intolerance, acute inflammatory phlebitis, a history or risk factors for deep vein thrombosis or pulmonary embolism, significant arteriosclerosis or other vascular ischemic disease, conditions affecting venous or lymphatic return, significant vascular impairment, or acute paroxysmal cold hemoglobinuria or cryoglobulinemia were excluded. To establish a difference of small effect in JPS[3], 54 participants were required to achieve 80% power with a 5% two-sided type I error rate and a 1:1 allocation ratio.

The order in which participants received treatment was randomly allocated using a block randomized design (block size = 4) to either cryotherapy without compression followed by cryotherapy with compression a week later, or the inverse. In both instances, the game ready unit was filled with crushed ice equivalent to that of two standard ice bags (2392 cm^2) and applied locally via a standard shoulder wrap for 30 minutes, as per manufacturing guidelines and previous trials conducted in healthy participants. During the cryotherapy with compression intervention, cyclical pneumatic compression was applied at 5 to 75 mmHg for approximately 3-minute pressure cycles (90 seconds to pressurize and 90 seconds to depressurize) for the duration of treatment.

The primary outcome, shoulder JPS, was measured on four separate occasions immediately before and immediately after each intervention using an isokinetic dynamometer (ICC2, k = 0.99, r>0.999)[4,5]. Due to individual variability in shoulder internal and external rotation it was necessary to obtain relative mid-range values for each participant. Participants were instructed to relax their shoulder whilst a trained clinician measured their total range of motion by passively internally rotating the shoulder to end of range before passively rotating the shoulder externally to end of range. The mid-range position was calculated as the 50th percentile and was chosen because joint afferents (muscle spindles) are more stimulated in this position[6,7] and previous research found poorer accuracy in mid-range[8].

The midpoint position was set, and the shoulder was rotated internally for 10 seconds. It was then passively rotated back to the midpoint and held for a further 10 seconds, with the participant being instructed to remember the position. The shoulder was then returned to the starting position (internal rotation) and after 10 more seconds, they were asked to reproduce the midpoint position. This was repeated three times for reliability (ICC2, k = 0.980)[9].



Figure 1. Joint Position Sense Starting Position

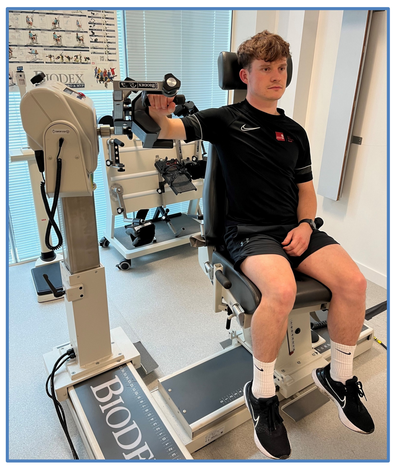


Figure 2. Joint Position Sense Target Position



Figure 3. Cryotherapy Shoulder Compression Wrap

RESULTS

Fifty-four (54% male) participants (age 22.1 (6.16) years, height 172.3 (10.85) centimetres, and weight 73.2 (16.93) kilograms) were recruited to this study. Most of the participants (87%) were right-handed. Prior to completing the cryotherapy without compression, the average total range of movement was 200.4° (33.24), and prior to completing the cryotherapy with compression, the average total range of movement was 202.2° (33.16).

Before cryotherapy without compression was administered, participants achieved an average a joint position angle of 95.72° (18.46), which compared with the average target angle (100.33°) was a relative difference of 4.61° (4.91), and an absolute difference of 5.29° (4.15). After cryotherapy without compression was applied, participants scored an average joint angle of 95.81° (18.24); a relative difference of 4.53° (5.51), and an absolute difference of 5.37° (4.67) (Table 1).

Table 1: Mean, relative and joint position sense scores for pre and post cryotherapy **without** compression

				95% Confidence Interval		
	N	Missing	Mean	Lower	Upper	SD
Pre Treatment Mid-Range Position	53	1	100.33	95.75	104.91	16.62
Pre Treatment JPS Mean	53	1	95.72	90.63	100.80	18.46
Post Treatment JPS Mean	53	1	95.81	90.78	100.83	18.24
Pre Treatment JPS Relative Difference	53	1	4.61	3.26	5.97	4.91
Post Treatment JPS Relative Difference	53	1	4.53	3.01	6.04	5.51
Pre Treatment JPS Absolute Difference	53	1	5.29	4.15	6.44	4.15
Post Treatment JPS Absolute Difference	53	1	5.37	4.09	6.66	4.67

Note. The CI of the mean assumes sample means follow a t-distribution with N - 1 degrees of freedom

Prior to cryotherapy with compression, participants achieved an average joint position of 97.94° (17.57), which compared to the target angle (101.24°) resulting in a relative difference of 3.29° (4.68), and an absolute difference of 4.20° (3.87). After cryotherapy with compression participants exhibited an average joint angle of 98.33° (17.50), resulting in a relative difference of 2.90° (4.88), and an absolute difference of 4.37° (3.60) (Table 2).

Table 2: Mean, relative and joint position sense scores for pre and post cryotherapy **with** compression

				95% Confidence Interval		
	N	Missing	Mean	Lower	Upper	SD
Pre Treatment Mid-Range Position	53	1	101.24	96.66	105.81	16.60
Pre Treatment JPS Mean	53	1	97.94	93.10	102.79	17.57
Post Treatment JPS Mean	53	1	98.33	93.51	103.16	17.50
Pre Treatment JPS Relative Difference	53	1	3.29	2.00	4.58	4.68
Post Treatment JPS Relative Difference	53	1	2.90	1.56	4.25	4.88
Pre Treatment JPS Absolute Difference	53	1	4.20	3.13	5.26	3.87
Post Treatment JPS Absolute Difference	53	1	4.37	3.38	5.36	3.60

Note. The CI of the mean assumes sample means follow a t-distribution with N - 1 degrees of freedom

The results of the Wilcoxon Signed Rank test indicated that there were no statistically significant changes, in either the cryotherapy without compression or cryotherapy with compression interventions, in the accuracy of achieving the target angle. These findings suggest that neither intervention had a significant impact on shoulder joint position sense

CONCLUSION

The objective of this pre-registered, randomized, crossover trial, with a 1:1 allocation ratio, with baseline control and double-blind design was to investigate the effects of cryotherapy, with or without compression, on JPS. Despite having sufficient statistical power to detect small differences in JPS, the results did not provide enough evidence to conclude that cryotherapy has an impact on JPS. It is important to note that the 'absence of evidence is not evidence of absence' [10]

However, the small effect sizes observed between the groups suggest that it is highly unlikely that cryotherapy has a clinically significant negative effect on shoulder JPS. This finding was consistent with most studies that have investigated the effects of cryotherapy on JPS.

This paper is the first pre-registered study to assess the impact of cryotherapy on joint position sense, aligning with CONSORT and TIDieR guidelines. Prior research featured just one study with a sample size calculation, focusing on a large effect size, which we now view as overly ambitious. In contrast, our study is uniquely powered to detect a small within-participant effect size.

Previous cryotherapy studies mainly used superficial techniques, which may not significantly affect the nerve conduction velocity of deep muscle structures like muscle spindles and golgi tendon organs. Our hypothesis was that continuously circulating cold water through crushed ice could consistently and significantly reduce the temperature of deep tissues. The rising use of such devices in athlete care emphasized the need for a better understanding of their impact.

A limitation of our study is that we conducted it on healthy, active adults, while cryotherapy is typically used on the field for soft tissue injuries. Therefore, it's unclear if our findings apply to injured individuals. We also assessed JPS at a single joint angle and in a fixed plane of motion. It is plausible that effects of cryotherapy may differ at alternative joint angles and or when the limb is free to move through multiple planes, which might be possible through 3D biomechanical analysis.

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