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Article Title: The Acute Effect of Cryotherapy on Muscle Strength and Shoulder Proprioception

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"The Acute Effect of Cryotherapy on Muscle Strength and Shoulder Proprioception" by Torres R et al.
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Abstract

Context*:** A common intervention used by clinicians, cryotherapy poses several benefits in managing acute injuries. However, cooling muscle tissue can interfere with muscular properties and the sensory-motor system. ***Objective: The aim of this study was analyse the influence of cryotherapy with a crushed-ice pack on shoulder proprioception concerning joint position sense, force sense, the threshold for detecting passive movement, and maximal force production. ***Design:*** A randomised, double-blind controlled trial. ***Participants****:* 48 healthy women aged 22.6±0.4 years with a mean body mass index of 22.8 ±0.37 kg/m^2 and percentage of body fat of 15.4±1.5%. ***Methods*:** In the experimental group, a crushed-ice pack was applied to the shoulder for 15 min, whereas participants in the control group applied a sand of bag at skin temperature, also for 15 min. An isokinetic dynamometer was used to assess maximal voluntary contraction, force sense, joint position sense, and the threshold for detecting passive movement. ***Results*:** Paired sample *t*-tests revealed that maximal voluntary isometric contraction decreased significantly after cryotherapy ($p \leq .001$), or approximately 10% of the reduction found in both muscular groups assessed. Shoulder position sense ($p < .001$) and the threshold for detecting passive movement ($p = .010$ and p=.009 for lateral and medial shoulder rotator muscles, respectively) also suffered significant impairment. Nevertheless, no significant differences emerged in force sense at 20% and 50% of maximal force reproduction ($p = .410$ and $p = .097$ for lateral rotator muscles at 20% and 50%, respectively; and, $p = .197$ and $p = .090$ for medial rotator muscles at 20% and 50%, respectively). ***Conclusion*:** Applying a crushed-ice pack to the shoulder for 15 min negatively affected muscle strength and impaired shoulder proprioception by decreasing joint position sense and the threshold for detecting passive movement.

Introduction

Cryotherapy is a common intervention used in clinical and athletic environments, especially to treat acute injuries, in which applying a crushed-ice pack, ice massage, and cold water immersion are the most effective for inducing greater and faster cooling [1-4]. The decreased temperature of tissues by transferring their thermal energy to the cryotherapeutic agent via conduction induces therapeutic effects, including reduced pain, muscle spasm, and hypometabolism, thereby making the intervention important in preventing post-traumatic oedema [5-7]. Accordingly, cryotherapy could constitute an approach to accelerate recovery from tissue injury.

Among the body's joints, the shoulder exhibits a complex biomechanical and structural function, which leaves the glenohumeral joint highly susceptible to the injury of its intra- and extra-articular structures [8]. Due to repetitive stress placed upon the shoulders of overhead athletes, which can affect the integrity of both soft tissue and bony structures, cryotherapy is a typical intervention performed in clinical and athletic environments. However, the effect of cooling muscle tissue can harm neuromuscular muscle function. In fact, research has found that cryotherapy in particular can impair sensory receptors' functioning and motor nerve conduction [9], as well as the functioning of extrafusal muscle fibres, thereby prompting force-generating capacity reduction [10] likely related to reduced myosin ATPase activity.

A lowered body temperature, even if local, reduces nerve membrane current, thus lengthening the refractory period in the case of a stimulus. Consequently, the duration of the nerve action potential increases, whereas the rate of impulse transmission decreases [5,7]. Indeed, reductions of 33% and 17% in nerve conduction velocity were found when the skin temperature was reduced to 10 °C and 15 °C, respectively that is, a decrease in nerve conduction velocity of 0.4 m/s given a drop in skin temperature of 1 °C [5].

As such, reduced nerve conduction velocity and reduced nerve impulse transmission following cryotherapy could suggest an increased activation threshold of some nerve fibres, chiefly those more sensitive to cooling. This alteration in the discharge synchronisation of nerve fibres could compromise the integrity of the central nervous system to detect, interpret, and respond to changes in internal and external conditions, thereby prompting changes in stimulus perception and reducing both motor control and functional joint stability [5,9,11].

In addition to nerve conduction and extrafusal muscle fibre impairment by cryotherapy, it is likely that the functioning of Golgi tendon organs could be negatively affected for similar reasons. However, the impact of cryotherapy upon these sensory receptors responsible for conveying information related to muscle tension remains poorly documented. Indeed, a consensus exists that force sense arises from the sense of the tendon generated by afferent feedback from the tendon. It is therefore reasonable to suggest that dysfunction involving these receptors could diminish the force-generating capacity and interfere in the individual's ability to discriminate weight.

Accordingly, *proprioceptive acuity* defined as an individual's ability to sense joint position, movement, and force as a means to discriminate body movement [12] could be affected by cryotherapy. However, available research on the potential of cryotherapy to generate muscle power remains limited, particularly concerning the submodality of proprioception related to force sense. Since the cryotherapy modality is regularly used in athletic and rehabilitation settings during the acute and rehabilitative phases of injury management, its impact upon proprioception could predispose musculoskeletal pathology to altered movement control, thus leading to the exertion of abnormal stress on tissues [13].

In response, the aim of this study was to analyse how cryotherapy with a crushed-ice pack affects the maximal force production of the rotator shoulder muscles and shoulder proprioception, specifically in different commonly used modalities, as a means to assess proprioception senses, including joint position sense (JPS), the threshold for detecting passive movement (TDPM), and force sense.

Methods

Design and Setting

In a laboratory experiment, a randomised double-blind controlled trial was performed to analyse how applying a crushed-ice pack affects shoulder proprioception and the maximal voluntary isometric contraction (MVIC) of rotator shoulder muscles.

Participants

A pilot study involving 12 participants was earlier conducted to estimate the effect size of each variable collected in the study using G*Power software, version 2.1.2 (University of Trier, Trier, Germany), with significance set at p = .05 and power set at (1-ß) = 0.80, in order to detect a large effect ($f^2 > .1$) [14]. The final sample size was thus set at 24 participants per group.

Accordingly, 48 healthy women volunteers aged 22.6 ± 0.4 years with an average body mass index of 22.8 ± 0.37 kg/m2 and percentage of body fat of 15.4 ± 1.5% formed the sample. Participants were recreational athletes recruited from the staff and student populations of the North Polytechnic Institute of Health (Portugal), and they were not involved in any sports or daily physical exercise with intense overhead activities.

Participants were randomly assigned into two groups: the experimental group (n = 24), whose members were submitted to 15 min of cryotherapy on the shoulder, and the control group (n = 24), which applied a sand of bag at skin temperature, also for 15 min. No significant differences were found between groups for the age, height and body mass index variables (p > 0.05). To assign participants into the groups and randomise the sequence of evaluation, opaque bags were used. The same researcher blinded to group allocation collected all variables, and participants were blinded to which intervention was considered to be therapeutic.

No participant had any history of shoulder injury or surgery, disorders of the cervical or thoracic spine at the time of assessment, any neurologic disorders, or known balance or proprioceptive deficits. Participants were excluded if they had any contraindications to cryotherapy, including areas of decreased sensation or decreased blood flow, Raynaud's disease, or any previous cold allergies [15].

The study was performed in accordance with ethical standards [16], and the local ethics committee approved all procedures prior to the start of the study, in accordance with the Helsinki Declaration (Fortaleza 2013). All participants provided their written informed consent and completed a medical questionnaire prior to participation.

Procedures

Demographic and anthropometric data were collected previous to the beginning of the experiment. Height and weight were assessed using a stadiometer (seca 217) and scale (seca 888), respectively.

To select a homogeneous sample related to body composition, three skinfold measurements (∑3S) were collected twice on the right side of the body (i.e., triceps, supra-iliac, and thigh) with a Harpenden skinfold caliper. To determine body density, the average of each skinfold was used to generalise the equation described by Jackson and Pollock [17]. The Siri (1956) equation was used to convert density to percentage of body fat [18].

Maximal voluntary isometric contraction, force sense of the rotator shoulder muscles, and both TDPM and JPS were assessed immediately before and after intervention (Figure 1) on the participant's dominant shoulder, determined by asking each participant which upper limb she would use to throw a ball [19]. MVIC was the initial variable examined in the first moments of assessment; however, the order of JPS, TDPM, and force sense was randomly determined, as was the angle tested for both JPS and the percentage of force reproduction for force sense.

Muscle Strength Assessment

The MVIC of the shoulder's medial and lateral rotators was recorded before and after cryotherapy. Briefly, the standard Biodex shoulder unit attachment was used to restrain the chest and pelvis, in accordance with the manufacturer's instructions (Biodex Pro Manual, Applications/Operations, Biodex Medical Systems). Each participant was seated in a dynamometer chair at 80° of hip flexion, with the shoulder positioned at 90° of abduction; the input axis of the dynamometer was aligned with the shoulder's rotation axis at 30° of the frontal plane (i.e., scapular plane). Lastly, the elbow was placed at 90° of flexion, and the handgrip was adjusted to have the wrist in a functional position.

After a trial set of four submaximal muscle contractions, participants completed three MVICs in a neutral position of 6 s, each separated by 12 s of rest. Participants received verbal encouragement, and the mean of the average torque (N.m) provided by dynamometric software (Biodex System 3 Advantage Software, Biodex Medical Systems) was used to define the target torque for force sense and characterise muscle strength.

Force Sense Assessment

Medial and lateral shoulder rotators' force-matching procedures were conducted at 20% and 50% of MVIC, which was obtained in the first assessment moment prior to intervention. For force sense testing, participants were positioned as in MVIC assessment and instructed to achieve the target force using visual feedback from the dynamometric software. Participants were asked to maintain three isometric contractions for 6 s with a rest period of 6 s at 20% of the MVIC with visual feedback done by Biodex Software. Immediately after, they were asked to reproduce the same target force, yet without visual feedback.

The force sense at 20% or 50% of the MVIC was assessed in random order and separated by 1 min. Throughout testing, participants did not receive feedback about their force-matching performance. The mean of the average of peak torque performed in the three trials without visual feedback was used for analysis. The difference between the target force and average peak torque produced in absolute value was calculated and used for analysis.

Joint Position Sense (JPS) Assessment

JPS testing was performed with an isokinetic dynamometer, with participants positioned in the same manner as in MVIC testing. The protocol for JPS assessment involved passive positioning and active repositioning (i.e., passive–active test) of the shoulder. Participants remained blindfolded, wearing headphones, and holding the remote control to the dynamometer so that they could stop its arm when they considered that they had achieved the target angle. In each trial, the shoulder was passively moved at 10°/s and placed at an index angle approximately 45° of the medial or lateral rotation. The target position was maintained for 5 s so that participants could memorise the position.

Each participant actively reproduced the index angle three times to the best of her ability. Absolute error of repositioning was obtained by calculating the average difference (in absolute value) between the index and reproduced angles of the three attempts. The start position was the neutral position of the shoulder (0°), and the direction of movement was a lateral rotation, which required concentric muscle action, and medial rotation, which required eccentric muscle action. The order of the tested angles was randomised, and the same researcher, who provided no feedback to participants about their performance during evaluation, performed all JPS assessments.

Threshold to Detect Passive Movement (TDPM) Assessment

TDPM in the shoulder was also assessed with the dynamometer. Participants were evaluated in the same seated conditions used for JPS evaluation. Each participant was asked to press the remote stop button upon sensing any movement or change relative to the initial shoulder position, which was engaged at random in the subsequent 20 s by the tester.

To maximally stimulate joint receptors and minimally stimulate muscle receptors, testing at slow angular velocity (0.25°/s) has been suggested [20]. Three trials from two starting positions (i.e., 45° of medial rotation and 45° of lateral shoulder rotation) were used, and the direction of movement was medial and lateral shoulder rotation, respectively. The number of degrees of the three consecutive trials was collected to determine TDPM, and mean values were calculated to analyse TDPM.

Intervention

The cryotherapeutic protocol was similar to that described by other researchers [11]. In the experimental group, a bag with a surface area of 500 cm^2 (20 × 25 cm) containing 1 kg of crushed ice cubes was applied to the shoulder for 15 min. The centre of the ice bag was applied atop the lateral border of the shoulder's acromion, and the size of the bag was sufficient to entirely cover the deltoid and both the supra- and infraspinatus fossa. Each ice bag was prepared similarly by the same researcher and comfortably adjusted by means of an elastic bandage.

To register surface temperature, a skin thermometer (HI 8751, Hanna Instruments, Ann Arbor, Michigan, USA) was used. The sensor (HI 765W, Ann Arbor, Michigan, Hanna Instruments), with an accuracy within 0.1 °C, was placed on the anterior deltoid, and skin temperature was recorded both before and immediately after intervention. Members of the control group participated in a similar intervention, in which they remained seated throughout, not with an ice pack, but with a sand of bag whose temperature was similar to that of the shoulder skin's surface (33 °C).

To assess proprioception in terms of JPS, TDPM, force sense, and MVIC, an isokinetic dynamometer (Biodex System 3 Pro, Biodex Medical Systems, Shirley, NY, USA) was used. Drouin et al. [21] have shown that this tool is a reliable instrument for assessing angular position, isometric torque, and slow-to-moderately high velocities, with high intraclass correlation coefficients (K = 0.99 for each variable). Similar procedures to assess proprioception and muscle strength have been used by other researchers [22,23].

Statistical Analysis

The Statistical Package for Social Sciences version 21 (SPSS, Chicago, IL, USA) for Windows 7 was used to perform statistical analyses. An *a priori* level of significance was set at $p < .05$.

The normal distribution of measured parameters was determined using the Shapiro-Wilks test. Thereafter, the Mann–Whitney U test was used to analyse JPS between the experimental and control groups, and Wilcoxon's signed-rank tests were used to discriminate differences between results obtained before and after intervention. All other variables, including those in data of sample characteristics, were tested with parametric tests (i.e., independent t-tests) to compare the two groups' data, whereas paired sample t-tests were used for between-moments data. Non-normally distributed data were reported as median (interquartile interval), whereas those with normal distribution were presented as M (SD).

Results

Related to cutaneous temperature, cryotherapy noticeably reduced the skin temperature in the experimental group (12.5 ± 1.0 °C) compared with that of the control group (33.5 ± 0.3 °C).

Table 1 shows the effect of cryotherapy upon MVIC in rotator shoulder muscles. This study's intervention induced significant impairment in the force production of the shoulder rotator muscles ($p < .001$ and $p = .001$ for lateral and medial rotator muscles, respectively) by approximately 10% of muscle strength in both muscular groups after 15 min of cryotherapy.

Results regarding force sense of the shoulder rotator muscles appear in Table 2. The error of reproduction force at 20% and 50% of MVIC showed no significant changes following cryotherapy in both muscle groups tested (p = .410 and p = .097 for lateral rotator muscles at 20% and 50%, respectively; and, p = .197 and p = .090 for medial rotator muscles at 20% and 50%, respectively).

Concerning JPS (Table 3), the median of the absolute error assessed before cryotherapy at 45° of lateral (p = .351) and medial shoulder rotation (p = .544) was similar between groups. However, the error of JPS in the lateral rotation increased significantly (p < .001), having shifted from 1.2° (1.4) to 2.7° (1.9). This impairment in JPS, verified in the experimental group, made the groups significantly different after cryotherapeutic intervention. Similar results were found concerning JPS in the medial shoulder rotation (p < .001); in this case, the median error increased by 2° [1.4° (1.0) to 3.4° (2.1)].

Similar results were found both in JPS and TDPM. In fact, cryotherapy significantly diminished the participant's ability to detect motion in the rotator muscles (Table 4). Indeed, lateral shoulder rotator muscles increased significantly the degrees necessary to sense movement (p = .010) from 0.45 (±0.23) to 0.64 (±0.27), and medial shoulder rotator muscles similarly increased significantly the degrees to detect the passive motion (p = .009) from 0.50 (±0.22) to 0.73 (±0.30) degrees.

Discussion

The results of this study demonstrate impairment of maximal force production and shoulder proprioception, namely in JPS and TDPM, after 15 min of cryotherapy. Nonetheless, the force sense of the rotator muscles showed no significant changes after the intervention. Indeed, an approximately 10% decrease in MVIC of the lateral and medial shoulder rotator muscles occurred after cooling the local tissues of the shoulder to 12.5 °C. Such muscle strength and power impairment thus confirm the dysfunction of extrafusal muscle fibres after cryotherapy. This loss of force after cryotherapy aligns with the primary results found in a systematic review conducted by Bleakley et al. (2012). To explain this negative impact, a reduction in myosin ATPase activity [24] and nerve conduction velocity has been suggested [5]. As a result, dynamic contractile force could diminish by 4–6% for each 1 °C reduction in muscle temperature [25].

Concerning JPS, the role of muscle spindles and skin receptors in this modality of proprioception is well known [26]. Bearing in mind that deep cooling muscles can pose similar implications in the contractibility of intrafusal muscle fibres compared to those mentioned in extrafusal fibres, the contractile region localised at either end of the intrafusal fibres could suffer analogous dysfunction due to cryotherapy, thereby compromising the regulation of the sensitivity of muscle spindles.

As a consequence, incorrect information could be transmitted to the central nervous system via sensory neurons, thus increasing the possibility of error in the position of the body segment. Apart from this aspect that involves cryotherapy and changes in the contractibility of intrafusal and extrafusal muscle fibres, cooling muscle tissues could also interfere with mechanical muscle tissue properties, namely in muscle spindle viscoelasticity. As a result, it interference with spindle firing characteristics after local muscle cooling can be expected.

Indeed, the 15 min of applying a crushed-ice pack to the shoulder impaired the passive repositioning of JPS for both angles tested. However, the effect of this intervention upon JPS is not consensual. In a systematic review, Costello and Donnelly (2010) analysed seven studies involving a total of 204 healthy participants, in which four studies found no effect upon JPS, though the other three found significant decreases in JPS after cryotherapy 27. Explaining these contradictory results, different reasons are appointed such as some heterogeneity in the intervention among studies and also different protocols used in proprioception in different populations.

Apart from the muscle spindles, it is well known that cutaneous receptors are also involved in proprioception[28] . It is rational to admit that this type of nervous endings, due to their superficial localisation, might experience more cooling than muscle receptors and, therefore, their afferent signals generated during movement could be blocked or suffer dysfunctions, contributing to impair JPS and TTDPM.

Although several studies have investigated the impact of cooling upon JPS [27], the effect of this intervention upon the accuracy of force reproduction has received less attention [29]. It is likely that the viscoelasticity of tissues, particularly the mechanical property of the tendon, might be changed by cryotherapy, thereby suggesting that decreased compliance with the muscle–tendon unit may directly impair its force-generating capacity and also influence neural activation patterns. In examining the effect of cryotherapy upon tendon organ activation, force sense was used as an indirect marker in this study, primarily to determine whether cryotherapy impairs neural activation and increases the error of effort sensation.

Our protocol to assess force sense included 20% and 50% of MVIC reproduction and was performed by both shoulder rotator muscles. Since both groups had shown parallel impairment in the MVIC after cryotherapy, the negative impact upon this dependent variable could be expected. However, no significant increment of error in the reproduced force was detected following intervention.

Our findings corroborate those of Tremblay et al. (2001). Although using a substantially different method to assess this aspect of proprioception, their study found no effect of local cooling upon proprioceptive acuity in the quadriceps. Nevertheless, it should be mentioned that the intervention was applied in the muscle region lacking the Golgi tendon organs, suggesting that any decreased perception of force would be less expected [29].

Indeed, several forms of cryotherapy are used to manage acute soft tissue injuries, particularly in athletic environments (e.g., cold water immersion, cold spray application, and icepacks). Although the present evidence suggests that athletes are at a disadvantage in terms of performance if they return to activity immediately after cooling [9], cryotherapy continues to be used before sport activities despite its potential negative neurophysiological effects. Due to the fact that cryotherapy is indicated in acute injuries and this study only selected participants with uninjured shoulders, could be seen as a limitation.

Our protocol to assess proprioception was composed of several muscle contractions to assess MVIC and TTDPM. This fact could have induced muscle fatigue and consequently have been related to the impairment of the proprioception. Nevertheless, the hypothetical fatigue does not seem to have had influence in the proprioception due to the results found in the control group, i.e., the control group remained with the same level of errors between moments.

Moreover, in view of the fact that there were found differences between men and women in proprioceptive acuity[30] this research included only female. Consequently, the extrapolation of these results for other populations or clinical conditions must be done with prudence.

Furthermore, it is important to emphasize that the impairment observed in proprioception has an acute effect, and the results are not clear in relation to when the sensory-motor system returns to its normal functioning.

Clinical implications

Bearing the results of the present study in mind, we discourage the use of cryotherapy, particularly when it precedes immediately the return to activity. The resultant abnormal proprioception could predispose musculoskeletal pathology, thus leading to abnormal stress upon tissues. More attention should, therefore, be given to the neurophysiological effects of deep cooling tissues prior to immediately initiating activity. Furthermore, to minimise if not prevent harm to functional performance and proprioception, only a brief application should be implemented.

Conclusions

In sum, 15 min of cryotherapy applied to the shoulder induces negative effects upon muscle strength and impairs shoulder proprioception. Cryotherapy reduces a person's ability to generate force by shoulder rotator muscles. Moreover, changes in sensory inputs arising from proprioceptors after cooling can diminish JPS and TDPM. With this in mind, more attention should be paid to this clinical intervention before athletic practice, especially in the light of a growing consensus that reduced proprioception increases the risk of musculoskeletal pathology and athletic injury. Future research should continue studying changes in proprioception subsequent to cryotherapy, particularly its effect on Golgi tendon organ functioning, and other ways of cooling frequently used in athletic environments (e.g., cooling spray and ice massage).

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Participants testing order

Before

Step 1 - Collect demographic and anthropometric data

Step 2 - Determine the maximal voluntary isometric contraction (MVIC)

Step 3 - Five minutes at rest

Step 4 - Assess the force sense

- 3 trials at 20% of the MIVC *
- 3 trials at 50% of the MIVC *

Step 5 - Assess the joint position sense

- 3 trials at middle range of motion of lateral rotation *
- 3 trials at middle range of motion of medial rotation *

Step 6 – Assess the threshold to detect passive movement

(Steps 4–6: *)

Step 7 - Intervention: 15 minutes of cryotherapy vs 15 minutes of "sandbag"

After

Step 8 - Assess the force sense

- 3 trials at 20% of the MVIC *
- 3 trials at 50% of the MVIC *

Step 9 - Assess the joint position sense

- 3 trials at middle range of motion of lateral rotation *
- 3 trials at middle range of motion of medial rotation *

Step 10 – Assess the threshold to detect passive movement

(Steps 8–10: *)

Figure 1 – Experimental protocol

* The order of these testes was randomly determined

Table 1.

Maximal voluntary isometric contraction

	Lateral rotator muscles				Medial rotator muscles			
	Before intervention	After intervention	Percentage of variation		Before intervention	After intervention	Percentage of variation	
	Mean (±SD)	Mean (±SD)	Mean (±SD)	*Paired-sample t test*	Mean (±SD)	Mean ((±SD)	Mean (±SD)	*Paired-sample t test*
Experimental group	20.5 (±4.3)	18.0 (±4.1)	-13.5 (±8.2)	**p<0.001***	35.3 (±5.4)	31.8 (±5.6)	-11.0 (±13.2)	**p=0.001***
Control group	19.7 (±4.1)	19.8 (±4.0)	-0.3 (±3.9)	p=0.934	33.7 (±5.7)	34.5 (±5.8)	2.1 (±4.2)	p=0.239
Independent-sample t test	p=0.881	p=0.931			p=0.582	p=0.503		

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Table 2A.

Force sense of the lateral rotator muscles

	At 20%				At 50%			
	Before intervention	After intervention	Percentage of variation		Before intervention	After intervention	Percentage of variation	
	Mean (±SD)	Mean (±SD)	Mean (±SD)	*Paired-sample t test*	Mean (±SD)	Mean (±SD)	Mean (±SD)	*Paired-sample t test*
Experimental group	0.26 (±0.14)	0.34 (±0.30)	30.8 (±114.2)	0.410	0.70 (±0.42)	0.63 (±0.40)	-10.0 (±4.8)	p=0.097
Control group	0.28 (±0.16)	0.36 (±0.28)	28. 6 (±75.0)	0.142	0.67 (±0.43)	0.75 (±0.55)	11.9 (±27.9)	p=0.303
Independent sample t test	p=0.106	p=0.250			p=0.987	p=0.519		

Table 2B.

Force sense of the medial rotator muscles

	At 20%				At 50%			
	Before intervention	After intervention	Percentage of variation		Before intervention	After intervention	Percentage of variation	
	Mean (±SD)	Mean (±SD)	Mean (±SD)	*Paired-sample t test*	Mean (±SD)	Mean (±SD)	Mean (±SD)	*Paired-sample t test*
Experimental group	0.46 (±0.33)	0.40 (±0.23)	-13.0 (±30.3)	p=0.197	0.70 (±0.32)	0.73 (±0.46)	4.3 (±43.8)	p=0.090
Control group	0.47 (±0.36)	0.45 (±0.40)	-4.3 (±11.1)	p=0.627	0.67 (±0.52)	0.64 (±0.42)	-4.5 (±19.23)	p=0.064
Independent sample t test	p=0.939	p=0.901			0.314	0.140		

Table 3.

Joint position sense

	45° of the lateral rotation			45° of the medial rotation		
	Before intervention	After intervention		Before intervention	After intervention	
	Median (Interquartile interval)	Median (Interquartile interval)	*Wilcoxon test*	Median (Interquartile interval)	Median (Interquartile interval)	*Wilcoxon test*
Experimental group	1.2 (1.4)	2.7 (1.9)	**p<0.001***	1.4 (1.0)	3.4 (2.1)	**p<0.001***
Control group	1.3 (1.7)	1.2 (1.5)	p=0.634	1.5 (1.3)	1.3 (1,2)	p=0.443
Mann-Whitney U test	p=0.351	**p=0.003***		p=0.544	**p=0.013***	

"The Acute Effect of Cryotherapy on Muscle Strength and Shoulder Proprioception" by Torres R et al.
Journal of Sport Rehabilitation

Table 4.

Threshold for detecting passive movement

	At 45° of lateral shoulder rotation			At 45° of medial shoulder rotation		
	Before intervention	After intervention		Before intervention	After intervention	
	Mean (±SD)	Mean (±SD)	*Paired-sample t test*	Mean (±SD)	Mean (±SD)	*Paired-sample t test*
Experimental group	0.45 (±0.23)	0.64 (±0.27)	**0.010***	0.50 (±0.22)	0.73 (±0.30)	**p=0.009***
Control group	0.48 (±0.36)	0.46 (±0.28)	0.920	0.57 (±0.33)	0.55 (±0.35)	p=0.703
Independent sample t test	p=0.601	**p=0.020***		p=0.897	**p=0.019***	