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ORIGINAL ARTICLE

The Effect of Cryotherapy on the Normal Ankle Joint Position Sense

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Abstract

***Purpose*: To determine whether a fifteen-minute water immersion treatment affects the normal ankle joint position sense (JPS) at the middle range of dorsiflexion and plantar flexion actively and passively.**

***Methods*: Thirty healthy female volunteers aged between 18 and 30 years were treated by a 15-minute cryotherapy (6 ± 1°C). The subject's skin temperature over antromedial aspect of dominant ankle was measured by the Mayomed device before, immediate and 15 minutes after water immersion. Ankle JPS was tested trough the pedal goniometer at 3 stages similar to the skin temperature. ANOVA (α = 0.05) was performed on each of variables using SPSS 19.0 software.**

***Results*: Skin temperature was seen to decrease after water immersion but subjects did not return to pre-test skin temperature after 15 minutes (P<0.001). The research found no significant difference in JPS at middle range of dorsiflexion and plantar flexion actively and passively before and after cryotherapy.**

***Conclusions*: These findings suggest that 15-minute water immersion at 6°C dose not significantly alter the middle range of plantar flexion/ dorsiflexion JPS at the ankle and is not deleterious to JPS.**

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INTRODUCTION

Proprioception is essential in coordinating body segments and controlling muscles to perform movements. Sherrington first defined proprioception as afferent information traveling to the central nervous system (CNS) in 1906, which encompasses a number of different components including kinesthesia, somatosensation, balance, reflexive joint stability, and JPS[1]. More recently, the term proprioception has evolved into including measures of joint position sense, threshold of detection of passive movement and force reproduction[2]. Proprioceptive control may differ depending on the joint tested. However, exact mechanism of proprioceptive control remains unclear[3].

Angular measurements have been used by researchers to assess joint position sense (JPS) as one of the submodalities of proprioception[4-10]. JPS in the ankle has been investigated in several experiments, the apparatus used in each case varies. Gordon designed a pedal goniometer to assess proprioception at the ankle[11]. Chan et al designed also a pedal goniometer to measure the range of ankle inversion in a plantar flexed position. The device was proven highly reliable with values of the Pearson's correlation coefficient for intra-tester and inter-tester reliability of r=0.96 and r=0.91 respectively[12]. According to previous studies, the various instruments that measure joint position are reliable. The ankle joint was selected for the assessment of proprioception in this study because of its predominant role in postural control[13].

The term cryotherapy refers to the lowering of tissue temperature by the withdrawal of heat from the body to achieve a therapeutic objective [14,15]. Despite this conceptual simplicity, controversy and confusion exist within clinical practice and published literature over the therapeutic benefits and application protocols of cold modalities [16,17]. The confusion can be attributed in part to the heterogeneous nature of pathologic conditions, an incomplete understanding of the physiologic responses to cold, and the variety of available cryotherapy modalities [18].

Various methods of applying cryotherapy are as follows: Ice massage/ Ice bag/ Chemical cold pack/ Cold whirlpool/ Cold water immersion ("slush bath"). This form of cryotherapy is both convenient and economical. Equal parts of ice and water are placed in a plastic bucket and the injured area is submerged in the ice water slurry for 15 minutes. This form of cryotherapy is used primarily for distal extremities such as hands and feet[19] and because of the increased area of surface contact, water immersion likely causes more joint and muscle cooling compared with more superficial applications such as ice.

Cryotherapy, or icing and/or submersion of the foot and ankle in cold water, is a very popular treatment method for both acute and chronic athletic injuries because of its ability to reduce pain, inflammation, and muscle spasm [20]. Moreover, cryotherapy influences neuromuscular properties including nerve conduction velocity and muscle contraction [21].

In fact, results from previous research suggest a linear relationship between the rate of muscle spindle discharge and muscle temperature. This is important, because any change in afferent signal can in return lead to motor response modification [22].

Discharge of the muscle spindles is not stimulated by the somatic fibers only. Rather, muscle sympathetic activation is also effective[23]. Therefore, any factor stimulating autonomic system such as thermal modalities, some drugs and eatable materials can be effective in the sensitivity of muscle spindles and consequently on the proprioceptive acuity.

The proprioceptive effects of cryotherapy may be explained neurophysiologically by reference to the reduction of nerve conduction velocity (NCV) and the eventual blocking of conduction. Abramson et al showed an approximately linear inverse correlation between NCV and the degree of tissue cooling [21]. Lee et al reported that the skin temperature at which subcutaneous nerves start to show significant reductions in conduction velocity is approximately 25°C and nerve conduction failure occurs below 15°C[24].

Although the slowing of nerve conduction is commonly a desired effect of cryotherapy, it may be undesirable before therapeutic exercise or training[25]. Cryotherapy before exercise may result in inadequate peripheral feedback on the position sense and may change biomechanic properties of the ankle joint. Afferent input from the dynamic stabilizer muscles surrounding the ankle joint may play a critical role in the prevention of ankle sprains [26]. If neuromuscular function is compromised by the treatment, ankle injury may occur when exercise is resumed.

Therefore, the purpose of this study was to present data on the position sense of healthy ankle after cryotherapy to clarify the effectiveness and safety of this therapy before resuming sports activities.

METHODS AND SUBJECTS

Subjects:

Thirty healthy female volunteers participated in the experiment. Volunteers' anthropometric characteristics are presented in Table 1. Prior to participation, all subjects signed an informed consent agreement approved by the university's institutional review board. All subjects reported to be right leg dominant (The dominant leg was defined as the leg that the subject would choose to kick a ball). Dominant leg was chosen

Table 1: Anthropometric characteristics of the participants

Anthropometric characteristics	Mean (SD)
Weight (Kg)	55.85 (5.96)
Height (Cm)	161.53 (4.62)
Age (Years)	21.93 (0.82)

SD: Standard Deviation

as the treatment leg in this study. None of the subjects were in the menstrual cycle or professional athletic. Subjects were excluded if they had special disease as diabetes, musculoskeletal disease and history of fracture or other orthopedic problems.

Instruments:

Firstly, skin surface temperature was measured by using a SST-1 flexible surface temperature electrode with a contact surface area of 0.8cm^2. The electrode was connected to a thermometer with a range of 0° to 100°C and an accuracy of ±0.2°C.

The temperature of the cold water was also closely monitored with a battery operated digital thermometer from Acu-Rite (Chaney Instrument Co., Lake Geneva, WI). The digital thermometer consisted of a 50-cm water-resistant wire with a submersible probe attached to the end and was accurate to the nearest tenth of a degree. The probe was placed near the bottom of the cold whirlpool and secured in place with tape. The temperature was maintained at 6±1°C using ice.

Ankle JPS was measured using a pedal goniometer consisting of four parts: a pedal with two clamps and pointer/ a back piece with a protractor/ a leg fixator and a metal base. Information such as age/ weight/ height) were recorded in a questionnaire.

Procedures:

- First section

In the first section of this research, the accuracy and reliability of the angle reproduction measured by pedal goniometer were evaluated. The intra-tester reliability was high (r = 0.97) and the measurement error factor was within the range of 0.6 degree and therefore was considered negligible.

- Second section

Prior to testing, all subjects completed the questionnaire and were screened for any contraindication. Main experiment was performed at 3 stages after recording personal information. During all tests, each subject was dressed in shorts and no shoes and socks and was seated at the end of the table so that her feet were not arriving to the ground. Proprioceptive differences were measured in dominant ankle joint. The difference between the perceived angle and the actual angle was recorded as the proprioceptive difference.

First stage: The subject was instructed to remove her pants to acclimatization to room temperature (range: 18.7°–22.5°C, mean: 20.6°C). To measure the subject's skin temperature, the disk sensor of a thermometer was applied over the anteromedial aspect of the ankle (lateral to medial malleolus) and skin temperature was recorded.

Then, volunteer's leg was set in the goniometer and fixed by Velcro strap. Subject was also blindfolded to eliminate any visual cues. The subject's foot was moved to the target angle after preparation [from neutral position to the middle range of dorsiflexion (10 degrees)], and the subject was asked to focus on the position of her ankle joint in space for 3 seconds- a period of time utilized in the literature[27,28]. After returning to the starting position, foot was moved towards dorsiflexion with constant velocity. Then, subject was asked to inform us once she felt the target angle has been achieved and to report the angle. This experiment was repeated but this time the subject was asked to actively reproduce the test position. These two experiments were repeated at 20 degrees of plantar flexion.

2nd stage: The volunteer's foot, 5 cm above the malleolus, was immersed in the 6±1 degree water.

Table 2: Mean (SD) skin temperature before, after and 15 minutes after water immersion (°C)

	Before WI	After WI	15 minutes after WI	*P*
skin temperature	32.25 (0.92)	15.12 (0.93)	29.23 (1.66)	<0.001

SD: Standard Deviation

After 15 minutes of cooling, skin temperature and JPS were immediately measured.

3rd stage: 15 minutes after cooling, skin temperature and JPS were measured. In interval of 2nd and 3rd stage, subject was relaxed and barefoot.

Generally, JPS was measured in 4 ankle position × 3 cooling time. One trial was done in each condition for data collection.

Statistical analysis:

Repeated measures ANOVA (α=0.05) was performed on each of variables using SPSS 19.0 software.

RESULTS

Skin temperature was seen to decrease after water immersion but subjects did not return to the pre-test skin temperature after 15 minutes (p= 0.00) (Table2).

The research found no significant difference in JPS at the middle range of active plantar flexion $F(2, 58)= 0.32$, $P= 0.72$ & passive plantar flexion $F(2, 58)= 0.36$, $P=0.69$ and active dorsiflexion $F(2, 58)= 0.21$, $P= 0.80$ & passive dorsiflexion $F(2, 58)= 2$, $P=0.14$ following cryotherapy (Table 3).

DISCUSSION

Our results revealed that 15-minute water immersion with 6±1°C has no significant effect on the ankle JPS at the plantar flexion & dorsiflexion.

When nerve temperature decreases, nerve conduction velocity decreases in proportion to the degree and duration of the temperature change. It is not identical at the fibers with different diameters; rather, researches indicate cold has the greatest effect on conduction by myelinated and small fibers and the least effect on conduction by unmyelinated and large fibers. A-delta fibers which are small diameter-myelinated and pain-transmitting fiber demonstrate the greatest decrease in conduction velocity in response to the cooling (29), but afferent fibers that translate the proprioceptive information from muscle spindles to the CNS are type of Iα and II meaning large myelinated fiber that have fast conduction (30). So, it is possible that is less affected by cold.

Fifteen-minute cooling at 6±1°C may have no effect on the function of proprioception but using lower temperatures or longer periods may indicate the other findings because of further affecting conduction velocity of afferent fibers running from receptors to CNS, and further activation of pain receptors. Of course researches that have investigated effects of

Table 3: JPS scores of dorsiflexion and plantar flexion before and after water immersion (WI)

		Before WI	After WI	15 minutes after WI	*P*
JPS Plantar flexion	**Active**	1.44 (3.14)	1.30 (2.89)	1.67 (2.98)	0.72
	Passive	1.87 (3.33)	1.30 (2.89)	1.67 (2.98)	0.69
JPS Dorsiflexion	**Active**	0.30 (2.58)	- 0.06 (2.76)	0.37 (2.49)	0.80
	Passive	1.44 (1.97)	0.77 (1.56)	0.84 (1.48)	0.14

Note: data are mean difference between the perceived angle and the actual angle (SD)/ JPS: joint position sense pain on the proprioception have found different findings and no exact correlation has been found between perceived pain intensity and decreased acuity so far. For instance, Mater et al reported that muscle pain declines the proprioception [31].

Eight studies have assessed 3 specific joints after a cryotherapy intervention: the ankle [28,32], knee [8,33,34,38] and shoulder [33,35]. Cryotherapy had a negative effect on JPS in 3 studies [8,28,38], whereas it had no effect on JPS in 5 studies [32-35]. Our results are in accordance with those who found no change in JPS after a cold therapy session [32-35]. LaRiviere and Osternig [32] concluded that an ice treatment had no effect on JPS at the ankle joint.

Dover believed that the afferent information from the glenohumeral joint (GH joint) may have been affected by the cryotherapy, but subjects were able to use peripheral information from other areas to modify the motor response. Perhaps even little afferent information which travels to the CNS is enough for the efferent or central command information to correct the JPS despite the alternation caused by the cryotherapy in this experiment. Besides, the temperature of the GH joint may be difficult to be lowered to a level of clinical significance. Hence, the shoulder may have not been cooled enough to measure a difference in the motor output (JPS) [33].

Ozmun et al concluded that cooling the knee joint for 20 minutes does not have an adverse effect on proprioception. There was no difference in proprioceptive ability between ice treatment and control sessions[34].

In Wassinger's study no difference was found in active joint position replication (AJPR) of the shoulder after cryotherapy. It is possible that the portions of the sensorimotor system are not affected by the application of cryotherapy (mechanoreceptors deep to the cryotherapy application region were able to compensate for mechanoreceptors influenced by cryotherapy)[35].

As mentioned previously, muscle spindles have autonomic fibers besides somatic innervation [36,23]. Therefore, each factor stimulating autonomic system may change sensitivity of muscle spindles and accuracy proprioception. For instance, cold as one stimuli of sympathetic system may be effective in proprioceptive acuity.

Animal studies have reported reduced muscle spindle sensitivity in jaw muscles during electrical stimulation of sympathetic nerves[36]. However, Matre et al at a study on the human observed that stimulation of sympathetic nerves through cold pressor has no effect on the proprioception, but after glucose intake which is a natural stimuli of sympathetic system, the proprioceptive acuity is higher into flexion, but not into extension. Generally, it is not possible with the current method to link the improved proprioception to direct sympathetic actions on the human muscle spindle endings. It could be an effect secondary to change in skeletal muscle blood flow[31], whereas most animal studies seem to agree that changes in muscle spindle sensitivity during sympathetic stimulation are independent of vasomotor changes supported by the unchanged intramuscular blood flow[36,37]. Other authors have found deficits in proprioception after cryotherapy[8,28,38].

Uchio et al indicated that applying cooling pad to the knee for 15 minutes under the circulating medium at 4°C increases inaccuracy of position sense by 1.7 deg that is in consistent with our study. One of the plausible reasons may be related to 4°C, because pain receptors are very fired at this temperature. Hence, this matter may have negative effect on the proprioception. Uchio et al identified decreases in nerve conduction velocity after cryotherapy as the culprit for altered proprioception [8].

A significant difference in ankle JPS following fifteen minutes of ice immersion was found in Hopper's study. However, the magnitude of this difference (0.5 degree) would not be deemed significant in clinical practice [28].

Surenkok et al were the only investigators who employed proprioceptive tests (JPS and static balance) after 2 separate cryotherapy interventions in a crossover study design. In this research, significant differences were found before and after cold pack application and also before and after cold spray application. In other words, both methods affected JPS after treatment negatively [38]. However, applying spray until participants report a feeling of cold is a subjective measurement. Because neither application duration nor skin temperature was reported, the findings should be treated with caution.

Only 3 groups recorded the skin temperature and none reported intramuscular temperatures [8,28,33]. Riemann and Lephart [39] suggested that cutaneous afferents play only a minor role in joint proprioception, whereas muscle spindles and joint receptors have a much more significant role. Therefore, whether superficial applications of cryotherapy such as cold spray or ice can cool deep tissue sufficiently to elicit a reduction in proprioceptive or joint position acuity is questionable.

Previous investigators have suggested that nerve conduction velocity decreases in a linear fashion with tissue cooling and without skin cooling, and the rate of decrease in muscle tissue temperature depends on the cooling temperature. Furthermore, ice massage reduces muscle temperature more than an ice-bag application, and a cool-whirlpool treatment is better than crushed ice packs in maintaining muscle temperature reductions. Different cooling techniques may produce different degrees of joint cooling. Hence, we believe that the modality of cooling (ice-water immersion, a cooling pad, or ice application) may be critical in governing the effect on JPS [1].

Generally, Skin surface temperature serves as a useful measure in determining the cooling efficiency of cryotherapeutic agents. Authors reported that a skin surface temperature of 13.6°C reflects local analgesia and 12.5°C reflects a 10% reduction in nerve conduction velocity. Skin surface temperatures between 10°C and 11°C reflect a 50% reduction in cellular metabolism, with the onset of cell hypometabolism occurring at a skin surface temperature of 15°C. These findings define a therapeutic skin surface temperature ranging from 10°C to 15°C. Therefore, an efficient agent has a post-application temperature within this range [40]. In Hopper's study, application of water immersion (15 minutes, 4°C) produced a significantly greater reduction in skin surface temperature (15°C)[28]. Therefore, we selected the 15-minute water immersion of 6°C to achieve a skin temperature within this range.

This study has been done on the ankle joint. However, this point should be regarded that mechanism of proprioception in various joints (ankle, knee and shoulder) is different. Hence, obtained results are not proportionable to each other. Furthermore, differences between the results may be related to the various methods of studies; because soft tissue thickness, type of modality, contact time, primary temperature of tissue and modality are very important in cooling process and can influence the results.

Limitations:

Several limitations should be noted. All subjects participating in this study had uninjured ankles. Since the injury or acute inflammatory processes may affect the results, findings of the present study are not applicable to an injured population. Moreover, cutaneous fat thickness and changes in intramuscular and joint temperature were not measured. We assumed that our cryotherapy application has altered the tissue temperature, yet this was not verified. More studies should be performed to investigate various sectors of the ankle's range of motion.

CONCLUSION

These findings suggest that a 15-minute cryotherapy (6 ± 1°C) is not deleterious to JPS and can be safely used without fear of reinjury due to decreased proprioception.

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Conflict of interests: The authors declare that they have no conflict of interests.

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