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Skin Cooling and Force Replication at the Ankle in Healthy Individuals: A Crossover Randomized Controlled Trial

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Context: Proprioception of the ankle is determined by the ability to perceive the sense of position of the ankle structures, as well as the speed and direction of movement. Few researchers have investigated proprioception by force-replication ability and particularly after skin cooling.

Objective: To analyze the ability of the ankle-dorsiflexor muscles to replicate isometric force after a period of skin cooling.

Design: Randomized controlled clinical trial.

Setting: Laboratory.

Patients or Other Participants: Twenty healthy individuals (10 men, 10 women; age = 26.8 ± 5.2 years, height = 171 ± 7 cm, mass = 66.8 ± 10.5 kg).

Intervention(s): Skin cooling was carried out using 2 ice applications: (1) after maximal voluntary isometric contraction (MVIC) performance and before data collection for the first target force, maintained for 20 minutes; and (2) before data collection for the second target force, maintained for 10 minutes. We measured skin temperature before and after ice applications to ensure skin cooling.

Main Outcome Measure(s): A load cell was placed under an inclined board for data collection, and 10 attempts of force replication were carried out for 2 values of MVIC (20%, 50%) in each condition (ice, no ice). We assessed force sense with absolute and root mean square errors (the difference between the force developed by the dorsiflexors and the target force measured with the raw data and after root mean square analysis, respectively) and variable error (the variance around the mean absolute error score). A repeated-measures multivariate analysis of variance was used for statistical analysis.

Results: The absolute error was greater for the ice than for the no-ice condition ($F_{1,19} = 9.05$, $P = .007$) and for the target force at 50% of MVIC than at 20% of MVIC ($F_{1,19} = 26.01$, $P < .001$).

Conclusions: The error was greater in the ice condition and at 50% of MVIC. Skin cooling reduced the proprioceptive ability of the ankle-dorsiflexor muscles to replicate isometric force.

Key Words: proprioception, isometric force, cryotherapy

Key Points

- The decrease in skin temperature after ice application decreased the precision in isometric force replication.
- The absolute error in isometric force replication was greater in target forces with higher percentages of maximal voluntary isometric contraction.
- Clinicians should be cautious in applying ice when full proprioceptive capacity is needed.

Researchers[1–4] have evaluated proprioception in different joints owing to its importance regarding movement refinement and motor control and its potential involvement in injury prevention. Proprioception at the ankle has been evaluated widely because of its importance as a cause or consequence of sprains; recurrences; and long-term sequelae, such as instabilities commonly seen in this joint.[5,6]

Ankle proprioception commonly is investigated in terms of the ability to sense the position[7–9] and the discrimination of speed and direction of movements.[10,11] An alternative proprioceptive assessment concerns the ability to sense muscle-contraction intensity.[12–14] Overall, this assessment form involves the attempt to produce a target force, and the protocols for such assessments may vary according to aspects such as the use of feedback, single-limb or double-limb assessments, and consideration of individual characteristics (eg, age, level of physical activity).[15–18] However, considering this assessment is carried out by instructing an individual to replicate a target force, concern exists as to whether the participant recognizes the intensity of contraction via either information from the muscle receptors or changes in pressure on tissues from contact with the equipment. Researchers have reported the skin is an organ capable of influencing proprioception[18–20] and that decreasing the skin temperature can change the sensory afferent information from cutaneous receptors.[19]

Ice application has been used to reduce skin temperature during proprioceptive assessment,[21,22] and the physiologic effects of ice application are likely to include the decrease in sensory afferent information.[19,23–25] Therefore, to further understand the role of ice application around the ankle, the purpose of our study was to investigate whether ice

Table 1. Characteristics of Participants and Maximal Voluntary Isometric Contraction

Variable	Mean ± SD
Age, y	26.8 ± 5.2
Height, cm	171 ± 7
Mass, kg	66.8 ± 10.5
Maximal voluntary isometric contraction, N	
With ice application	258.15 ± 70.47
No ice application	248.25 ± 71.69

application to the ankle would affect dorsiflexion force replication in healthy individuals.

METHODS

Design

The study was a crossover randomized controlled clinical trial.

Participants

Twenty people (10 men, 10 women) without a history of lower limb injury during the 60 days preceding data collection or vascular or circulatory disease, diabetes, or any condition that could compromise skin sensibility took part in the study (Table 1). Data collection was carried out in a laboratory setting at the Center of Health and Sports Sciences of the University of the State of Santa Catarina, Brazil. All participants provided written informed consent, and the study was approved by the Human Research Ethics Committee of the University of the State of Santa Catarina (number 231/2010) and registered at the Australian New Zealand Clinical Trials Registry under number ACTRN 12611000290998.

Procedures

All participants were allocated randomly to the control (no-ice condition first) or ice (ice condition first) intervention. An investigator (M.N.) who was not involved in the intervention or assessments prepared sealed envelopes

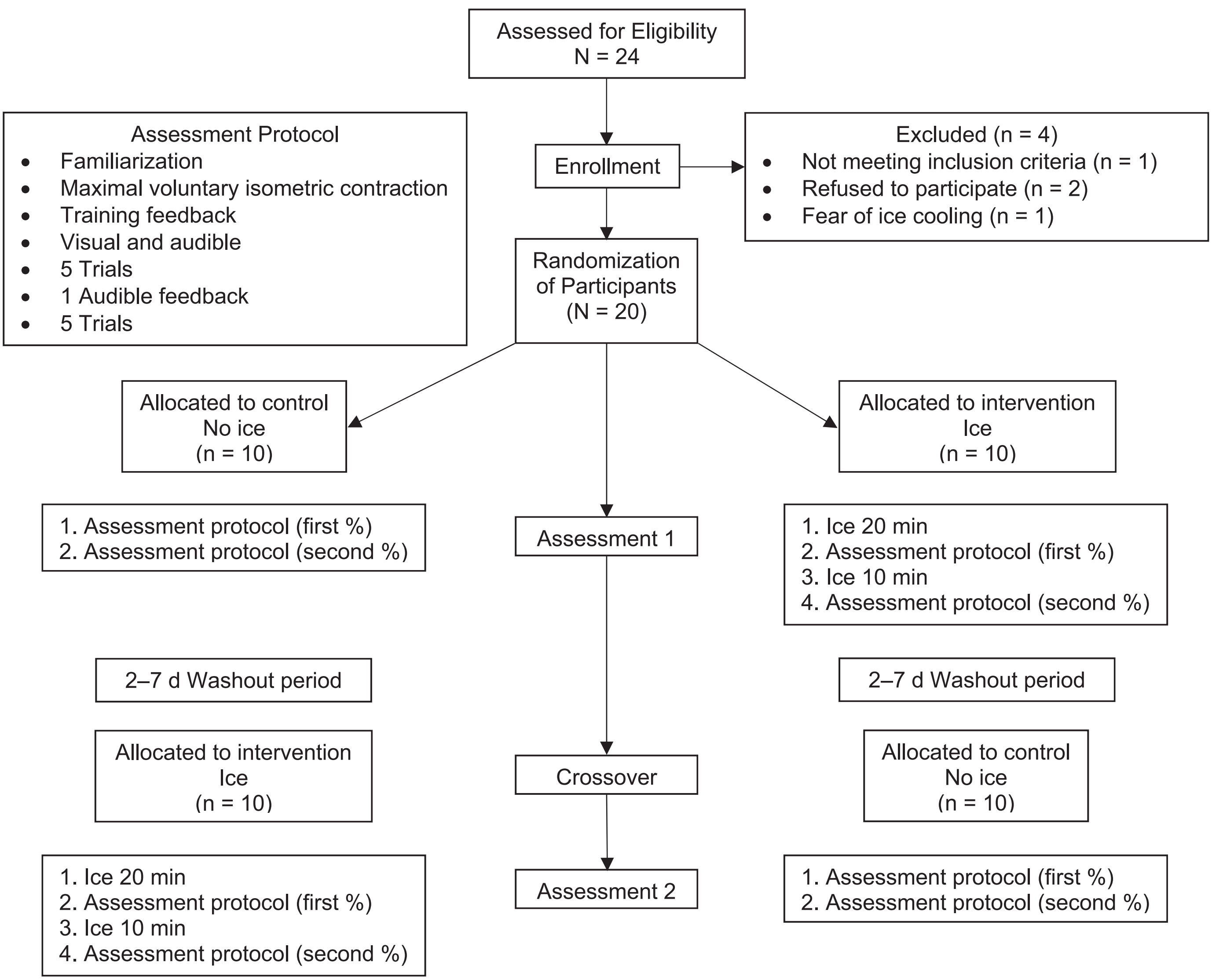

Figure 1. Study randomization and design.

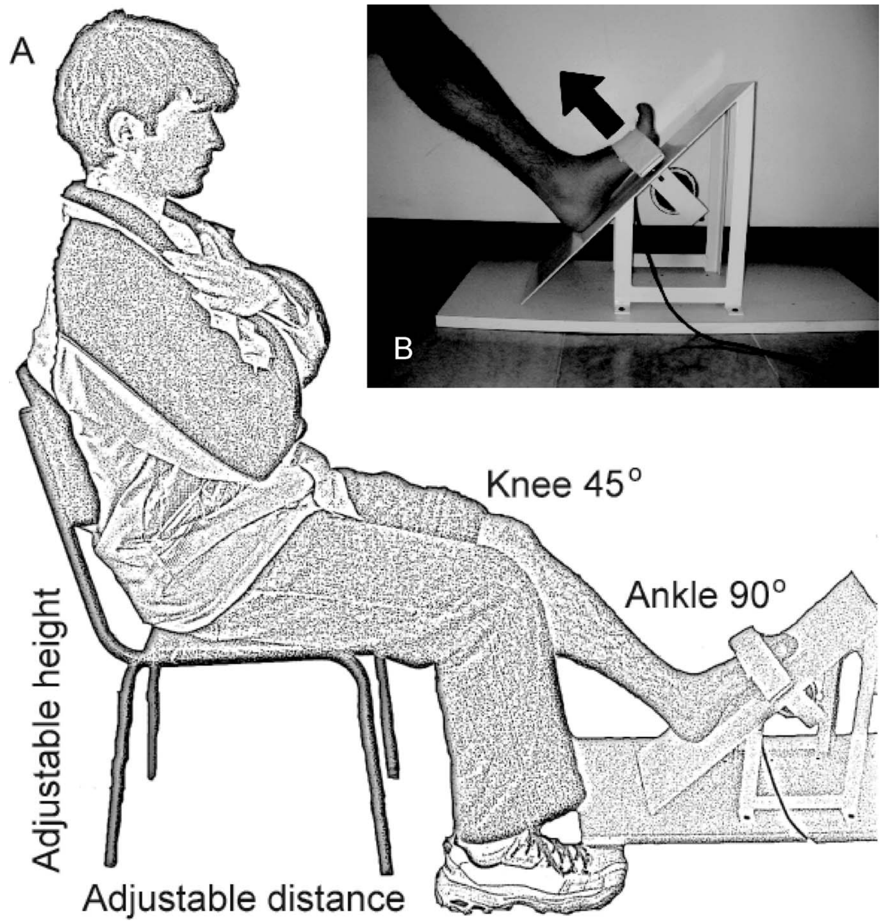

Figure 2. Positioning for data collection. A, General view of position, including knee flexion to approximately 45°. B, The position of the foot on an inclined board at a 45° angle. The foot was fastened with a hook-and-loop band over the dorsal region during isometric force replication. The load cell was attached under the inclined board. The arrow indicates the force direction.

containing the order of the interventions (ie, ice followed by no ice or no ice followed by ice). Another investigator (D.P.S.H.) opened the envelope in front of each participant only after his or her eligibility was established. Participants in the ice-intervention group were first assessed under the effect of ice application; after a washout period of 2 to 7 days, they were assessed again without ice application. Participants allocated to the control group underwent the same assessment with the same washout period; however, ice application was performed in reverse order (first no ice application, then ice application; Figure 1). Only 1 ankle for each participant was assessed, and that ankle was determined by randomization (right or left), as was the order of target forces to be replicated (20% and 50% of maximal voluntary isometric contraction [MVIC]). These conditions were repeated for the second assessment occasion.

Assessment

During the assessment, participants were seated on a chair with the upper limbs crossed over the chest. We evaluated them in a seated position to minimize cutaneous clues from the sole of the foot, which could have been more prominent in a standing position. The lower limb was positioned with the knee as close as possible to a 45° angle and the ankle at a 90° angle on the supporting surface of the inclined board (Figure 2A). To adjust the angle for the ankle in 90°, the seat height and the distance between the chair and the inclined board were changed as needed, and the participant was instructed not to move the trunk during the assessment. The final variation in position for the knee angle was ±5°. The foot was supported on the inclined board without allowing the toes to touch the board surface (Figure 2B).

In this position, participants performed 5 submaximal ankle dorsiflexions to become familiar with the equipment. Next, they were instructed to perform 1 MVIC for ankle dorsiflexion and to hold the contraction isometrically for 5 seconds.[26] They were encouraged orally during the MVIC. The target forces to be used for replication were set at 20% and 50% of the MVIC.

A computer (model Aspire 5050; Acer Inc, New Taipei City, Taiwan) was positioned on a table in front of the participants so they clearly could see the values equivalent to 20% and 50% of the MVIC during training. Participants were comfortable and aware of what was required during data collection. Two types of training were performed immediately before data collection at each target force. For the first training, participants were instructed to replicate the target force by controlling the contraction intensity of the dorsiflexors until it reached the target force. The visual feedback comprised a line going up on the computer screen as the contraction intensity increased and a line going down as the contraction intensity decreased; the target force was marked clearly on the computer screen so participants could increase or decrease intensity as necessary. For the second training, participants were blindfolded and increased or decreased contraction intensity according to oral feedback given by 1 investigator (D.P.S.H.). Each type of training was repeated 3 times.

We calculated the intraobserver reliability for this procedure by means of the intraclass correlation coefficient (ICC; 3,1) for the investigator (D.P.S.H.) who performed all data collection. The ICC = 0.79 (95% confidence interval = 0.54, 0.91), which was considered satisfactory for the purpose of the study.

Data collection started immediately after training. Participants were blindfolded, and they performed 10 attempts to replicate each target force and hold each contraction for 5 seconds, with 15 seconds of rest between the attempts. After the fifth attempt, participants performed 1 extra training trial with oral feedback. The time interval between the target forces was around 15 minutes and will be explained further in the "Ice Application" subsection. All data were color coded to guarantee that the investigator (C.R.) who processed the data was blinded to the ice and no-ice conditions.

Measurement Instruments

The force produced by the dorsiflexor muscles was measured with a load cell (sensitivity = 2 N, error <1%) placed under an inclined board at a 45° angle (Figure 2). The load cell was connected to the ADS2000-IP system (Lynx Electronic Technology Ltd, São Paulo, Brazil) for data acquisition and signal conditioning. Data were collected and exported using AqDados software (version 7.02; Lynx Electronic Technology Ltd) and were analyzed through a processing routine created using the Scilab 4.1.2 software (Institut Nationale de Recherche en Informatique et en Automatique, Paris, France). We set the sampling rate at 50 Hz and used a 5-Hz low-pass Butterworth filter determined from 99% of the spectral density of the signal strength. In addition, we used the MT-350 infrared thermometer (Minipa do Brasil LTD, São Paulo, Brazil) to measure the temperature of the plantar and dorsal surfaces of the foot.

Ice Application

Ice was applied twice on 1 collection day. The participant was instructed to plunge his or her foot into a rectangular container with water and ice, keeping the plantar surface in contact with the ice to ensure cooling of the appropriate regions. For the comfort of the participant, the toes were not immersed in the icing water. A bag with water and ice was applied over the dorsal region.

First Application. The first application was accomplished after the MVIC performance and the measurement of skin temperature. Ice was applied for 20 minutes before data collection for the first target force.

Second Application. The second application was accomplished over the same region of the foot before data collection for the second target force and maintained for 10 minutes.

The times chosen for both applications were based on the study by Janwantanakul,[27] who found that maximal cooling of the tissue was reached between 5 and 9 minutes, and on a pilot test conducted by our research group in which 5 participants received ice application for 20 minutes and had skin sensitivity measured with monofilaments after 5, 10, and 20 minutes. Skin sensitivity was affected most after 20 minutes of ice application.

We measured skin temperature 5 times: (1) before the ice application (after MVIC performance), (2) immediately after the first ice application, (3) immediately after data collection for the first target force, (4) immediately after the second ice application, and (5) immediately after data collection for the second target force. The skin temperature of the plantar (calcaneus and metatarsus) and dorsal (metatarsus) regions of the foot was measured using a standard distance of 5 cm between the infrared thermometer and the foot.

Outcome Variables

Absolute Error. The *absolute error* (Ae) is the difference between the target force and the force generated by the participant (extracted from the force × time curve; Figure 3A and B). A negative value represents an underestimation of the values during replication, and a positive value represents an overestimation of the force produced by the participant.

Root Mean Square Error. The *root mean square (RMS) error* is the difference between the target force and the RMS of the force generated by the participant (extracted from the RMS force × time curve). Thus, the absolute values were used to extract the final mean error (Figure 3A and C). This procedure was carried out to eliminate the signal (negative and positive) factor to extract the final mean of the error.

Variable Error. The *variable error* is the value corresponding to the mean of the standard deviations (SDs) for Ae. It is a measure of the variability of errors during the attempts to replicate force (Figure 3: compare parts D and E and parts F and G).

Statistical Analysis

To calculate the sample size, we assumed values around 10 N for SD and a minimal difference of 8 N between conditions after a pilot test conducted by our research group with 5 participants. Therefore, to reach a power of 0.80 with an α level of .05, 18 participants would be necessary.[28] The sample size was increased by 10% to account for participants possibly not completing the study.

The statistician (A.H.) who analyzed the data was blinded to the ice and no-ice conditions. The means and SDs were calculated for each variable from the 10 attempts in each target-force condition. We conducted a multivariate analysis of variance for repeated measures with 2 factors: ice application (ice, no ice) and target force (20% or 50% of MVIC). Effect sizes were calculated using the Cohen d index. The α level was set at <.05. We used SPSS for Windows software (version 17.0; SPSS Inc, Chicago, IL) for all analyses.

RESULTS

All participants completed both data-collection sessions (Figure 1). No adverse effects of ice application were

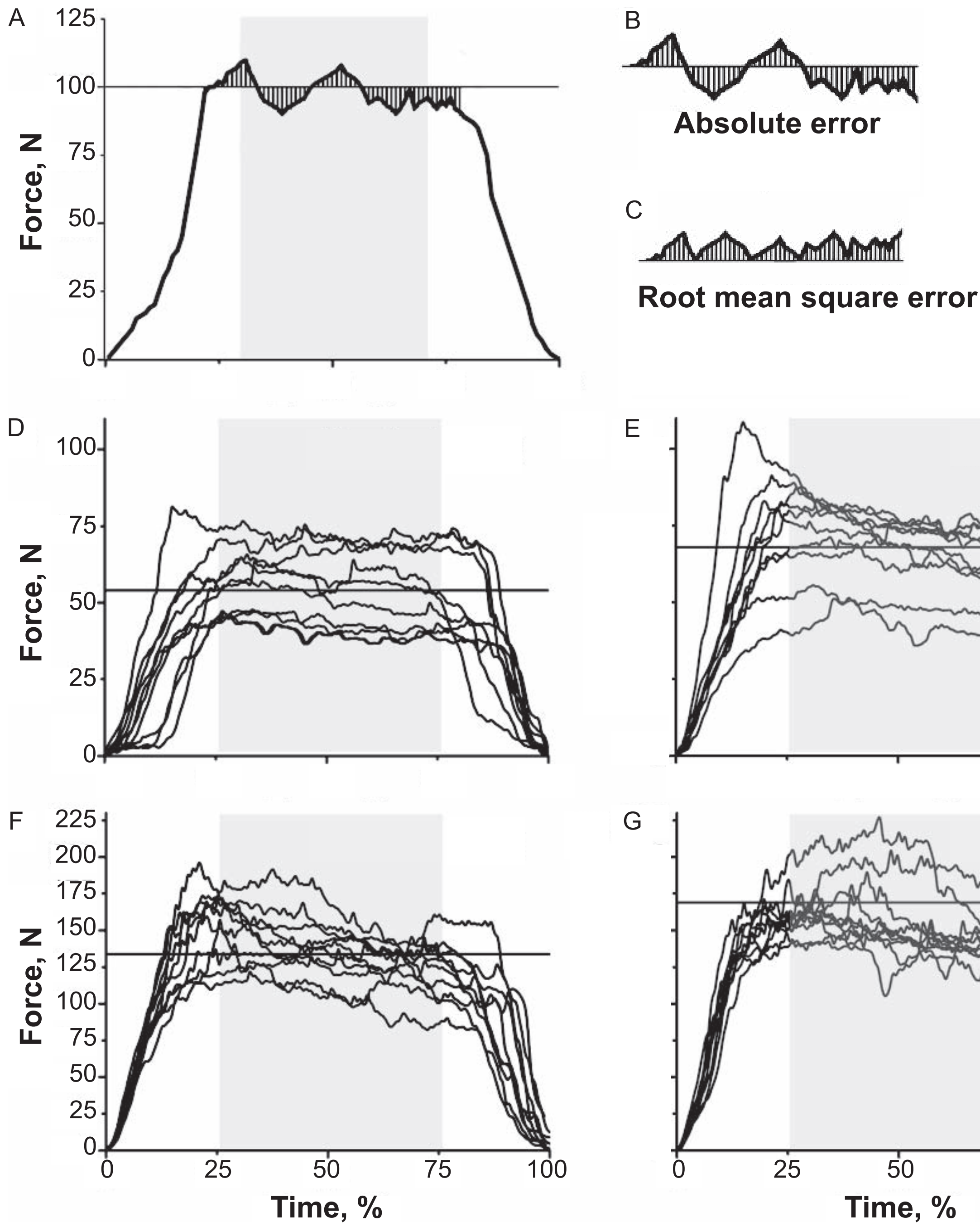

Figure 3. Example of data collection from a single participant. The straight lines represent the target force, and the shaded boxes represent the time interval used for data analysis. A, Simplified raw data after a single force-replication attempt. B, The distance between the target force (straight line) and the curve produced during the attempt for all possible points is averaged and represents the absolute error (2.5 N). C, The same process as B is repeated after the root mean square of the attempt is calculated (root mean square error = 5.4 N). D, Ten attempts for the target force 20% of maximal voluntary isometric contraction (MVIC) after the control intervention (no-ice condition). E, Ten attempts for the target force 20% of MVIC after the ice intervention (ice condition). F, Ten attempts for the target force 50% of MVIC after the control intervention. G, Ten attempts for the target force 50% of MVIC after the ice intervention.

reported. Three participants reported moderate pain during ice application using an oral 5-point scale (*no pain*, *light pain*, *moderate pain*, *intense pain*, and *worst possible pain*).

No differences were found for MVIC between the 2 data-collection sessions. Whether they received ice or no ice, participants produced the same effort. Data on the average temperature of the 3 ice-application regions throughout assessment for the ice condition are shown in Table 2. After the first ice application, we found an average reduction of 15°C in skin temperature. The reduction was maintained after the second ice application, and no significant temperature variation was observed between the first and second target force replications.

The results obtained for the outcome variables in each data-collection condition are presented in Table 3. No significant interaction was present between factors (ice and no-ice conditions and target forces). The errors represent

Table 2. Temperature (°C) Measured Immediately After Each Data Collection Within Ice Application[a] (Mean ± SD)

Region	Before Application	After First Application (20 min)	After Replication of First Target Force	After Second Application (10 min)	After Replication of Second Target Force
Calcaneus	26 ± 3	15 ± 4	22 ± 2	14 ± 6	21 ± 2
Dorsal metatarsus	28 ± 3	12 ± 5	23 ± 4	12 ± 5	22 ± 4
Plantar metatarsus	31 ± 2	13 ± 5	23 ± 4	13 ± 5	23 ± 5

[a] The temperature measurements were carried out immediately after ice application and immediately after each force replication.

how closely the participants matched the target force. We found no difference for the RMS error between the ice and no-ice conditions ($F_{1,19} = 2.99$, $P = .10$) or between target forces ($F_{1,19} = 1.02$, $P = .32$). The Ae was higher for the ice than the no-ice condition ($F_{1,19} = 9.05$, $P = .007$) and was higher for the target force at 50% of MVIC than for the target force at 20% of MVIC ($F_{1,19} = 26.01$, $P < .001$).

The variability is a measure of signal variation and represents how inconstant and variable the force generated by the participant was. For the variable error, we found no difference between conditions ($F_{1,19} = 1.53$, $P = .23$) and no interaction between condition and target force ($F_{1,19} = 1.30$, $P = .26$). The response variance in the force was higher for 50% of MVIC than for 20% of MVIC ($F_{1,19} = 61.25$, $P < .001$).

DISCUSSION

Proprioception of the ankle in terms of force replication for the ankle-dorsiflexor muscles was reduced when assessed immediately after ice application. Our results showed higher error levels for the highest target force tested (50% of MVIC), which is similar to the findings of Docherty et al[12–14] and Vuillerme and Boisgontier.[17] Skin cooling did not change the response to the MVIC; however, it affected the magnitude of the error measured and the variability of force that the participants developed (Table 3). Interestingly, precision after skin cooling seemed to decrease when the task to be performed involved those senses or sensations generated from cutaneous receptors.

Ice application before a force-replication task decreased task precision by increasing error when participants tried to replicate a given force using the ankle dorsiflexors. The increase in error due to the ice application may be related to factors such as changes in the perception of the pressure and tactile sensations,[22] reduction of nerve conduction velocity,[23,24,29] and metabolic changes.[25] However, Rubley et al[22] investigated force replication during pinching forces at 10%, 25%, and 40% of MVIC after 15 minutes of ice application and reported that ice application had no effect on force replication, in opposition to our results. Nevertheless, some methodologic differences existed between the studies, such as the muscle groups investigated (eg, different numbers of muscle receptors); choice of target forces, which is likely to change the number of receptors involved; durations of the isometric contractions during force replication (which differ in how the receptors send afferent information); and techniques used for ice application, which could differ in the amount of tissue cooling.

Temperatures of the skin and subcutaneous tissue decrease rapidly after ice application, whereas the temperatures of deep tissues decrease more slowly.[25,29] These studies have led us to believe that the cutaneous sensory receptors are the primary receptors affected by ice application and likely are the reason for changes in tactile perception that, as we noted, modified the force-replication capacity even before the deeper structures and tissues were affected. Therefore, our result possibly is largely due to the change in cutaneous receptors because the measurements were carried out immediately after ice application.

Therefore, although our ice application was not used for therapeutic purposes, these results could have implications for clinical practice. Given that the isometric force-replication ability was altered after ice application, clinicians need to be cautious when applying it before tasks that require integrity of the proprioceptive system. Proprioceptive training usually involves activities such as balance training, unipodal support, functional exercises that simulate activities of daily living, and sport-specific movements. In contrast, given that ice application decreased force-replication ability, it might be useful in a controlled condition during rehabilitation when the aim is to increase the level of difficulty and further challenge the varied proprioceptive pathways. However, the effectiveness of these suggestions needs appropriate investigation.

Regarding the variability in force replication, researchers[22,30] also have found greater variability at higher target forces. Salonikidis et al[31] investigated force replication by the wrist flexors and also found results different from ours, as they reported less variability at the higher target forces. The reason for this difference seems to be the longer familiarization period with the equipment (three 40-minute sessions in 1 week) and the use of visual feedback for force replication throughout the test. In addition, one may argue that for activities of daily living, wrist flexion is more often required to perform higher percentages of MVIC than ankle dorsiflexion, which would help explain the greater motor control at the wrist. Therefore, investigators have indicated that differences in force replication may depend on the muscle groups being tested, types of movement typically performed by the joint tested (wide or precise), degree of task difficulty, intensity of muscle contraction, and use of feedback during the task.

We acknowledge that we were not able to control the pain participants may have felt during ice application, and this could have influenced our results, because pain can affect proprioception.[32,33] However, only 3 participants reported pain at levels that could represent a concern, and they felt it only during the first 5 minutes of ice application and toward the end of the second application. In addition, according to Lowrey et al,[19] skin temperature is not the best indicator of changes in the cutaneous receptors. However, they applied ice for shorter times than we did and concluded that 20 minutes (as seen in our protocol) would be necessary to promote changes to the cutaneous receptors.[19]

Table 3. Variable, Root Mean Square, and Absolute Error Under Both Conditions

Outcome	Condition, % of MVIC (Mean ± SD)				Difference (Effect Size; 95% Confidence Interval)			
	No Ice		Ice		Within Target Force 20%–50% of MVIC		Within Condition: Ice (% of MVIC)	
	20	50	20	50	Ice	No ice	20	50
Variable error[a]	1.5 ± 0.9	3.6 ± 2.1	1.6 ± 1.8	4.3 ± 2.3	2.65 (−1.30; 1.91, 3.39)	2.13 (−1.29; 1.37, 2.88)	0.18 (−0.07; −0.43, 0.78)	0.70 (−0.30; −0.30, 1.70)
Root mean square error	5.0 ± 6.8	2.4 ± 17.8	5.3 ± 10.8	13.9 ± 20.7	8.67 (−0.52; −0.81, 18.15)	2.56 (−0.19; −4.96, 10.07)	0.30 (−0.03; −5.33, 5.93)	11.53 (−0.59; −0.05, 23.10)
Absolute error[a,b]	9.9 ± 4.7	19.0 ± 7.5	12.2 ± 6.2	24.1 ± 11.6	11.92 (−1.27; 5.99, 17.85)	9.08 (−1.44; 5.65, 12.51)	2.23 (−0.41; −0.59, 5.05)	5.07 (−0.52; 0.86, 9.28)

Abbreviation: MVIC, maximal voluntary isometric contraction.

[a] Indicates a difference between target forces ($P < .05$).

[b] Indicates a difference between conditions (ice, no ice) ($P < .05$).

CONCLUSIONS

The decrease in skin temperature after ice application by immersion in iced water decreased precision in isometric force replication. The Ae in isometric force replication was greater at target forces equivalent to higher MVIC percentages. Ice application requires caution if applied when full proprioceptive capacity is expected. In further studies aimed at understanding the effects of ice application on proprioception, researchers should consider investigating the effects of ice application on force replication at different times after ice application and perhaps involve other joints and other force-measurement modalities.

REFERENCES

1. Payne KA, Berg K, Latin RW. Ankle injuries and ankle strength, flexibility, and proprioception in college basketball players. *J Athl Train*. 1997;32(3):221–225.
2. de Jong A, Kilbreath SL, Refshauge KM, Adams R. Performance in different proprioceptive tests does not correlate in ankles with recurrent sprain. *Arch Phys Med Rehabil*. 2005;86(11):2101–2105.
3. Lafargue G, Paillard J, Lamarre Y, Sirigu A. Production and perception of grip force without proprioception: is there a sense of effort in deafferented subjects? *Eur J Neurosci*. 2003;17(12):2741–2749.
4. Spanos S, Brunswic M, Billis E. The effect of taping on the proprioception of the ankle in a non-weight bearing position, amongst injured athletes. *Foot*. 2008;18(1):25–33.
5. Munn J, Sullivan SJ, Schneiders AG. Evidence of sensorimotor deficits in functional ankle instability: a systematic review with meta-analysis. *J Sci Med Sport*. 2010;13(1):2–12.
6. Hughes T, Rochester P. The effects of proprioceptive exercise and taping on proprioception in subjects with functional ankle instability: a review of the literature. *Phys Ther Sport*. 2008;9(3):136–147.
7. Holme E, Magnusson SP, Becher K, Bieler T, Aagaard P, Kjaer M. The effect of supervised rehabilitation on strength, postural sway, position sense and re-injury risk after acute ankle ligament sprain. *Scand J Med Sci Sports*. 1999;9(2):104–109.
8. Boyle J, Negus V. Joint position sense in the recurrently sprained ankle. *Aust J Physiother*. 1998;44(3):159–163.
9. Gross MT. Effects of recurrent lateral ankle sprains on active and passive judgements of joint position. *Phys Ther*. 1987;67(10):1505–1509.
10. Djupsjöbacka M, Domkin D. Correlation analysis of proprioceptive acuity in ipsilateral position-matching and velocity-discrimination. *Somatosens Mot Res*. 2005;22(1–2):85–93.
11. Fitzpatrick R, McCloskey DI. Proprioceptive, visual and vestibular thresholds for the perception of sway during standing in humans. *J Physiol*. 1994;478(pt 1):173–186.
12. Docherty CL, Arnold BL. Force sense deficits in functionally unstable ankles. *J Orthop Res*. 2008;26(11):1489–1493.
13. Docherty CL, Arnold BL, Hurwitz S. Contralateral force sense deficits are related to the presence of functional ankle instability. *J Orthop Res*. 2006;24(7):1412–1419.
14. Docherty CL, Arnold BL, Zinder SM, Granata K, Gansneder BM. Relationship between two proprioceptive measures and stiffness at the ankle. *J Electromyogr Kinesiol*. 2004;14(3):317–324.
15. Descarreaux M, Blouin JS, Teasdale N. Isometric force production parameters during normal and experimental low back pain conditions. *BMC Musculoskelet Disord*. 2005;6:6.
16. Simon AM, Ferris DP. Lower limb force production and bilateral force asymmetries are based on sense of effort. *Exp Brain Res*. 2008;187(1):129–138.
17. Vuillerme N, Boisgontier M. Muscle fatigue degrades force sense at the ankle joint. *Gait Posture*. 2008;28(3):521–524.

18. Choi JT, Lundbye-Jensen J, Leukel C, Nielsen JB. Cutaneous mechanisms of isometric ankle force control. *Exp Brain Res*. 2013;228(3):377–384.
19. Lowrey CR, Strzalkowski ND, Bent LR. Cooling reduces the cutaneous afferent firing response to vibratory stimuli in glabrous skin of the human foot sole. *J Neurophysiol*. 2013;109(3):839–850.
20. Collins DF, Refshauge KM, Todd G, Gandevia SC. Cutaneous receptors contribute to kinesthesia at the index finger, elbow, and knee. *J Neurophysiol*. 2005;94(3):1699–1706.
21. Costello JT, Donnelly AE. Cryotherapy and joint position sense in healthy participants: a systematic review. *J Athl Train*. 2010;45(3):306–316.
22. Rubley MD, Denegar CR, Buckley WE, Newell KM. Cryotherapy, sensation, and isometric-force variability. *J Athl Train*. 2003;38(2):113–119.
23. Carvalho G, Chierichetti H. Evaluation of the cutaneous sensibility palmar in the cryotherapy applications for ice packs and gel packs. *Rev Bras Ciênc Mov*. 2006;14(2):23–32.
24. McMeeken J, Lewis M, Cocks S. Effects of cooling with simulated ice on skin temperature and nerve conduction velocity. *Aust J Physiother*. 1984;30(4):111–114.
25. Hocutt JE Jr, Jaffe R, Rylander CR, Beebe JK. Cryotherapy in ankle sprains. *Am J Sports Med*. 1982;10(5):316–319.
26. Caldwell LS, Chaffin DB, Dukes-Dobos FN, et al. A proposed standard procedure for static muscle strength testing. *Am Ind Hyg Assoc J*. 1974;35(4):201–206.
27. Janwantanakul P. The effect of quantity of ice and size of contact area on ice pack/skin interface temperature. *Physiotherapy*. 2009;95(2):120–125.
28. Faul F, Erdfelder E, Buchner A, Lang AG. Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. *Behav Res Methods*. 2009;41(4):1149–1160.
29. Bugaj R. The cooling, analgesic, and rewarming effects of ice massage on localized skin. *Phys Ther*. 1975;55(1):11–19.
30. Schiffman JM, Luchies CW, Richards LG, Zebas CJ. The effects of age and feedback on isometric knee extensor force control abilities. *Clin Biomech (Bristol, Avon)*. 2002;17(6):486–493.
31. Salonikidis K, Amiridis IG, Oxyzoglou N, de Villareal ES, Zafeiridis A, Kellis E. Force variability during isometric wrist flexion in highly skilled and sedentary individuals. *Eur J Appl Physiol*. 2009;107(6):715–722.
32. Bank PJ, Peper CE, Marinus J, Beek PJ, van Hilten JJ. Motor consequences of experimentally induced limb pain: a systematic review. *Eur J Pain*. 2013;17(2):145–157.
33. Cote JN, Hoeger Bement MK. Update on the relation between pain and movement: consequences for clinical practice. *Clin J Pain*. 2010;26(9):754–762.

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