Cryotherapy is routinely used to treat acute and chronic athletic injuries,\(^1\) which is supported by research evidence of pain reduction.\(^2,3\) Effects on cutaneous receptors may provide the benefits derived from cryotherapy administration for both injury management and exercise recovery. Pain modulation associated with altered cutaneous sensation is not fully understood, but may relate to a decrease in the conduction velocity of afferent nerve signals.\(^4\) Algaflfy et al.\(^5\) reported that cryotherapy treatments reduced afferent activity, and that the latency of action potential onset was increased.\(^5\) The complexity of altered sensory information created by cold application is believed to relate to its analgesic effect.\(^5-8\)

A better understanding of the cutaneous effects of the different modes of cryotherapy administration may help to guide clinician selection of treatment parameters (e.g., the mode that produces numbness in the shortest amount of time, and with the longest effect duration, may be considered the most desirable). The purpose of this study was to document the amount of time required to produce skin anesthesia, and the amount of time required for baseline skin sensation to be reestablished, after application of three different modes of cryotherapy: ice bag, cold water immersion, and ice massage.

**Procedures and Findings**

The same sample of 30 healthy adults (12 males, 18 females, age = 21.1 ± 1.9 years) who provided data for the study described in Part 1 of this two-part report received one of three different modes of cryotherapy application on three separate occasions that were separated by at least 24 hours. No potential participants were excluded on the basis of history of neurological disorders, cardiovascular disease, peripheral nerve disease, cold allergy or sensitivity, or lower extremity injury in the six weeks prior to testing; none were lost to follow-up. The order of administration of different modes of cryotherapy: ice bag, cold water immersion, and ice massage.
modes of cryotherapy to the lower leg was randomized. At baseline and at one-minute intervals, skin sensation was assessed through the use of Semmes-Weinstein nylon monofilaments (Smith and Nephew Inc., Germantown, WI), which have been found to provide reliable measurements of diminished and normal skin sensations. A detailed description of the procedures and methods is available with the online version of this article.

Because the data were non-normally distributed, non-parametric Wilcoxon Signed Ranks Tests were used to evaluate differences between each mode of cryotherapy at an alpha level of $P \leq 0.05$. Numbness was produced significantly faster by both ice massage (median: 6.5 minutes, interquartile range: 5.0, 11.0) and cold water immersion (median: 8.5 minutes, interquartile range: 5.8, 12.3) than through the application of a crushed ice bag (median: 12.1 minutes, interquartile range: 8.4, 15.0; see Figure 1). There were no significant differences between modes of cryotherapy administration for duration of numbness after removal of the cold modality, each of which resulted in a return to the baseline level of skin sensation within 5 minutes.

**Discussion**

All three modes of cryotherapy administration produced participant perception of numbness within a relatively short period of time (less than 12 minutes). Although ice massage and cold water immersion required significantly less time to produce numbness, there were no differences in terms of duration of post-treatment numbness (i.e., approximately 5 minutes for each). Our findings suggest that an optimal cryotherapy effect on cutaneous sensory receptors can be achieved in a substantially shorter amount of time than the typical duration of cold application for reduction of intramuscular temperature.

Pain relief derived from cryotherapy is probably attributable to cooling of skin receptors and alteration of sensory nerve signals to the central nervous system. Possible mechanisms of pain relief include altered nerve conduction velocity, inhibition of nociceptors, a reduction in muscle spasm, and reduction in metabolic enzyme activity. Herrera et al. reported that ice massage and cold water immersion decreased conduction velocity of the sural nerve to a greater extent than a crushed ice bag that was applied to the posterior calf. Research evidence indicates that pain tolerance and pain threshold increases are associated with a decrease in nerve conduction velocity following cryotherapy.

Skin anesthesia has been documented to occur when its surface temperature is lowered to 13.6°C. The combination of direct contact of 0°C ice with the skin and a continuous massage motion may explain

![Figure 1](image-url)  
*Figure 1*  Treatment time until participants reported numbness and duration of numbness in three modes of cryotherapy. Dark gray bars = time to numbness; light gray bars = duration of numbness postintervention
the shorter ice massage treatment duration required to achieve numbness. Cold water immersion involves removal of body heat from a greater skin surface area than that which is affected by ice massage and ice pack application. Both conduction and convection cool the skin surface at a constant temperature of 12°C.8,14,15 A crushed ice bag that is applied with a compression wrap is considered more effective for edema reduction than ice application without compression,16 but our results did not demonstrate an advantage in terms of the amount of time required to produce numbness in comparison to other modes of cryotherapy.

The rate at which tissue returns to a normal temperature varies among modes of cryotherapy administration and the duration of cold application.17 Ideally, a cryotherapy treatment for relief of pain should produce numbness in a short amount of time, with a long-lasting post-treatment effect. Because our participants were healthy, we did not evaluate the effect of cryotherapy on pain. However, our results may have relevance to treatment selection when pain relief is a therapeutic goal. We observed a return to a baseline level of sensation within 5–10 minutes after removal of each of the cold modalities. Thus, our findings suggest that a relatively brief window of opportunity may exist for performance of pain-free exercise after administration of any one the three modes of cryotherapy we studied. Yet another consideration for attainment of optimal cryotherapy benefit may be a body composition that requires longer treatment duration than others to achieve a comparable effect.18-20

Conclusions

All three modes of cryotherapy administration produced a sensation of numbness in healthy individuals within a relatively short amount of time. Both ice massage and cold water immersion produced numbness faster than the ice bag applied with a compression wrap. Each of the cryotherapy treatments had similar effects in terms of the duration of the numbness sensation.

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