

# Temperature Changes in the Human Leg During and After Two Methods of Cryotherapy

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**Objective:** To compare the cooling and rewarming effects of two clinical 20-minute cryotherapy treatments on the temperature of the human leg.

**Design and Setting:** Sixteen subjects were randomly treated with either 20 minutes of a 1.8-kg crushed-ice pack, placed directly over the left calf, or a 20-minute immersion in a cold (10°C) whirlpool. Data were collected at a university human performance research laboratory.

**Subjects:** Seventeen male and 15 female healthy college students.

**Measurements:** Subcutaneous and muscle tissue temperatures were measured by 26-gauge hypodermic needle microprobes inserted in the calf, just below the skin, or 1 cm below the subcutaneous fat, respectively.

**Results:** There was no significant difference in the decrease in intramuscular temperatures between treatments ( $t(30) =$

$-1.76, P = .09$ ). The ice pack treatment significantly decreased the subcutaneous temperature more than the whirlpool ( $t(30) = -2.64, P = .01$ ). The subcutaneous temperature rewarmed significantly more in the ice pack group ( $12.3 \pm 3.3^\circ\text{C}$ ) than the cold whirlpool ( $7.4 \pm 2.1^\circ\text{C}$ ) ( $t(30) = 4.98, P = .0000$ ). The ice pack group's intramuscular temperature increased over each 5-minute interval of the 30-minute post-treatment period for an overall increase of  $2.0 \pm 3.1^\circ\text{C}$ . During the 30-minute post-treatment the cold whirlpool group continued to cool, for an overall decrease of  $1.8 \pm 1.4^\circ\text{C}$ . This difference between groups at the end of the 30-minute post-treatment was significant ( $t(30) = 4.44, P = .0001$ ).

**Conclusions:** As administered in our protocol, cold whirlpool is superior to crushed-ice packs in maintaining prolonged significant temperature reduction after treatment.

**Key Words:** ice packs, whirlpool, rehabilitation

Cryotherapy has become a vital component in the immediate management and rehabilitation of musculoskeletal trauma due to sport injuries.<sup>1-10</sup> Several factors affect the degree of superficial and deep tissue temperature change accomplished during cryotherapy: eg, tissue type, depth of the target tissue, temperature gradient between the target tissue and the cooling agent, size of the area being treated, and length of the application.<sup>3,6,8-13</sup>

The methods available for applying cold are numerous, but perhaps two of the most commonly used clinical techniques are crushed-ice packs and cold whirlpool.<sup>2,3,5</sup> Both methods are inexpensive and widely available. Research is not in agreement with regard to the effects on intramuscular temperature produced by ice packs and cold water baths. Studies have reported increases,<sup>14,15</sup> decreases,<sup>13,14,16,17</sup> and little or no change<sup>10,12,14,18,19</sup> in intramuscular temperatures in the initial minutes after the application of cryotherapy. Reports on rewarming have varied as well. Some researchers have observed immediate rewarming<sup>18</sup> while others have seen continued declines at the conclusion of the cryotherapy treatment.<sup>10,19</sup> Little research has been done examining the effects of ice packs or cold water baths on subcutaneous tissue.<sup>6,12,15,18</sup> Much cryotherapy research has used surface

temperature as a dependent variable for evaluating the effectiveness of cryotherapy. Recent research has questioned the validity of this protocol.<sup>10</sup> It is important that the clinician be aware of the efficiency with which these modalities cool the target tissue (ie, muscle) and the length of time their effects are maintained in order to authoritatively prescribe treatment frequency and duration. Thus, the purpose of our study was to compare the cooling and rewarming effects of 20-minute treatments of crushed-ice pack and cold whirlpool cryotherapy, as commonly applied in the clinic, on the subcutaneous and intramuscular temperatures of the human lower leg.

## METHODS

Thirty-two college students (17 men, age =  $25.2 \pm 2.6$  yr, wt =  $84.7 \pm 12.7$  kg; 15 women, age =  $21.7 \pm 2.3$  yr, wt =  $65.2 \pm 10.5$  kg) volunteered and signed a Brigham Young University Human Subject's Institutional Review Board approved consent form to become subjects. We verbally screened subjects for a history of peripheral vascular disease or allergy to cephalixin hydrochloride (Keftab, Dista Products and Eli Lilly Co, Indianapolis, IN). Subjects were administered one 500-mg dose of Keftab immediately before the experiment to

minimize the risk of infection. Each subject was instructed to take three similar doses at 6-hour intervals following the conclusion of the experiment.

Our procedures were similar to those previously reported.<sup>11</sup> We measured each subject's height, weight, and maximum calf girth of the left lower leg. The skinfold was measured with a Lange Skinfold Caliper (Cambridge Scientific Industries, Ltd, Cambridge, MD) and we divided this measurement by two to determine the depth of subcutaneous fat over each subject's gastrocnemius. Subjects assumed a prone position on a standard examining table. A 4-cm × 4-cm area of skin was shaved over the muscle belly of the left medial calf. We cleansed this area thoroughly, first with a 10% povidone-iodine (Betadine, The Purdue Frederick Co, Norwalk, CT) scrub and then with a 70% isopropyl alcohol swab.

We measured subcutaneous and muscle tissue temperatures with 26-gauge hypodermic needle microprobes (Physitemp MT-26/2 and MT-26/4, Physitemp Instruments, Inc, Clifton, NJ). The microprobes were sterilized in a gas autoclave, using ethylene oxide, following hospital sterilization procedures. We inserted the intramuscular microprobe (MT-26/4) from the medial side into the midbelly of the left calf. The sensor tip of this probe was positioned in the center of the lower leg to a depth of 1 cm below the subcutaneous fat and skin. We measured the appropriate distance down vertically from the posterior surface of the lower leg with a caliper to ensure the probe was inserted at the proper depth.<sup>11</sup> A second probe (MT-26/2) was inserted just below the skin, perpendicular to the first, so that its sensor tip was approximately 0.5 cm distal to the sensor tip of the first probe (Fig 1). The microprobes were then connected to the digital monitor (Bailey Instruments BAT-12, Physitemp Instruments, Inc, Clifton, NJ) and after 3 minutes the baseline intramuscular and subcutaneous temperatures were recorded. Subjects were randomly assigned to either the crushed-ice pack or cold whirlpool treatment group. The ice pack group had 9 men and 7 women, while the whirlpool group had 8 men and 8 women. The ice pack group had a 1.8-kg ice pack (approximately 25 cm × 30 cm × 5 cm) placed directly over the triceps surae muscle group for 20

minutes (Fig 2). The cold whirlpool group immersed their left lower legs in the 244-L extremity whirlpool (Whitehall Manufacturing Inc, City of Industry, CA) to a depth of approximately 5 cm below the joint line (Fig 3). The leg was kept 15 to 20 cm away from the airflow, which remained on low throughout the treatment. The temperature of the water in the cold whirlpool was maintained at 10°C. We recorded intramuscular and subcutaneous temperature every 30 seconds over the entire treatment time and for 30 minutes post-treatment. At the conclusion of the recovery period of each treatment we removed the microprobes, dried the limb, and swabbed the area with 70% isopropyl alcohol. The dry and wet bulb temperatures and relative humidity of the room were  $23.8 \pm 0.5^\circ\text{C}$ ,  $13.5 \pm 0.9^\circ\text{C}$ , and  $31.6 \pm 5.8\%$ , respectively, over the duration of the study.

## Design and Analysis

Our independent variables were treatments and time. Our dependent variable was temperature. For the two treatment groups we calculated the temperature changes, in the two tissues, from the baseline (beginning of the treatment) to the end of each 20-minute treatment. We also calculated temperature change, in both tissues, over each 5-minute interval of treatment for both treatment groups. For each tissue, we analyzed the temperature change between treatments with *t* tests. The same calculations and analyses were performed for the 30-minute post-treatment period.

## RESULTS

In Figure 4 we show mean intramuscular temperature at each time point throughout the treatment and post-treatment along with error bars of  $\pm 2$  standard errors of the mean for both ice pack and cold whirlpool conditions. Table 1 gives the intramuscular temperature change over the same time periods for both conditions. Figure 5 shows the same information as Figure 4 for subcutaneous tissue. Table 2 gives the same information as Table 1 for subcutaneous tissue. Figures 4 and

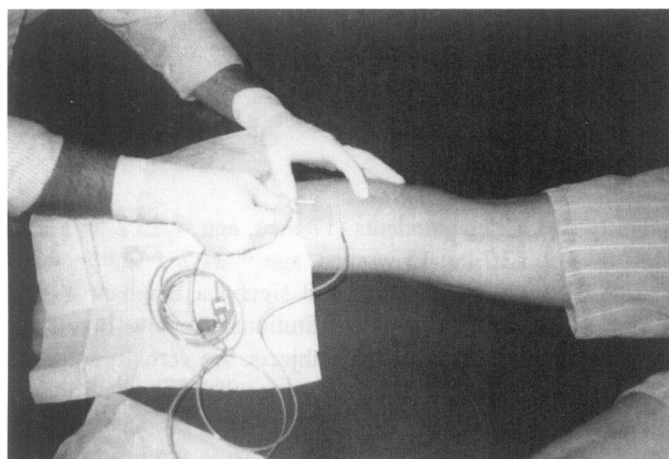


Fig 1. Insertion of the subcutaneous needle microprobe.



Fig 2. Ice pack placement over the triceps surae muscle group.

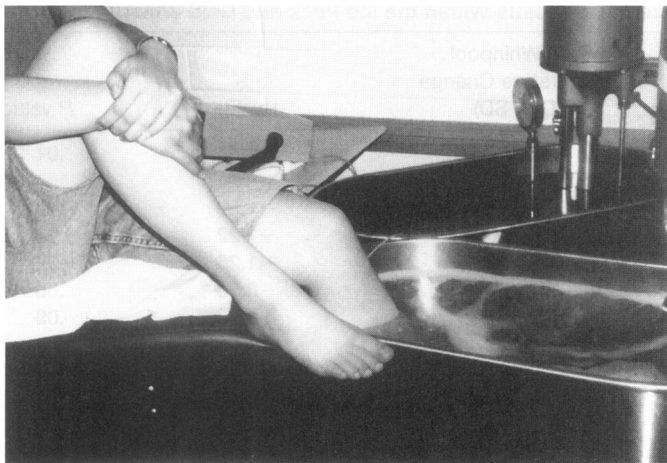


Fig 3. Immersion of the left lower leg in the cold whirlpool.

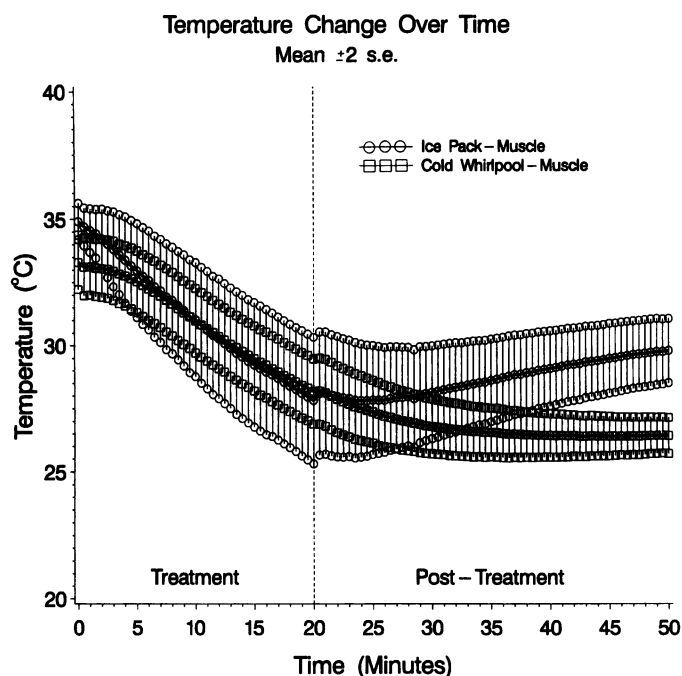


Fig 4. Intramuscular temperature during and after a 20-minute ice pack or cold whirlpool treatment. Figure shows mean values  $\pm$  2 standard errors for each treatment.

5 give an overall view of the temperature change along with appropriate measures of variability in each treatment condition.

There were no significant differences in the decrease in intramuscular temperatures between treatments at each 5-minute interval and at the end of the 20-minute treatment (Table 1). By the conclusion of the 20-minute treatment, the ice pack and cold whirlpool decreased intramuscular temperature  $7.1 \pm 4.1^\circ\text{C}$  and  $5.1 \pm 1.8^\circ\text{C}$ , respectively (Fig 4). The ice pack treatment significantly decreased the subcutaneous temperature more than the whirlpool,  $17.0 \pm 3.8^\circ\text{C}$  and  $13.8 \pm 3.0^\circ\text{C}$ , respectively (Table 2). The subcutaneous temperature rewarmed significantly more in the ice pack group ( $12.3 \pm 3.3^\circ\text{C}$ ) than the cold whirlpool ( $7.4 \pm 2.1^\circ\text{C}$ ) (Table 2). The ice pack group's intramuscular temperature increased over each

5-minute interval of the 30-minute post-treatment period, for an increase of  $2.0 \pm 3.1^\circ\text{C}$  (Table 1). The cold whirlpool group, however, continued to cool during the post-treatment period, for an additional decrease of  $1.8 \pm 1.4^\circ\text{C}$  (Table 1).

## DISCUSSION

Research is not in agreement with regard to the effects on intramuscular temperature produced by ice packs and cold water baths. An early experiment by Bing et al<sup>14</sup> exemplifies the variability found in the ice pack research. Twenty-three subjects had ice placed on their biceps brachii for 5 minutes. The temperature was recorded at a depth of 3 cm. In 10 of the 23 subjects, a rise in temperature of  $0.5^\circ\text{C}$  was observed at the beginning of the treatment. The increased temperature lasted for 3 to 4 minutes before it began to decline. They observed a continuous range from no decrease in muscle temperature to a decrease of  $5.7^\circ\text{C}$  in the 23 subjects. The mean decline was  $2.3^\circ\text{C}$ .<sup>14</sup>

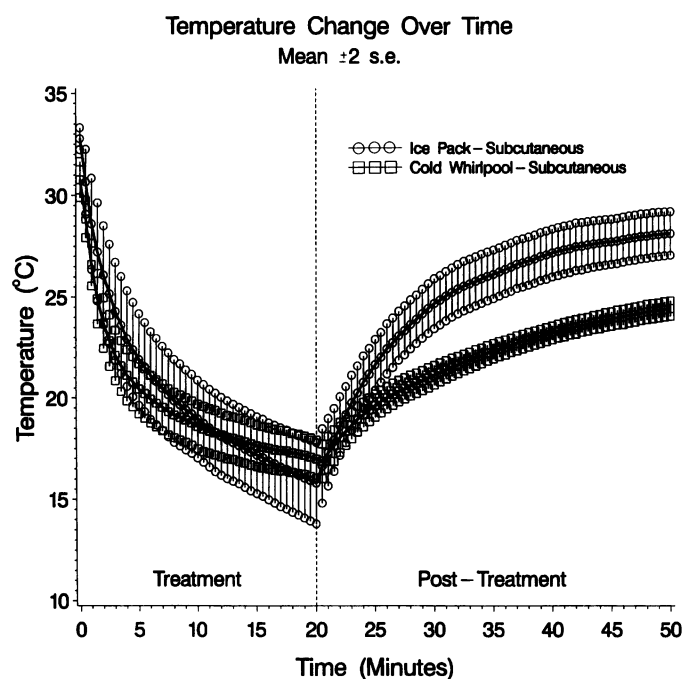
Other researchers<sup>12,18</sup> looked at the effects of ice packs on intramuscular temperature change in the triceps surae. They reported little or no change until 7 to 10 minutes after application. One researcher<sup>12</sup> reported a  $3.3^\circ\text{C}$  decrease at a depth of 5.0 cm after a 30-minute ice pack application. Researchers also have investigated the effects on intramuscular temperature at 1 cm below the subcutaneous fat in the anterior thigh during and after a 30-minute application of a crushed-ice pack.<sup>10</sup> They reported a linear decline in temperature after about 4 minutes.<sup>10</sup> We, on the other hand, observed an immediate linear decline in intramuscular temperature that was maintained throughout our 20-minute treatment (Fig 4). At a depth of 1 cm below the subcutaneous fat and skin, the intramuscular temperature in the triceps surae at the end of our 20-minute treatment had decreased  $7.1^\circ\text{C}$ .

It has been reported that deep intramuscular temperature (2.3 cm) continues to decline following the removal of an ice pack.<sup>18</sup> Merrick et al<sup>10</sup> reported that intramuscular temperature at a depth of 1 cm below the subcutaneous fat continued to decline for approximately 5 minutes after the removal of a crushed-ice pack. Our results indicated that the decline is very minimal and that by 5 minutes post-treatment the muscle has begun to rewarm (Fig 4).

The cold water bath research is just as varied. One researcher,<sup>15</sup> using a  $1^\circ\text{C}$  water bath, reported an initial minimal increase, which was followed by a substantially greater and longer decrease in intramuscular temperature of the brachioradialis at a depth of 1.5 cm. Another investigator,<sup>19</sup> using a  $12.5^\circ$  to  $13^\circ\text{C}$  water bath, noted no change in temperature in the triceps surae until 2 minutes, whereupon the decline was nearly linear. The depth was not given, but the target was the "center of the muscle" and a  $6^\circ\text{C}$  decrease was observed by the end of the 30-minute treatment. Several researchers<sup>13,16,17</sup> have reported an immediate and steady decline in intramuscular temperatures using cold water baths. Two studies,<sup>13,16</sup> using a depth of 2.5 cm in the brachioradialis as the target tissue,

**Table 1. Intramuscular Temperature Change (°C ± SD) Between Analyzed Time Points Within the Ice Pack and Cold Whirlpool Groups**

Time Points (5-Min Intervals)	Ice Pack Temperature Change (°C ± SD)	Cold Whirlpool Temperature Change (°C ± SD)	t-value	P value
Baseline temperature	34.9 ± 1.4	33.3 ± 2.1	2.54	.01
20 min treatment				
5 min-baseline	-1.9 ± 2.9	-0.8 ± 0.6	-1.60	.12
10 min-5 min	-1.9 ± 1.1	-1.5 ± 0.7	-1.22	.23
15 min-10 min	-1.8 ± 0.8	-1.5 ± 0.5	-1.25	.22
20 min-15 min	-1.4 ± 0.7	-1.3 ± 0.4	-0.53	.60
20 min-baseline	-7.1 ± 4.1	-5.1 ± 1.8	-1.76	.09
30 min post-treatment				
25 min-20 min	.0 ± 1.2	-.8 ± 0.4	2.60	.01
30 min-25 min	.3 ± 0.9	-.6 ± 0.4	3.66	.001
35 min-30 min	.5 ± 0.6	-.2 ± 0.3	4.51	.0001
40 min-35 min	.5 ± 0.4	-.1 ± 0.2	4.89	.0001
45 min-40 min	.4 ± 0.3	-.0 ± 0.2	4.30	.0002
50 min-45 min	.3 ± 0.3	-.0 ± 0.2	3.15	.0036
50 min-20 min	2.0 ± 3.1	-1.8 ± 1.4	4.44	.0001



**Fig 5. Subcutaneous temperature during and after a 20-minute ice pack or cold whirlpool treatment. Figure shows mean values ± 2 standard errors for each treatment.**

reported decreases of 12° to 13°C after 30-minute submersions in 12°C water baths. A third study,<sup>17</sup> using the same depth but in the triceps surae and a 10°C water bath, reported a 12°C decline after 30 minutes and an approximate 9.5°C decrease after 20 minutes of treatment. Our results indicated a 2- to 3-minute delay before a steady linear decline occurred throughout the remainder of the 20-minute treatment (Fig 4). The decrease by the end of our treatment was 5.1°C.

Both immediate re-warming<sup>18</sup> and continued decline<sup>19</sup> of intramuscular temperatures in the triceps surae have been reported following cold water baths. Petajan and Watts<sup>19</sup>

reported a further drop of 2°C during the first 10 minutes after treatment before re-warming began. We also had a continued decrease in temperature, although at a slower rate, for 25 minutes post-treatment (Fig 4).

We found little research<sup>6,12,15,18</sup> examining the effects of ice packs or cold-water baths on subcutaneous tissue temperature. The research did, however, (with one exception)<sup>6</sup> agree that the pattern of change for subcutaneous tissue was closer to the pattern exhibited by the skin than by muscle. Barcroft and Edholm<sup>16</sup> said the decline for all three tissues was linear. Others<sup>15,18</sup> have reported a very rapid decline in temperature for approximately the first 5 minutes, with a leveling off after about 10 minutes of treatment. We observed a similar initial decline, but our temperatures continued to decrease, though at a lesser rate, throughout the entire treatment (Fig. 5).

It is generally agreed that, to optimize the beneficial effects of ice during the immediate management of acute musculo-skeletal injury, ice should be applied as quickly as possible following a thorough evaluation.<sup>1-3,5</sup> Knight<sup>3</sup> contends that the primary reason for applying ice during immediate management is to minimize secondary hypoxic injury. The sooner the target tissue is cooled following injury, the less secondary hypoxic injury will occur.<sup>3,7</sup>

Our results indicate that significant intramuscular temperature decreases can be accomplished with either crushed-ice packs or cold whirlpool. Though statistically nonsignificant, the crushed-ice pack produced a temperature decrease of 2°C greater than the cold whirlpool. Second, the re-warming rate of the ice pack group was significantly faster than the whirlpool group. This is important when returning an athlete to play after receiving cryotherapy is desired, because any possible deficit in neural or muscular function that may occur due to the cold will be eliminated upon re-warming.<sup>3,8</sup> It may be, however, that the sustained temperature reductions brought about by the cold whirlpool, after the treatment is concluded, are more effective

**Table 2. Subcutaneous Temperature Change (°C ± SD) Between Analyzed Time Points Within the Ice Pack and Cold Whirlpool Groups**

Time Points (5-Min Intervals)	Ice Pack Temperature Change (°C ± SD)	Cold Whirlpool Temperature Change (°C ± SD)	t-value	P value
Baseline temperature	30.8 ± 1.8	32.8 ± 1.1	-3.8	.0006
20 min treatment				
5 min-baseline	-10.9 ± 4.5	-10.3 ± 3.4	-.39	.70
10 min-5 min	-2.9 ± 1.3	-1.9 ± .5	-3.11	.004
15 min-10 min	-1.8 ± 0.7	-1.0 ± .3	-4.28	.0002
20 min-15 min	-1.4 ± 0.7	-.3 ± .3	-4.41	.0001
20 min-baseline	-17.0 ± 3.8	-13.8 ± 3.0	-2.64	.01
30 min post-treatment				
25 min-20 min	5.8 ± 2.5	2.6 ± .4	4.38	.0001
30 min-25 min	3.0 ± 1.3	1.5 ± .4	4.60	.0001
35 min-30 min	1.4 ± .4	1.2 ± .3	2.29	.02
40 min-35 min	1.1 ± .3	.9 ± .2	1.36	.18
45 min-40 min	.5 ± .4	.7 ± .2	-1.30	.20
50 min-45 min	.4 ± .3	.5 ± .1	-1.27	.22
50 min-20 min	12.3 ± 3.3	7.4 ± 2.1	4.98	.0000

than ice packs in preventing secondary hypoxic injury that may resume with rewarming.

During rehabilitation, cryotherapy is primarily used to decrease pain and muscle spasm, thereby allowing therapeutic exercise to begin earlier than would otherwise be possible.<sup>1-4,20,21</sup> The most efficient use of cold during rehabilitation is with cryokinetics. The cold is used to partially desensitize the injured area, so that graded, progressive, active exercise can be performed by the injured athlete.<sup>1-4,9,20,21</sup> The longer the injured part remains cold, the longer pain and spasm will be reduced and active exercise can be performed. It is interesting to note that the intramuscular temperature in the cold whirlpool group continued to get progressively colder for 25 minutes after treatment, while the ice pack group was rewarming by the first 5 minutes post-treatment.

## CONCLUSIONS

We believe our results have significant clinical application. If rapid and significant temperature decrease is your goal, as in the immediate management of athletic injuries, our results suggest crushed-ice packs are superior to cold whirlpool. But if your goal is significant prolonged temperature reduction to facilitate active exercise during rehabilitation using cryokinetics, our results indicate cold whirlpool is superior to crushed-ice packs.

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