Comparison of Cryo5 Air Cooling, Crushed Ice Packs, Ice Massage, and Ice Water Immersion for Tissue Cooling and Numbness

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The Cryo5 cold air modality has recently been introduced to orthopedic medicine. The Cryo5 refrigerates air and blows it through an adjustable sized orifice (5 to 18 mm diameter). This technology is based on experience of European clinicians, but little is known about the physiological response of the body to localized cooling with forced air. Cryotherapy is used extensively in orthopedic and sports medicine, usually in the form of ice water immersion or crushed ice packs. This project wasdesigned to investigate the body's response to the Cryo5 and to compare this response to traditional modes of cryotherapy application.

Our specific focus was to answer the following research questions:

1. How do the Cryo5, ice pack, ice massage & immersion compare in reducing temperature and causing numbness in the ankle and thigh?
2. Do the ankle and thigh respond differently to 5 minute Cryo5 applications?

Methods

Experimental Design

The experimental design was a 2 x 3 factorial with pseudo repeated measures on both factors. The independent variables were body part (ankle & thigh) and modality (ice pack, cryo5 and either ice immersion (ankle) or ice massage (thigh). Three dependent variables were measured: pressure of sensation and surface temperature for the thigh and ankle and intramuscular temperature for the thigh.

Subjects completed 6 treatments each. Two subjects, a male and a female were randomly assigned to one of 6 treatment orders, established according to a 6x6 balanced Latin Square.

Our institutional review board approved the study.

Subjects

Subjects consisted of 12 student volunteers: 6 males (26±4.2 yrs, 78.48±12.4kg mass, 179.1±10.8 cm tall) and 6 females (22.6±0.5 yrs, 69.62±6.5kg mass, 167.22± 6.3cm tall). They give written informed consent after reading a memorandum which explained the procedures.

Instruments & Testing

Temperature was recorded every minute throughout the procedure using type T thermocouples interfaced with a Columbus Instruments (Columbus, OH) Isothermex 16-channel electronic thermometer as per Merrick, et al.[12] The instrument was factory calibrated for use with type T copper-constantan thermocouples. We also performed a 3-point calibration, just prior to testing, at temperatures of 50°C, 1°C, and 32°C.

Skin-modality interface temperatures were measured with TX#31 thermocouples. They were attached to the anterior ankles or thighs with a piece of 1½ inch by ½ inch plastic tape (Dermaclear, J&J, East Brunswick, NJ). The head of the thermocouple was midway between the ends of the tape with its distal 1mm exposed.

Thigh Intramuscular temperature was measured with the Isothermex using TX23-21 thermocouples inserted into the muscle 2cm beyond the subcutaneous layer through a 21 gauge teflon catheter.

Skin surface temperature was measured at 3 sites: in the middle of the application area (center point) and 8 cm distal and 8 cm proximal to the center point. Intramuscular temperature was measured 3mm distal to the center point.

Each site was marked with an ink pen so as to improve consistency in thermocouple placement during subsequent testing sessions.

Temperatures were monitored (with the Isothermex operating in "real time" mode) prior to the experiment until the temperature stabilized. Temperatures were then be measured and recorded every min for 5 min prior to cold application, during application, and for 60 minutes following application. Atmospheric temperature was measured with a Laboratory max-min electrothermic Thermometer (Fisher Scientific) just prior to the beginning of each session.

Sensation was tested with Semmes-Weinstein monofilaments prior to, and at approximately 1 min, 10 min, 30 min, 60 min post application. Semmes-Weinstein monofilaments

are designed to transmit only a predetermined pressure and any additional application pressure is lost through the bowing of the filament. Therefore, the pressure felt by the subject is a product of the monofilament and not the tester.[1, 7] The monofilament was applied perpendicular [1, 7] to the skin and held for 1.5 sec,[13] with enough pressure to cause the monofilament to bow. [1,7]

Testing proceeded from smaller monofilaments to larger, more easily felt monofilaments (larger monofilaments transmit more pressure). Subjects were instructed to say "yes" if they felt the monofilament. No verbal cues were given by the administrator to indicate when the monofilament was applied. Each monofilament was applied 2 or 3 times.[7] If there were two correct "yes" responses to the application it was assumed that the subject felt the monofilament.[7] If the subject did not respond correctly twice the next larger monofilament was applied. If there were two correct responses for the larger monofilament, then the smaller monofilament was applied again. If the subject did not make 2 of 3 correct responses, the test was over and the larger monofilament was recorded as the pressure sensitivity threshold.[1, 2, 7, 17]

It took about 45 seconds to complete a sensation measurement, so we began 45 seconds before the target time (i.e. 9:15 if the target was 10 minutes) and tried to end the measurement as close to the target time as possible. To check our accuracy, we recorded the exact time the measurement was completed.

Subjects came into the lab wearing gym shorts and laid on a mattress covered treatment table. They remain supine throughout the duration of the experiment, and were allowed to read, study, or converse with others in the lab. Subjects were tested at the same time of day with 24-72 hours between treatment conditions.

Ice packs were apx 1kg of crushed ice in a 1.5 gal plastic bag. The top was twisted and tied in a knot. These were placed on the surface of the body part so the center of the bag was over the target site.

The cryo5 was applied for 5 minutes with an air flow of 6 through the large (1.5cm) diameter orifice to an area of 4cm by 12cm (6cm proximal and distal, and 2 cm medial and lateral to the center point). The applicator was swept back and forth over the 12cm length at a rate of 1½ per second,. Each sweep overlapped the previous by about half so it took 5-6 sweeps to cover the 4cm lateral-medial area.

Ice massage was applied with an "popcycle" made by freezing water in an 8 oz paper cup with a tongue depressor in the middle. It was applied to 18cm by 12cm area (the ice was 9cm long) in a zig-zag motion at the rate of 1.8 sweeps per second.

The ankle was immersed in an ice water bath (0°-1°C) that covered the entire foot up to 5cm above the mallelous. Neoprene Toe Caps covered the distal forefoot.

Results

See figures 1-3 and tables 1-3 and 5-7 for temperature results and figure 4 and table 4 for the sensation of pressure results.

Conclusions

1. Surface and tissue cooling by the cryo5 appears to be as effective as ice immersion and ice massage, and more effective than ice packs.

2. Rewarming following cryo5 was quicker than the other modalities, probably because it was applied for 5 minutes rather than the 10 or 20 minute applications of the other modalities.

3. 5 minute applications are not cooling the tissue to a dangerous level. Furthermore, it appears from figures 1 & 2 that surface temperature levels out at 7-8°C at minute about minute 3.

4. Sensation of pressure was significantly increased (more numbness) at 1 and 10 minutes following cryotherapy in both the ankle and thigh, and at 30 minutes following immersion of the ankle.

5. Sensation of pressure was much less following Cryo5 application than the other

modalities. Two possibilities for this is that the Cryo5 was applied for less time than the other modalities and that the Cryo5 stimulated only cold receptors whereas the other modalities stimulated both cold and pressure receptors.

Recommendations for future studies

1. Investigate longer applications of the Cryo5 to determine how low the surface temperature gets. A study of 5, 10, and 20 minutes, compared with ice packs and ice massage would be warranted.

2. Compare tissue rewarming following equal application times of the cryo5, ice pack, and ice massage. This study could be combined with the study suggested above.

3. Compare changes in sensation of pressure following equal application times of the cryo5, ice pack, and ice massage to determine if the differences in the present study were due to differences in modality or time of application. This study could also be combined with the two studies suggested above.

Fig 1. Ankle Surface

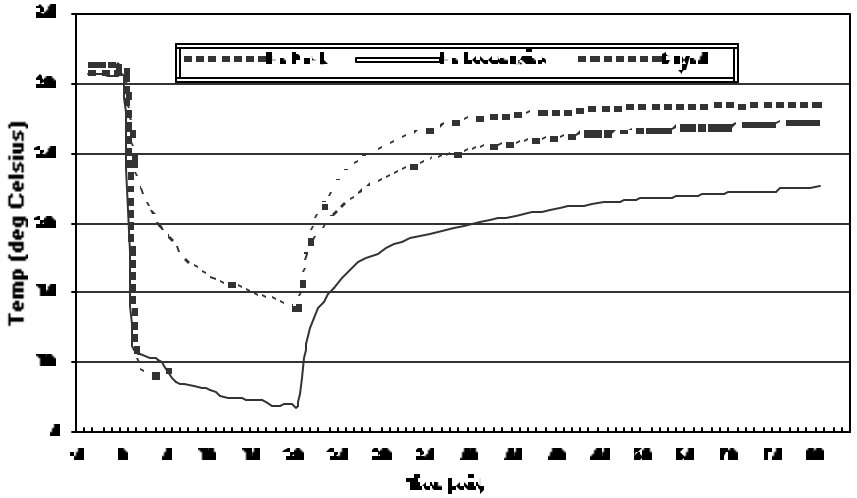

Figure 2. Thigh Surface

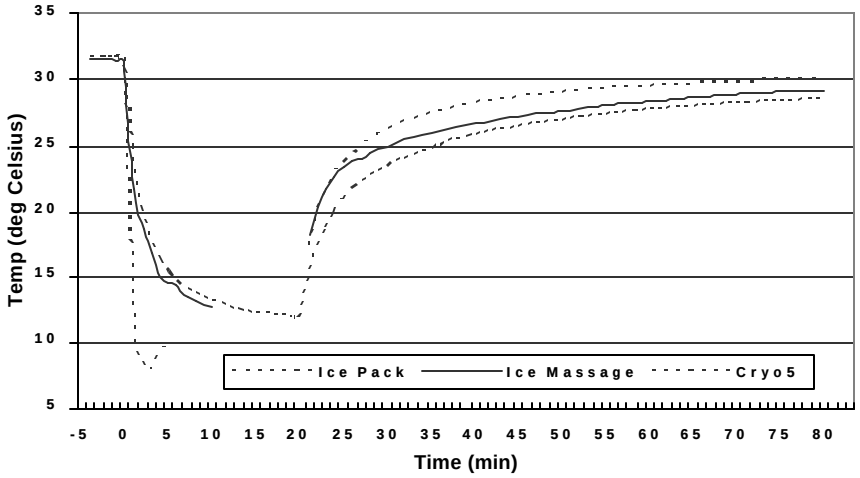

Figure 3. Thigh IM

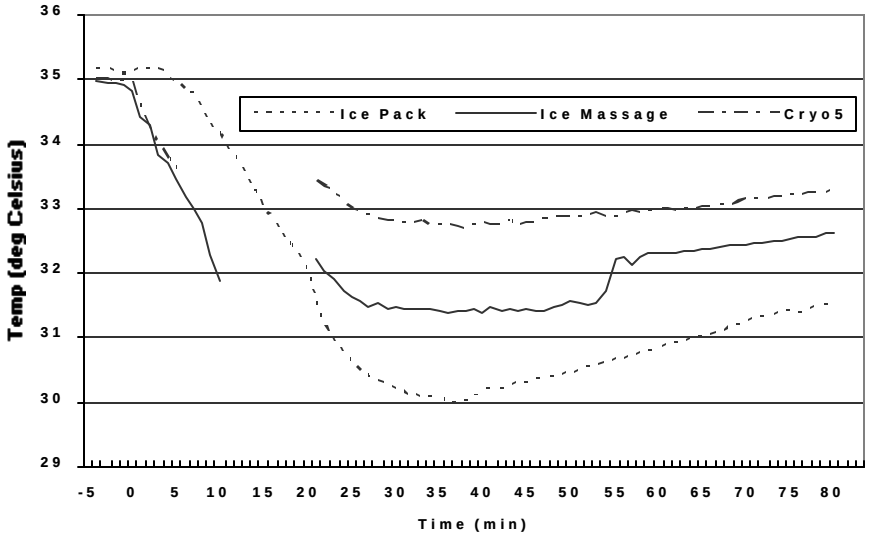

Figure 4. Sensation of Pressure

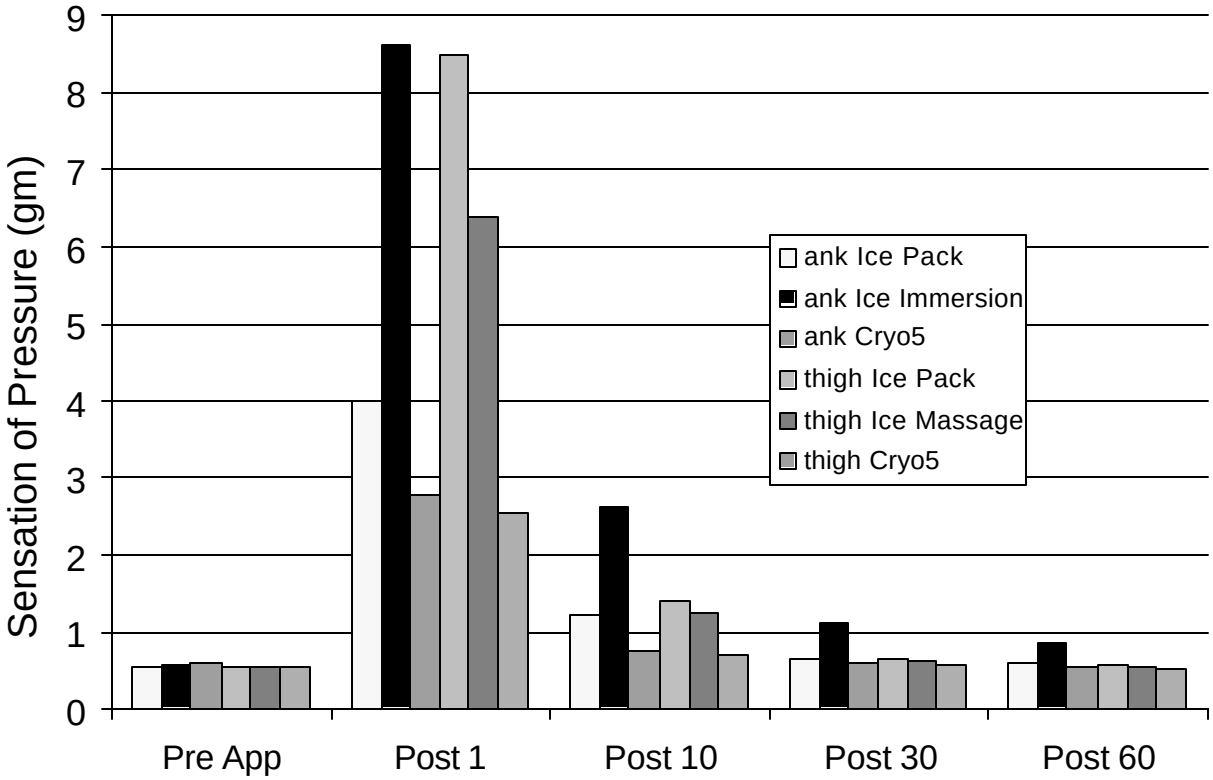

Table 1. Subject and Room Environmental Statistics

Subj	Age	BW (kg)	Ht (cm)	Room Temperature		Room Humidity	
				Avg	Range	Avg	Range
Males	26±4.2	78.48±12.4	179.1±10.8	22.6±0.5	22-23	38.2±7.1	28-48
Female	22± 5.5	69.62±6.5	167.22± 6.3	22.5±0.5	22-23	35.89±8.78	26-48

Table 2. Surface temperature, average of 3 sites (°C, Mean±SD)

	Pre (n=60)	Treatment5 (N=60)	Treatment all* (N= 240*)	10 min Post (N=120)	11-60 min Post (n=600)
Thigh			#	§	§
ice pack‡	31.7±0.8	18.4±3.8	14.2±3.7	20.6±2.8	27.0±1.5
ice massage‡	31.5±1.1	17.3±5.8	15.4±5.9	22.8±2.7	27.8±1.4
Cryo5‡	31.5±1.9	9.1±1.9	9.1±1.9	23.2±2.9	29.1±1.2
Ankle			¶	†	*f*
ice pack‡	31.2±1.1	21.3±2.8	17.0±4.0	21.0±3.5	26.1±2.8
ice immersn‡	30.6±1.2	10.4±2.1	8.3±1.8	15.8±2.6	21.1±2.4
Cryo5‡	30.9±1.1	9.7±2.0	9.8±2.0	22.8±2.8	27.9±1.9

*N=60 for the Cryo5 & N=120 for ice massage
#IP<Cryo5
§IP<IM,Cryo5
¶ IM, Cryo5<IP
f IM<IP,Cryo5
†IM<IP<Cryo5
‡App<Post10<Post60<Pre-app

Table 3. Intra Muscular temperature, 2 cm beyond skin fold (°C, Mean±SD)

	Pre (n=60)	Treatment5 (N=60)	Treatment all* (N= 240*)	10 min Post (N=120)[#]	11-60 min Post (n=600)[§]
Thigh					
ice pack¶	35.1±0.5	35.1±0.5	33.9±1.4	30.7±1.5	30.7±1.2
ice massage*f*	34.9±0.7	33.9±2.8	33.3±3.9	31.7±3.2	31.9±1.9
Cryo5†	35.0±1.0	34.0±3.7	34.0±3.8	33.0±3.2	32.9±1.4

*N=60 for the Cryo5 & N=120 for ice massage
#IP<Cryo5
§IP<IM,Cryo5
¶ Post10,Post60<App<Pre-app
f Post10,Post60,App<Pre-app
†Post10,Post60<Pre-app

Table 4. Sensation of Pressure (g, mean±SD)

	pre	post1	post10	post30	post60
Ankle		*	*	*	*
Ice Pack	0.53±0.17	4.01±2.47	1.20±0.85	0.65±0.22	0.58±0.18
Immersion	0.56±0.20	8.62±3.37	2.62±1.62	1.14±0.65	0.86±0.52
Cryo5	0.59±0.19	2.76±1.50	0.74±0.30	0.59±0.20	0.53±0.14
Thigh		§	§		
Ice Pack	0.55±0.17	8.49±4.26	1.41±0.91	0.65±0.16	0.56±0.16
Massage	0.55±0.18	6.40±3.39	1.24±0.91	0.61±0.19	0.53±0.17
Cryo5	0.54±0.20	2.56±1.54	0.71±0.35	0.56±0.21	0.52±0.21

*Immers>IPack, Cryo5
§IPack,IMass > Cryo5

Table 5. Surface temperature, Proximal site (°C, Mean±SD)

	Pre (n=60)	Treatment (N= 240*)	10 min Post (N=120	11-60 min Post (n=600)
Thigh				
ice pack	31.6±1.0	13.2±4.0	19.3±3.1	26.9±1.8
ice massage	31.5±1.1	14.5±6.7	22.0±3.0	27.3±1.7
Cryo5	31.5±1.6	8.5±2.7	22.7±3.0	29.1±1.4
Ankle				
Ice pack	30.9±1.2	14.4±4.1	19.6±4.2	25.4±2.9
ice immersion	30.5±1.2	7.6±2.0	15.0±2.9	20.5±2.6
Cryo5	30.7±1.5	10.8±3.2	22.5±2.5	27.8±2.2

*N=60 for the Cryo5 & N=120 for ice massage

Table 6. Surface temperature, middle site (°C, Mean±SD)

	Pre (n=60)	Treatment (N= 240*)	10 min Post (N=120	11-60 min Post (n=600)
Thigh				
ice pack	32.1±0.8	16.7±4.5	21.4±2.7	27.2±1.4
ice massage	31.6±1.2	18.2±6.2	23.8±2.6	28.3±1.2
Cryo5	31.7±1.5	9.2±2.2	24.1±3.2	29.2±1.0
Ankle				
ice pack	31.2±1.2	18.7±5.5	21.6±3.9	26.0±2.8
Ice immer	30.6±1.3	9.0±2.0	16.1±2.9	21.2±2.4
Cryo5	31.0±1.1	8.9±2.5	23.1±3.3	27.9±1.9

*N=60 for the Cryo5 & N=120 for ice massage

Table 7. Surface temperature, distal site (°C, Mean±SD)

	Pre (n=60)	Treatment (N= 240*)	10 min Post (N=120	11-60 min Post (n=600)
Thigh				
ice pack	31.5±1.2	12.7±4.5	20.9±3.2	27.0±1.5
ice massage	30.8±1.3	13.4±6.1	22.7±2.9	27.9±1.7
Cryo5	30.9±1.0	9.5±3.0	22.9±3.1	29.0±1.3
Ankle				
ice pack	31.5±0.9	18.0±4.3	21.7±3.1	27.0±2.9
Ice immersion	31.3±1.1	8.3±2.3	16.3±3.0	21.7±2.8
Cryo5	31.2±2.5	9.6±3.2	22.8±2.9	27.9±1.9

*N=60 for the Cryo5 & N=120 for ice massage