

The Effect of Cold Air Application on Intra-Articular and Skin Temperatures in the Knee

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The present study was performed to investigate the effect on the skin and the intra-articular structures of 5-minutes of cold air application. During and after 5 minutes of cold air application on 20 healthy subjects, the skin and intra-articular temperatures were measured by means of an infrared thermogram and a digital k-wire probe, respectively. The results showed that 1) Skin temperature dropped very rapidly by a total of 22.1°C after 5 minutes of cold air application. 2) Intra-articular temperature dropped by 3.9°C after 5 minutes of cold air application. 3) Two hours after the start of treatment with cold air, intra-articular temperatures had still not returned to their baseline values ($p < 0.01$). 4) The baseline skin temperature and the baseline intra-articular temperature were significantly correlated $r = 0.51$ ($p < 0.05$). However, there was no significant correlation between the skin temperature change and the intra-articular temperature change after 5 minutes and after two hours of cold air application. Finally, 5) a significant correlation $r = -0.72$ ($p < 0.01$) between the body mass index and the baseline skin temperatures was found. There was no significant correlation between the body mass index and the temperature changes, at the skin or in the knee joint, either during or after cryotherapy ($p > 0.05$).

Key Words: Cryotherapy, skin temperature, intra-articular temperature

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INTRODUCTION

Cryotherapy has been used as a method of physical therapy along with heat therapy for a long time. It is a superficial treatment with both a conductive and a convective effect.¹ The most commonly used cold therapies include the use of ice, cold water, chemical packs, vaporized liquids and refrigeration units. Recently, cryotherapy units using cold air have been developed, and have been applied to the diseased area using a cold air temperature of -30°C.

In general, heat or cold therapy on a localized area is known to be effective for arthritis. However, some investigators do not recommend its use, because of the fact that the associated increase in intra-articular temperature has a detrimental effect, due to the resulting increase in the number of destructive articular enzymes.^{2,3} Cold therapies on inflammatory joints and on the bursa result in a decrease in edema, due to vasoconstriction. Although pain relief is achieved indirectly because of the resulting decrease in edema, it can also be accomplished by directly treating the nerve fiber. When sufficient cold therapy is performed on the painful joint, the pain is reduced due to the increased pain threshold.⁴

In 1949, Horvath and Hollander⁵ reported that intra-articular temperature decreased when a hot pack was applied for four minutes, and increased when an ice pack was applied for the same period of time. In addition, Oosterveld and Rasker⁶ and Oosterveld et al.⁷ measured intra-articular temperature during heat and cold therapies for three

hours, and reported that heat and cold therapies resulted in increasing and decreasing intra-articular temperatures, respectively.

The purpose of this study was to investigate the effects of local cold air application on the skin, to measure the associated intra-articular temperature changes and to observe the rebound temperature changes after cooling.

MATERIALS AND METHODS

The subjects for the present study were 20 healthy volunteers for whom there was neither evidence of disease or physical damage, nor of inflammatory symptoms, including fever or swelling, and who agreed to participate in the experiment (Table 1). As shown in Fig. 1, each subject was maintained in a supine position with

Table 1. Subject Characteristics

	Mean \pm SD
Number of subjects	20
Age (years)	33.8 \pm 12.7 (23 - 68)
Gender	male 15/female 5
Height (cm)	170.3 \pm 6.5
Weight (kg)	66.9 \pm 7.7
Body mass index (kg/m ²)	23.0 \pm 2.2

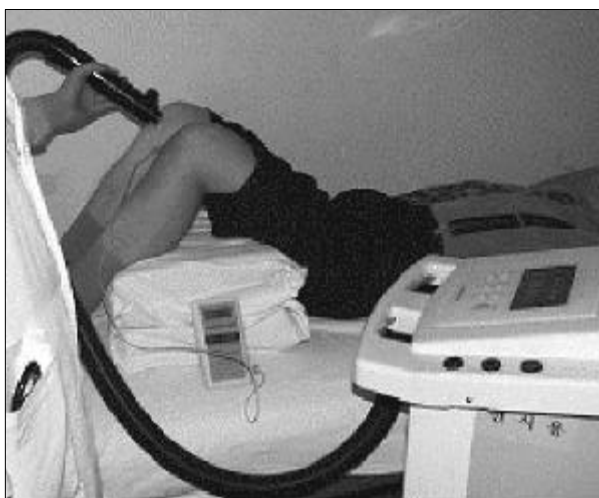


Fig. 1. The measurement of intra-articular temperatures during cold air application.

the knee flexed to 90 degrees, with the ambient temperature kept between 26 and 28 °C. The knee was prepared using an aseptic technique, and anesthetized at the site of the needle thermometer probe with 2% lidocaine. A 20G spinal needle was inserted using an anterior approach to the knee. Then, a thermometer probe, with a k-wire thermostat mounted on its tip, was inserted into the intra-articular cavity through the spinal needle. The intra-articular temperature was measured with an accuracy of \pm 0.2 °C using a digital thermometer (Barnant 90, Barnant Co, Barrington, IL, U.S.A.), and the skin temperature was measured by means of an infrared thermogram (Thermovision 900, Agema, Taby, Sweden). Cold air at -30°C, ejected from a CRAis (Century, Seoul, South Korea), was applied in a circular manner on the lateral aspect of the knee joint from a distance of 10 cm perpendicular to the skin surface for 5 minutes. The skin and intra-articular temperatures were measured simultaneously every 30 seconds during the 5-minute cold air application, every minute after cold air application, and every five minutes for two hours after the application. Fig. 2 shows an example of the thermogram image obtained following cold air application at the knee using the CRAis. The average skin temperature was measured at the two cold areas in the lateral aspect of the knee, which appeared dark in an infrared thermogram image.

RESULTS

Skin and intra-articular temperatures

Statistical analysis was performed to determine the statistical significance of the changes in skin and intra-articular temperatures after the cold air therapy. Since the insertion of the spinal needle, required for the measurement of the intra-articular temperature, failed on two subjects, only 18 subjects were included in the statistical analysis. We first applied the Kolmogorov-Smirnov normality test, to check the normality assumption with a significance level 0.01, in order to determine the appropriate statistical procedure to apply in each case. Based on the result of the Kolmogorov-Smirnov test, we applied either the

paired t-test or the Wilcoxon signed rank test for determining the statistical significance of the changes in skin and intra-articular temperatures.

The baseline skin temperature was $31.8 \pm 1.0^\circ\text{C}$ before the application of the cold air (Table 2). After 5 minutes of cold air application, it dropped to $9.7 \pm 2.9^\circ\text{C}$ with a significant statistical difference, compared with the baseline skin temperature ($p < 0.01$) (Fig. 2). Two hours after the removal of the cold air application, the skin temperature was $30.7 \pm 1.3^\circ\text{C}$, which is still significantly lower than the baseline intra-articular temperature ($p < 0.01$).

The baseline intra-articular temperature was initially $33.9 \pm 1.2^\circ\text{C}$ and then dropped to $30.0 \pm 1.8^\circ\text{C}$ following the cold air application with a significance ($p < 0.01$). The intra-articular temperature two hours after the removal of the cold air application was $31.4 \pm 2.2^\circ\text{C}$, which is still significantly lower than the value observed at the onset of the cold air application ($p < 0.01$) (Table 2).

The skin temperature decreased dramatically right from the onset of the cold air therapy, increased rapidly a few minutes after the removal of the cold air, and then slowly returned to equilibrium. It took 35.3 ± 31.5 minutes to attain the minimal intra-articular temperature, and the intra-articular temperature remained low until 2 hours after the cryotherapy (Fig. 3).

Body mass index and skin and intra-articular temperatures

We investigated the relationship between body mass index, skin temperature and intra-articular temperature. A significant correlation $r=0.51$ was found between the baseline skin temperature and the baseline intra-articular temperature ($p < 0.05$). However, the skin temperature changes do not correlate with the intra-articular temperature measured after 5 minutes and after two hours of cold air application (Table 3).

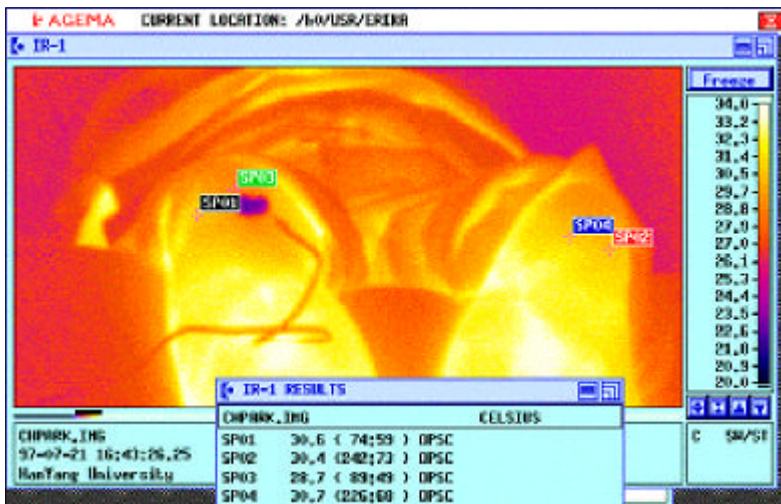


Fig. 2. An example of thermography after cold air application of knee using CRAIs.

Table 2. Changes in Skin Temperatures and Intra-articular Temperatures during and after Cold Air Application Using CRAIs*

Sites	Temperatures				
	Baseline(A)	The lowest(B)	After 2 hours(C)	B-A ¹	C-A ²
Skin(°C)	31.8 ± 1.0	9.7 ± 2.9	30.7 ± 1.34	$-22.1 \pm 3.1^\dagger$	$-1.1 \pm 1.1^\dagger$
Intra-articular (°C)	33.9 ± 1.2	30.0 ± 1.8	31.4 ± 2.22	$-3.9 \pm 1.1^\dagger$	$-2.6 \pm 1.7^\dagger$

*Values are the mean ± S.D. degrees centigrade.

[†] $p < 0.01$.

A: Baseline temperature, B: The lowest temperature during cold therapy, C: The temperature after 2 hours.

¹⁾paired t-test.

²⁾Wilcoxon signed rank test.

Table 3. Correlation Coefficients for Changes in Skin and Intra-articular Temperatures

Intra-articular	Skin A	B-A	C-A
D	r=0.51*	-	-
E - D	-	r=0.18	-
F - D	-	-	r=-0.28

* $p < 0.05$.

r Pearson correlation coefficient.

A: Baseline skin temperature, B: The lowest skin temperature, C: the skin temperature after 2 hours,

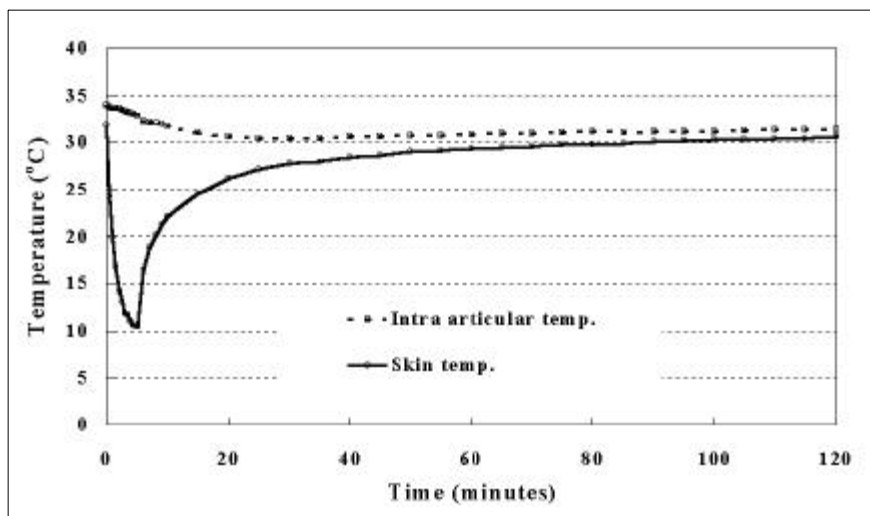
D: Baseline intra-articular temperature, E: The lowest intra-articular temperature, F: The intra-articular temperature after 2 hours.

There was a correlation ($r = -0.72$) between the body mass index and the baseline skin temperature ($p < 0.01$). However, there were no significant correlations between the body mass index and the skin or intra-articular temperature changes, either during or after the cryotherapy ($p > 0.05$) (Table 4).

DISCUSSION

Cold air therapy is used to reduce tissue edema,

inflammation, hematoma formation and pain, as well as for the treatment of arthritis.⁸⁻¹⁰ In rheumatoid arthritis and active osteoarthritis, destructive enzymes are produced, which become more active as the temperature increases, resulting in the destruction of the cartilage and other tissues. The destruction of cartilage increases rapidly at 35-36°C, when the cartilage is in a state of active synovitis, but at below 30°C the activity of the associated enzymes may be negligible.^{2,3,6,7} Therefore, one way of reducing the synovitis might be

**Fig. 3.** Mean skin temperatures and intra-articular temperatures of the knee, during and after cold air application using CRAIs.**Table 4.** Correlation Coefficients for B.M.I.* to Intra-articular and Skin Temperature

	A	B - A	C - A	D	E - D	F - D
B.M.I.*	r = -0.72 [†]	r = 0.19	r = 0.18	r = -0.17	r = 0.38	r = 0.36

*Body Mass Index.

[†] $p < 0.01$.

r Pearson correlation coefficient.

A: Baseline skin temperature, B: The lowest skin temperature, C: the skin temperature after 2 hours,

D: Baseline intra-articular temperature, E: The lowest intra-articular temperature, F: The intra-articular temperature after 2 hours.

to decrease the intra-articular temperature by means of cold air therapy.

Cryotherapy can be used to relieve pain both indirectly by reducing muscle spasm, spasticity, swelling after trauma and inflammation, and directly by applying a low-threshold mechano-receptor and a cold sensitivity unit or by extruding endorphins.^{11,12} Our results showed that when the baseline skin temperature was high, the baseline intra-articular temperature was also high, which implies that there exists a correlation between the baseline skin temperature and intra-articular temperature. However, changes in temperature in deep tissues take place relatively slowly when subjected to cold air.^{2,13} Since the vasoconstricted subcutaneous fat layer acts as an insulating material during the cryotherapy, the temperature of the deeper structure changes very little.^{1,8} Therefore, the effects of cold therapy lasts longer than those of heat therapy of equal strength. In addition, because vasoconstriction induced by the cryotherapy reduces blood flow, it takes longer for the cold tissue to recover its original temperature, in comparison with warmed tissue. The present study also revealed that the intra-articular temperature dropped much more slowly than the skin temperature. Furthermore, the intra-articular temperature returned to its original level at a slower rate than did the skin temperature.

The body mass index was correlated with the skin baseline temperature, but not with the temperature change at the skin or in the knee joint. These results show that the body mass index is related to both the skin temperature and the intra-articular temperature before the cryotherapy, but that during or after the cryotherapy it is not related to either of these temperatures. The body mass index might not accurately reflect the amount of subcutaneous fat layer present, especially in the vicinity of the knee joint. It may be necessary to measure the thickness of the subcutaneous fat layer directly, and to determine its relationship with the changes in intra-articular temperature. It has been reported that for a few minutes during the cryotherapy, the superficial tissue is vasoconstricted, but that the intra-articular temperature may increase due to the effects of vasodilatation in the deep tissues. However, in the present study no rise in temperature or

vasodilatation was observed. This may be because any vasodilatation occurring in the deep tissue, as a result of the cryotherapy, would not be able to directly influence the temperature rise. However, another theory is that the intra-articular temperature dropped very slowly during the cryotherapy and continued to drop even after the cryotherapy.

Our results showed that the intra-articular temperature, measured two hours after the cold air application, remained lower than the baseline temperature when the subject's knee joint remained in the supine static position. Since joint motion would tend to increase the intra-articular temperature,¹⁴ gait training or other practices could reduce the decrease intra-articular temperature.

The present study investigated the changes in skin and intra-articular temperatures resulting from cold air application. The following conclusions can be drawn from our results:

- 1) After 5 minutes of cold air application, the skin and intra-articular temperatures dropped by 22.1°C and 3.9°C, respectively. Two hours after the start of the treatment with cold air, the intra-articular temperatures had still not returned to their baseline values ($p < 0.01$). A significant correlation $r = 0.51$ was found between the baseline skin temperature and the baseline intra-articular temperature ($p < 0.01$).
- 2) The baseline skin temperature and the baseline intra-articular temperature are significantly correlated $r = 0.51$ ($p < 0.05$). However, there is no significant correlation between the skin temperature change and the intra-articular temperature change following cold air application by means of cryotherapy.
- 3) A significant correlation $r = -0.72$ ($p < 0.01$) between the body mass index and the baseline skin temperatures was found. There was no significant correlation between the body mass index and the temperature changes, at the skin or in the knee joint, either during or after the cryotherapy ($p > 0.05$).
- 4) No rise in intra-articular temperature was observed by the localized application of cold air. The rebound rise of the temperature, due to reactive vasodilatation, did not occur in the skin or in the knee joint cavity.

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