

# Temperature Changes in Superficial and Deep Tissue Layers with Respect to Time of Cold Gel Pack Application in Dogs

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Despite the widespread clinical use of cryotherapy, there is only limited and inconsistent data on application times. The aim of this study was to determine the changes in tissue temperature and the duration of this effect. In this experimental study, five adult dogs were used. A cold gel pack (10 × 20 cm) was applied transversally over the right leg femoral region.

Temperatures were recorded simultaneously: rectal by a mercury thermometer; right leg skin by probe of Nihon Kohden 6000 polygraph; and right leg subcutaneous, intramuscular, and periosteal, and left leg intramuscular temperatures by a fluorooptic biomedical fiber optic (0.6 mm diameter) thermometer connected to a computer system. Total system accuracy was 0.01°C. Cold gel packs were applied for 10, 15, 20, 25, and 30 minutes duration.

The results can be summarized as cooling and rewarming data. 1) The superficial tissues such as skin and subcutaneous demonstrated the most rapid and profound cooling effect. The deeper tissues such as bone and muscle exhibited a smaller and more gradual decline in temperature. 2) There was a prolonged rewarming period in all tissues after the removal of the cold gel pack but this period was longer in deeper tissues. According to cold gel pack application time, the rewarming time in intramuscular layers to baseline or plateau temperatures was about: 60 ± 3 minutes for 10 minutes application, 100 ± 4 for 15, 130 ± 5 for 20, 140 ± 7 for 25, and 145 ± 8 for 30.

It can be concluded from these results that with increased cold gel pack application time, deep tissue temperature decreased and the duration of cooling effect increased. However, the data indicated that the length of application time and the duration of cooling effect were not linearly related. Especially after 20 minutes of application this ratio decreased

progressively. There may be implications of these results for clinical practice.

**Key Words:** Cold, cryotherapy, temperature, rewarming time

## INTRODUCTION

Cryotherapy is used in the treatment of various musculoskeletal and neurological disorders.<sup>1,2</sup> Various methods such as ice packs, ice towels, ice massage, gel packs, refrigerant gases and inflatable splints can be used.<sup>3</sup> Cold packs are commonly used by clinicians, trainers, and others, often as an interim treatment for many acute conditions, but the extent of temperature change associated with this form of treatment remains poorly understood.<sup>4</sup>

Both physiological and clinical evidence suggest that cold application in various forms can be valuable in reducing musculoskeletal pain, muscle spasm, connective tissue distensibility, nerve conduction velocity, haemorrhage, oedema, inflammation, and intramuscular temperature.<sup>5,6</sup> Despite the widespread use of cryotherapy, a lack of quantitative data exists for determining the exact specification for its use. For example, the most effective mode of cold application, the length of time needed to cool an area, the amount of time that an area remains cool after the removal of the cold source, and the amount of cooling that occurs beyond the area in contact with the cooling agent have not been addressed fully.<sup>3,4,6</sup>

Cold gel packs are applied for quite different durations. Elucidating the most effective and shortest application duration is very important for

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clinical use. The aim of this study was to determine the changes in tissue temperature and the duration of this effect.

## MATERIALS AND METHODS

In this experimental study, five adult dogs weighing  $17.6 \pm 3.8$  kg were used. Anesthesia was induced by intravenous injection of 35 mg/kg sodium pentathol through the leg vein. The dogs were positioned supine, their thighs shaved and a catheter was inserted into the left leg vein for supplementation of anesthetic material as required. Twenty minutes following anesthesia, a cold gel pack ( $10 \times 20$  cm) was applied transversally over the right leg femoral region.

### Recorded temperatures were:

- Rectal temperature by an ordinary laboratory mercury thermometer (Istanbul, Turkey) (with 0.1 C sensitivity),
- Right leg skin temperature by a probe of Nihon Kohden 6000 polygraph (Tokyo, Japan) (with 0.1 sensitivity)
- Right leg subcutaneous (0.3 cm. deep from the surface), right leg intramuscular (2.5 cm deep from the surface, deep quadriceps muscle mass adjacent to the femoral shaft), right leg periosteal (about 4 cm deep from the surface) and left leg intramuscular (2.5 cm deep from the surface) temperatures by a fluoro-optic biomedical fiber optic (0.6 mm diameter) thermometer (Luxtron, Model 3100 (Santa Clara, CA, USA), connected to a computer system. Total system accuracy was 0.01°C.

Fluoro-optic fibers were inserted through a

needle, used as a guide, into the tissue. After the fiber optic microprobes were inserted into the tissue at the aimed depth, the guiding needle was removed. Fluoro-optic fibers were secured by tapes during the experiment to maintain them at the same depth.

Temperature recordings were taken at 30-second intervals during the application of the cold gel pack at 0°C for 10, 15, 20, 25 and 30 minutes duration. After the removal of the cold gel pack, recordings were continued until the temperatures returned to baseline or plateaued (rewarming time). In this study every dog was used at 3-week intervals for 10, 15, 20, 25 and 30 minutes duration of application.

The difference between the lowest recorded temperature and the baseline temperature, and the period that the lowest temperature was maintained constant were compared by one period, one tailed "t" test.

## RESULTS

Mean room temperature was 21.4°C during the experiments. The mean baseline skin temperature ( $32 \pm 4.6^\circ\text{C}$ ) was lower than the mean baseline rectal ( $36.3 \pm 1.2^\circ\text{C}$ ), periosteal ( $36.1 \pm 1.1^\circ\text{C}$ ), intramuscular ( $35.9 \pm 1.1^\circ\text{C}$ ), and subcutaneous ( $34.4 \pm 1.3^\circ\text{C}$ ) temperatures.

The animals' rectal, right leg intramuscular, periosteal, subcutaneous, and skin, and left leg intramuscular temperatures were measured for 10, 15, 20, 25, and 30 minutes application. According to these measurements the mean maximum temperature decreases after cryotherapy were calculated and are shown in Table 1.

Fig. 1 - 5 shows the recordings of the application. The superficial tissues such as skin and

**Table 1.** Mean Maximum Temperature Decreases After Cryotherapy

	Skin (°C)	subcutaneous (°C)	intramuscular (°C)	periosteal (°C)	contralateral (°C)	rectal (°C)
10 Min	$13.4 \pm 2.1$	$9.1 \pm 1.4$	$3.8 \pm 0.7$	$3.1 \pm 0.9$	$0.6 \pm 0.2$	$0.2 \pm 0.1$
15 Min	$15.2 \pm 2.3$	$9.3 \pm 1.4$	$4.1 \pm 0.8$	$3.4 \pm 0.9$	$0.7 \pm 0.2$	$0.3 \pm 0.1$
20 Min	$15.5 \pm 2.7$	$10.1 \pm 1.5$	$4.6 \pm 0.8$	$3.8 \pm 0.9$	$0.8 \pm 0.2$	$0.3 \pm 0.1$
25 Min	$15.9 \pm 3.1$	$11.1 \pm 1.5$	$4.7 \pm 0.9$	$4.0 \pm 0.9$	$0.8 \pm 0.2$	$0.3 \pm 0.1$
30 Min	$16.2 \pm 3.6$	$11.2 \pm 1.7$	$5.0 \pm 0.9$	$4.0 \pm 0.9$	$0.9 \pm 0.2$	$0.4 \pm 0.1$

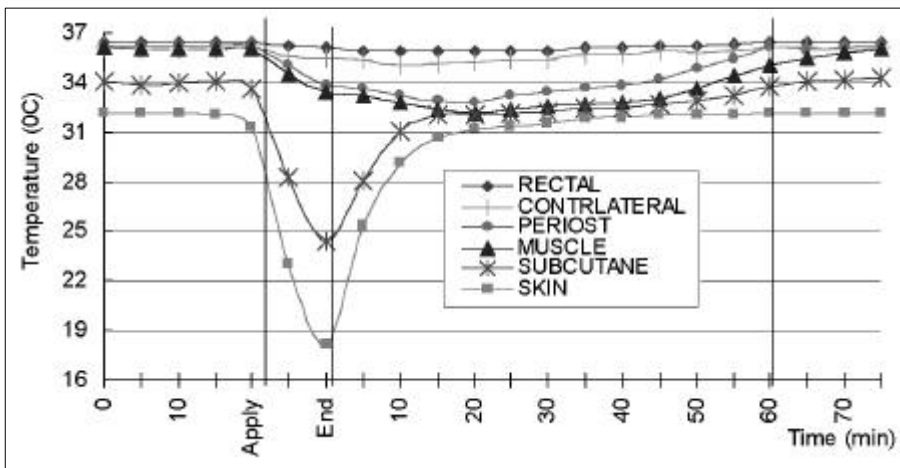


Fig. 1. Temperature changes of the different tissues of the dog before and after 10 min. cold gel pack application on the right leg femoral region.

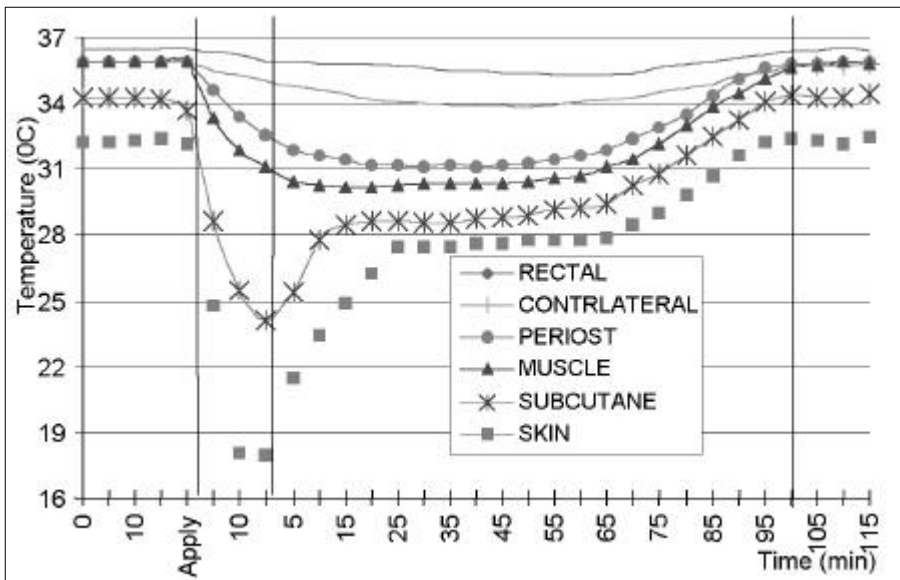


Fig. 2. Temperature changes of different tissues of the dog before and after 15 min. cold gel pack application on the right leg femoral region.

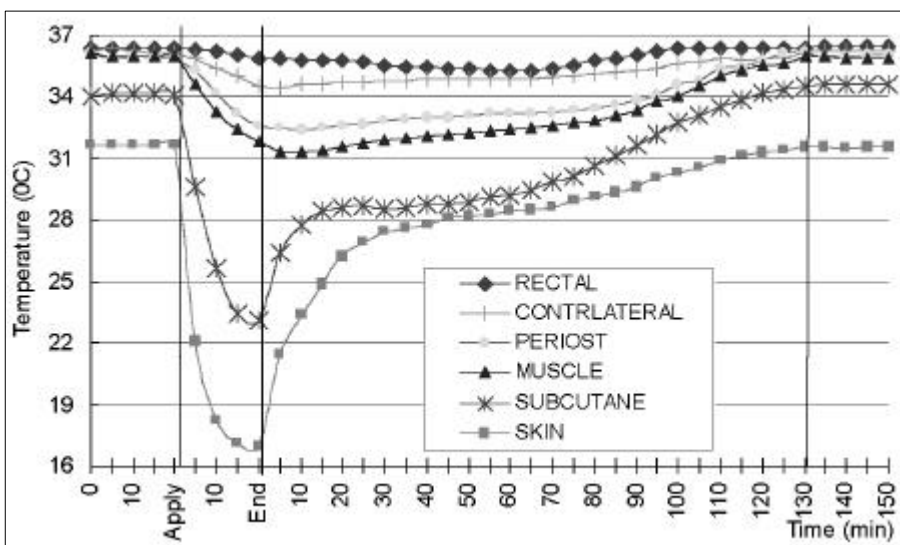


Fig. 3. Temperature changes of the different tissues of the dog before and after 20 min cold gel pack application on the right leg femoral region.

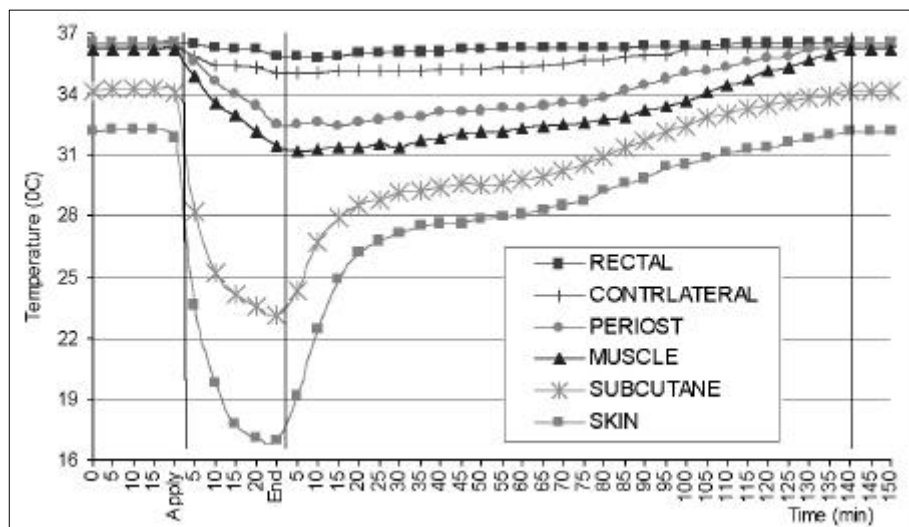


Fig. 4. Temperature changes of the different tissues of the dog before and after 25 min. cold gel pack application on the right leg femoral region.

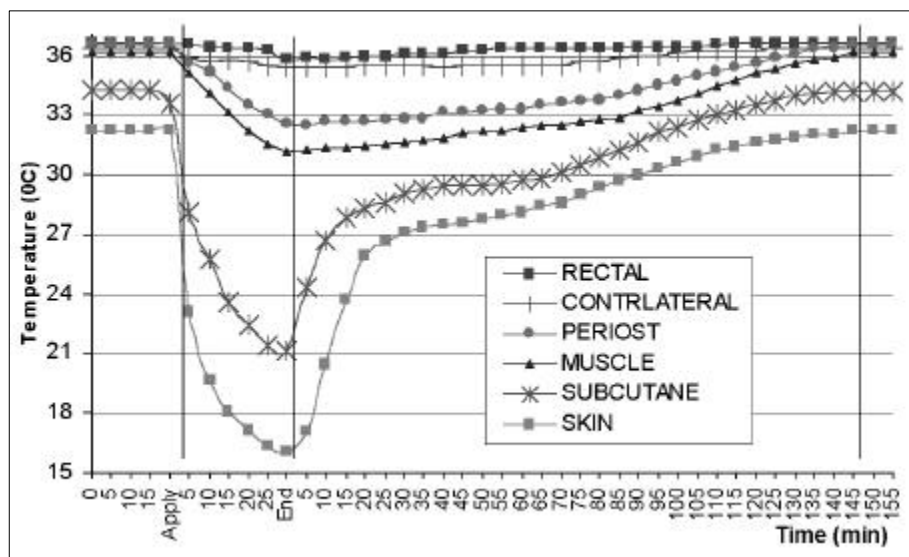


Fig. 5. Temperature changes of the different tissues of the dog before and after 30 min. cold gel pack application on the right leg femoral region.

subcutaneous demonstrated the most rapid and profound cooling effect. The deeper tissues such as bone and muscle exhibited a smaller and more gradual decline in temperature. The surface temperatures (skin and subcutaneous) continued to decrease for a short period of time and then began to rise. There were prolonged rewarming periods in all tissues after the removal of the cold gel pack but these periods were longer in deeper tissues.

According to cold gel pack application time, the rewarming time in intramuscular layers to baseline or plateau temperatures was about:  $60 \pm 3$  minutes for 10 minutes application,  $100 \pm 4$  for

15,  $130 \pm 5$  for 20,  $140 \pm 7$  for 25, and  $145 \pm 8$  for 30.

Decreases of intramuscular and periosteal temperatures following 10, 15, 20, 25, and 30 minutes applications were found to be statistically significant in comparison to decreases of rectal temperatures ( $p < 0.05$ ). The minimum temperature of the intramuscular and periosteal regions compared with rectal temperatures are shown in Fig. 6 and 7. The maximum temperature decreases of the intramuscular region are shown in Fig. 8.

Rewarming times following 10, 15, 20, 25, and 30 minutes of cold gel pack applications were compared for intramuscular region (Fig. 9).

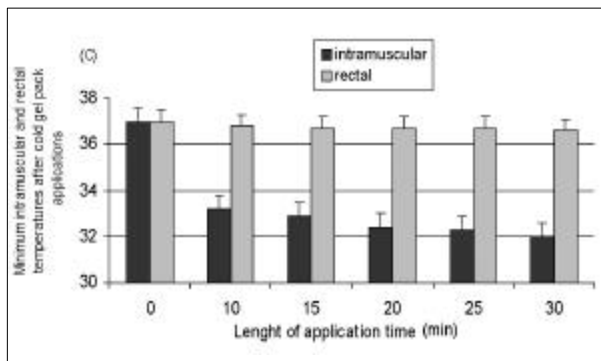


Fig. 6. Comparison of the minimum intramuscular and rectal temperatures on different cold application times.

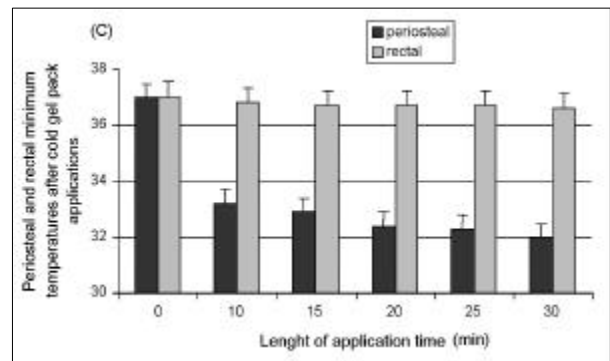


Fig. 7. Comparison of the minimum periosteal and rectal temperatures on different cold application times.

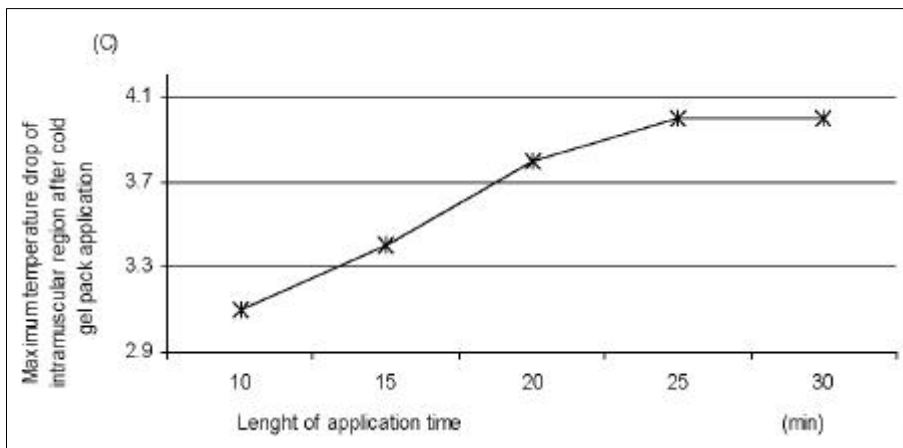


Fig. 8. Maximum temperature decreases of the intramuscular region after cold gel pack application.

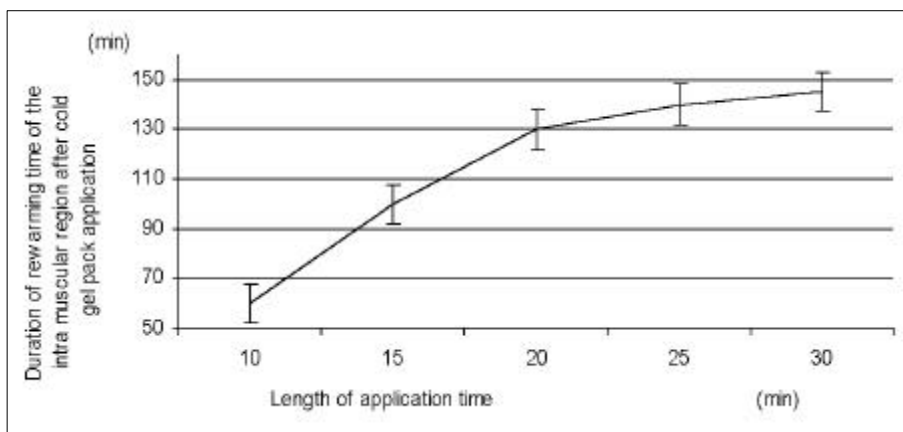


Fig. 9. Duration of rewarming time of the intramuscular region after cold gel pack application.

The differences of rewarming times following 15 minutes application compared to 10 minutes application, of 20 minutes compared to 15 minutes, of 25 minutes compared to 20 minutes, and of 30 minutes compared to 25 minutes, were found to be statistically significant ( $p < 0.05$ ).

## DISCUSSION

Studies reporting the effects of surface cryotherapy on intramuscular temperatures have always demonstrated a gradient cooling effect, with the most rapid and pronounced cooling appearing

at the skin and with a diminution and delay of cooling effect at progressively deeper levels in the muscle.<sup>7-10</sup> We found the same result.

The superficial application of cold was reported to reduce intraarticular temperature.<sup>8,11</sup> Local topical application of cryotherapy in various forms rapidly lowered the temperature of various structures in animal models.<sup>12</sup> The magnitude of the tissue cooling was quite different. Wakim et al.<sup>13</sup> reported a change in muscle temperature of  $-17.4^{\circ}\text{C}$  and a change in articular temperature of  $-18.4^{\circ}\text{C}$  in the joints of normal dogs. McMaster et al.<sup>14</sup> reported the temperature change in canine thigh muscles to be  $-11.3^{\circ}\text{C}$  with ice application,  $-8.4^{\circ}\text{C}$  with cold pack and  $-3.5^{\circ}\text{C}$  with chemical pack.

In healthy human subjects, Bell and Lehmann<sup>15</sup> measured skin and muscle temperatures during cold application and found an average decrease of  $18.4^{\circ}\text{C}$  and  $12.1^{\circ}\text{C}$ , respectively.

Temperature changes induced in deeper tissues by application of cold have not received widespread study. Superficial muscles or subcutaneous fat usually were the sites chosen for temperature measurement. Johnson and co-workers<sup>16</sup> measured the intramuscular temperature of the gastrocnemius muscle in 10 healthy subjects, after submersion for 30 minutes in cold water at  $10^{\circ}\text{C}$ . The mean intramuscular temperature decreased by  $12.0^{\circ}\text{C}$ . Wolf<sup>17</sup> measured dorsal forearm temperatures in 10 healthy volunteers, after exposure for 15 minutes to a cooling agent at  $10^{\circ}\text{C}$ . Muscle temperature decreased by an average of  $2.7^{\circ}\text{C}$ . Oosterveld et al.<sup>18</sup> reported that ice chips and nitrogen-cold air lowered both skin temperature (from a mean of  $27.9^{\circ}\text{C}$  to  $11.5^{\circ}\text{C}$  and from  $28.8^{\circ}\text{C}$  to  $13.8^{\circ}\text{C}$ , respectively) and intraarticular temperature (from  $31.9^{\circ}\text{C}$  to  $22.5^{\circ}\text{C}$  and from  $32.9^{\circ}\text{C}$  to  $28.8^{\circ}\text{C}$ , respectively). Enwemeka et al.<sup>4</sup> monitored skin temperature, and recorded the temperature of the quadriceps muscle at 1, 2, and 3 cm depths below the skin, before, during, and after 20 min of cold pack treatment. Cold pack therapy produced significant temperature falls in cutaneous and subcutaneous superficial tissues without directly changing the temperature of tissues at or more than 2.0 cm below the skin.

Kim et al.<sup>19</sup> observed that 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. But Lehmann<sup>9</sup> reported that the slowness of the decrease of the muscle temperature depends largely on the thickness of fat layer. Otte et al.<sup>20</sup> found that there is a clinically important, direct relationship between adipose thickness and required cooling time, during cold application.

The rate of cooling of the localized skin was more rapid than the rate of rewarming.<sup>21</sup> The temperature gradients of both layers of tissue reversed after treatment, indicating that the deep tissue beneath was at least one of the sources of heat used to rewarm the cooled superficial tissue.<sup>4</sup> Fifteen minutes after the removal of the cold modality, rapid rewarming occurred in the study of Belitsky et al.<sup>6</sup> and a similar trend was reported by Waylonis,<sup>7</sup> Bocabbo,<sup>8</sup> Lewis and Clayfield<sup>22</sup> and McKeeken et al.<sup>23</sup> In our study the return to baseline temperature (rewarming time) was very gradual. Prolonged rewarming periods were reported by other studies as well. Oosterveld et al.<sup>18</sup> observed that three hours after the initiation of treatment with ice chips or nitrogen-cold air, the mean intraarticular temperatures had still not recovered to baseline values and still differed significantly from baseline temperature. Kim et al.<sup>19</sup> reported that two hours after the start of treatment with cold air, intraarticular temperatures had still not returned to their baseline values.

In the study of Bugaj et al.<sup>21</sup> the ice massage had no significant effect on the temperature of the skin of the contra lateral extremity. Similarly, we observed no significant effect on the intramuscular temperature of the contra lateral extremity.

Clinical application time of cold modalities varies from 10 to 45 minutes, although the average is 15 minutes. Belitsky et al.<sup>6</sup> preferred 15 minutes for their study because this time period is commonly used clinically and because observations have shown that minimal patient discomfort within this time frame has resulted in high patient compliance. Prolonged application at very low temperatures should be avoided as this may cause serious side-effects, such as frost-bite and nerve injuries.<sup>3</sup> Lundgren and associates<sup>24</sup> have shown that cooling over an excessive period of time may

retard healing. They showed that the retardation of wound healing seems to be secondary to the vasoconstriction. Sympathectomy in experimental animals prevented this retardation of wound healing. Drez and co-workers<sup>25</sup> reported four cases in which ice application around the knee resulted in peroneal nerve damage with foot drop. Collins and associates<sup>26</sup> described one case of peroneal nerve damage which occurred when the patient fell asleep during the application of ice around the knee joint. In all of these cases, the ice application was not controlled sufficiently, and the authors concluded that special precautions should be taken to prevent nerve damage: limiting ice application to 20 minutes and avoiding compression of the peroneal nerve.

Cold application causes vasoconstriction resulting in decreased intramuscular temperature and reduced oedema, which are well known effects. In our study, a decrease in target tissue temperatures followed cold gel pack application in dogs. Temperatures continued to decrease even after the cold gel packs were removed. Various durations of cold gel pack applications resulted in different decreases in temperature at target tissues and different rewarming times. Temperature decreases and rewarming periods increased with increasing application times. As was shown in Fig. 8, temperature decreases following application durations exceeding 20 minutes were not linear like those following 10 and 15 minutes applications were. It is likely that the rewarming periods following prolonged application durations were not linearly related (Fig. 9). Therefore we concluded that applications exceeding 20 minutes are not be recommended due to the risk of clinical complications.

It can be concluded from these results that with increased cold gel pack application time, deep tissue temperatures decreased and the duration of cooling effect increased. However, the data indicated that the length of application time and the duration of cooling effect were not linearly related. Especially after 20 minutes of cold application this ratio decreased progressively. There may be implications of these results for clinical practice.

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