THE EFFECT OF LOCAL HEAT AND COLD THERAPY ON THE INTRAARTICULAR AND SKIN SURFACE TEMPERATURE OF THE KNEE

F. G. J. OOSTERVELD, J. J. RASKER, J. W. G. JACOBS, and H. J. A. OVERMARS

Objective. To evaluate the effects of local application of ice chips, ligno-paraffin, short-wave diathermy, and nitrogen-cold air on skin and intraarticular temperature.

Methods. Forty-two healthy subjects were divided into 4 treatment groups. A temperature probe was inserted into the knee joint cavity and another placed on the overlying skin, and changes in temperature over 3 hours, by treatment group, were recorded.

Results. The mean skin surface temperature dropped from 27.9°C to 11.5°C after application of ice chips, and from 28.8°C to 13.8°C after application of cold air. The mean intraarticular temperature decreased from 31.9°C to 22.5°C and from 32.9°C to 28.8°C, respectively, after these 2 treatments. Short-wave diathermy increased skin temperature by 2.4°C; intraarticular temperature was increased only 1.4°C by short-wave diathermy. Treatment with ligno-paraffin increased the skin surface temperature 8.9°C; the temperature in the joint cavity was increased 3.5°C.

SUBJECTS AND METHODS

Forty-two healthy subjects with no history of disease of or injury to the knee were included in the trial. All volunteers were students at the Academy for Physiotherapy, Enschede, The Netherlands.

The study design was approved by the ethics committee of the Hospital Medisch Spectrum Twente.

The subjects were assigned at random to 4 groups. Group 1 subjects were treated by local application of ice chips (0°C) for 30 minutes. The ice chips were produced in a Scotsman AF 2 ice machine (Doorgeest Koeltechniek, Raalte, The Netherlands) and applied in a plastic bag cover-
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The knees of the subjects in group 2 were cooled by means of a 6.5-minute application of −160°C nitrogen-cold air from a Medivent NL (Hoek Loos Cryo Service, Schiedam, The Netherlands). The liquid nitrogen is kept in an expansion barrel at a temperature of −196°C, and by slight heating of the liquid, nitrogen-cold air becomes available for therapeutic purposes.

Subjects in group 3 received short-wave diathermy for 15 minutes, with an intensity that caused a just-perceptible warm feeling. A Curapuls 419 apparatus (Enraf-Nonius, Delft, The Netherlands) was used for this treatment. Electrodes (13 cm diameter) were placed at the medial and lateral aspects of the knee. The distance between the electrodes and the skin was 3 cm. The average intensity was 180W.

Group 4 subjects were treated with ligno-paraffin (Paraligno) for 10 minutes. This is a mixture of pure paraffin and ground birchwood, maintained at a temperature of 50°C in a Fango-oven FW 5070G (Enraf-Nonius). The mean application temperature was 47°C. The ligno-paraffin was wrapped completely around the knee and covered with two blankets.

To measure intraarticular temperature, an Intraflon-2 infusion needle with an outer diameter of 1 mm (Vigon Laboratories, Ecouen, France) was inserted into the knee joint by a lateral approach, under strictly sterile conditions. Ethyl chloride spray was used to anesthetize the skin. After introduction of the needle the metal trocar was withdrawn, while the Teflon cannula was kept in place. A flexible Exacon C-F04.30 catheter temperature probe (Exacon Scientific Instruments, represented by Polystan Benelux, Almere-Haven, The Netherlands) was then gently pushed through the cannula into the joint cavity. Thereafter, the Teflon cannula was carefully withdrawn, so only the catheter probe remained in the joint. Finally, the injection site was covered with Tegaderm Plus 9526 (3M, St. Paul, MN), a 10 × 15-cm transparent sterile plastic coating.

A second Exacon C-F04.30 probe was used to measure the skin surface temperature. The tip of the probe was placed over the joint line between the medial femoral condyle and the medial aspect of the tibial plateau. The measuring tip of the probe was protected from direct influence of the physiotherapy application by a 0.3 cm–thick layer of felt and fixed to the skin with tape. The possibility of temperature conduction through the probe to the measuring tip was investigated. Neither heat nor cold application to the wire of the probe changed the temperature as measured at the tip, indicating good isolation of the probe.

In groups 1, 2, and 4, the introduction of the intraarticular measurement probe and the positioning of the skin probe were performed before the treatment. In group 3 (short-wave diathermy group), the probes were placed immediately after treatment, because short-wave diathermy cannot be administered with a metal temperature probe in the joint cavity. Therefore, the intraarticular temperature before treatment could not be measured in this group. For statistical analysis in group 3, the mean initial intraarticular temperature as measured in the other 3 groups was used.

Both catheter temperature probes were connected to an Exacon MC 9200 medical thermometer with a measuring range of −80°C to 120°C and an accuracy of ±0.1°C. The Exacon thermometer was connected to an Exacon RC 2120 recorder for permanent recording of the temperature up to at least 3 hours after initiation of the physiotherapy treatment.

Before the physiotherapy and temperature recording were begun, all subjects acclimatized in the test room for at least 30 minutes; the knee was exposed to the environmental temperature of the room during the whole test procedure. The average room temperature was 21.2°C (SD 0.7). There were no statistically significant differences in the mean room temperatures (as measured with an Exacon S01 probe) used in the studies of the 4 experimental groups (21.5°C, 20.7°C, 21.6°C, and 21.0°C in groups 1, 2, 3, and 4, respectively).

By measuring skinfolds at the left side of the body over the triceps and biceps brachii muscle, under the angle of the scapula, and directly over the iliac crest, body fat percentage was calculated. The skinfold over the patella of the treated knee was also measured. These data were obtained because of a possible correlation between body fat mass and insulation of deeper tissues from superficial tem-

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Baseline temperature</th>
<th>Minimum/maximum temperature</th>
<th>Temperature after 3 hours</th>
<th>Change, minimum/maximum versus baseline</th>
<th>Difference from change produced by comparable procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ice chips</td>
<td>27.9 ± 0.4</td>
<td>11.5 ± 1.1§</td>
<td>25.2 ± 0.3§</td>
<td>−16.4 ± 1.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>28.8 ± 0.7</td>
<td>13.8 ± 1.3§</td>
<td>27.5 ± 0.9</td>
<td>−15.0 ± 1.2</td>
<td></td>
</tr>
<tr>
<td>Heat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short-wave diathermy</td>
<td>27.6 ± 0.5</td>
<td>30.0 ± 0.5§</td>
<td>27.0 ± 0.5</td>
<td>2.4 ± 0.5</td>
<td>6.5§</td>
</tr>
<tr>
<td>Ligno-paraffin</td>
<td>28.8 ± 0.6</td>
<td>37.7 ± 0.5§</td>
<td>28.8 ± 0.9</td>
<td>8.9 ± 0.4</td>
<td></td>
</tr>
</tbody>
</table>

* Values are the mean ± SEM degrees centigrade.
† Minimum refers to results with cold treatments; maximum refers to results with heat treatments.
§ Ice chips compared with nitrogen, or short-wave diathermy compared with ligno-paraffin.
$ P < 0.01.$
‡ $ P < 0.001.$
Table 2. Changes in intraarticular temperatures in the 4 treatment groups*

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Baseline temperature</th>
<th>Minimum/maximum temperature†</th>
<th>Temperature after 3 hours</th>
<th>Change, minimum/maximum versus baseline†</th>
<th>Difference from change produced by comparable procedure‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ice chips</td>
<td>31.9 ± 0.5</td>
<td>22.5 ± 1.1§</td>
<td>27.5 ± 0.5$</td>
<td>−9.4 ± 0.7$</td>
<td>5.3$</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>32.9 ± 0.5</td>
<td>28.8 ± 0.7§</td>
<td>31.0 ± 1.0#</td>
<td>−4.1 ± 0.3$</td>
<td></td>
</tr>
<tr>
<td>Heat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short-wave diathermy</td>
<td>32.5 ± 0.3**</td>
<td>33.9 ± 0.4§</td>
<td>30.8 ± 0.4§</td>
<td>1.4 ± 0.4</td>
<td></td>
</tr>
<tr>
<td>Ligno-paraffin</td>
<td>32.5 ± 0.7</td>
<td>36.0 ± 0.4§</td>
<td>32.3 ± 0.9</td>
<td>3.5 ± 0.4</td>
<td></td>
</tr>
</tbody>
</table>

* Values are the mean ± SEM degrees centigrade.
† Minimum refers to results with cold treatments; maximum refers to results with heat treatments.
‡ Ice chips compared with nitrogen, or short-wave diathermy compared with ligno-paraffin.
§ P < 0.01.
# P < 0.001.
** P < 0.05.
** Calculated as the mean in the other 3 groups (see Subjects and Methods).

The mean ± SD percentage body fat in the...
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**Figure 2.** Mean intraarticular temperatures in the 4 treatment groups, during and after treatment.

subjects was 24.7 ± 7.7%. The mean ± SD thickness of soft tissue over the knee was 8.0 ± 2.7 mm. No significant differences in these values were observed among the 4 groups. Because the amount of fat mass may influence the degree of temperature changes inside the joint, correlations of body fat percentage and soft tissue thickness with intraarticular temperature changes were calculated. No significant associations were found. A highly significant correlation was found between maximal skin temperature changes and maximal joint temperature changes induced by physiotherapy (Spearman’s $\rho = 0.87$).

**DISCUSSION**

The intraarticular temperature measurement technique used in the present study was relatively easy to apply, and no difficulties were encountered in introducing the probe or during or after the measurements. Comparable intraarticular measurement procedures have been described previously and have also proved to be simple and reliable (8–10).

The effects of thermo- and cryotherapy on skin temperature in healthy subjects have been studied before, mostly in small series. Skin temperature decreases of 6–19°C and minimum temperatures of 4°C have been reported, depending on the treatment used (11–15). The results reported by Belitsky et al (11) and Schmidt et al (15), who used ice or cryogel packs, are comparable with those in our study. According to the reports by Waylonis (12) and Bugaj (13), ice massage causes even larger decreases in skin temperature.

Abramson and coworkers studied skin temperature changes in 20 experiments with 16 subjects receiving various regimens of heat treatment (16). Temperature readings were obtained from the skin of the finger and hand. Temperature increased by an average of 13.0°C in response to paraffin treatment, whereas application of short-wave diathermy for 30 minutes increased skin temperature by only 1.3°C. Schmidt et al (15) heated the knee for 20 minutes with a 45–55°C hot pack and found a 6°C elevation in mean skin temperature (15).

In our trial, paraffin treatment did not cause temperature increases as high as those reported by Abramson et al (8.9°C versus 13.0°C). This may be explained by the fact that they applied heat for 30 minutes, compared with 10 minutes in our study; also the mean initial temperature of the paraffin was lower in our study (47.0°C versus 51.1°C). Despite the fact that Schmidt and coworkers heated the knee for 20 minutes with a hot pack, the increase in temperature found in their study was low compared with that produced by other heat treatments.

Temperature changes induced in deeper tissues by the application of heat or cold have not received widespread study. Superficial muscles or subcutaneous fat are usually the sites chosen for temperature measurement. Johnson and coworkers measured the intramuscular temperature of the gastrocnemius muscle in 10 healthy subjects, after submersion for 30 minutes in cold water at 10°C (17). The water level was maintained 5 cm above the patella. The mean intramuscular temperature decreased by 12.0°C. Wolf (18) measured dorsal forearm temperatures in 10 healthy volunteers, after exposure for 15 minutes to a cooling agent at 10°C. Muscle temperature decreased by an average of 2.7°C. Temperature measurements of the capsule of the wrist, first metacarpophalangeal and metatarsophalangeal joints, and flexor hallucis brevis muscles in healthy male subjects were recorded by Borrrell et al (7). Fluidotherapy, which is a dry heat application, was compared with hydrotherapy and paraffin wax treatment. Temperature increases of 4.3–9.0°C were reported.

It is difficult to compare the above results with the joint temperature changes recorded in our trial because of differences in joints or tissues studied, and in the heat or cold treatments used. Considering the results of our study and the temperature changes in deeper tissues found in other studies, the effect of local heating or cooling seems to change knee joint temperature more intensely than has been generally thought.

Our findings on joint temperature increases after application of ligno-paraffin are at variance with the results of classic studies by Hollander and Horvath...
The probable explanation is that they measured the temperature only over a few minutes. When measurements are performed over a longer period as in our study, it is clear that the intraarticular temperature rises. These findings may have great consequences with regard to policies on treatment of arthritis.

In inflammatory joint diseases such as rheumatoid arthritis and probably in osteoarthritis, destructive enzymes are produced (19–26). The activities of these cartilage-degrading enzymes are influenced by local pH and joint temperature. At temperatures of 30°C or lower, the activity of destructive enzymes can be negligible, but at temperatures of ~35–36°C, as are generally found during active synovitis, the enzymatic breakdown of cartilage increases exponentially (1,2). Higher temperatures may thus lead to joint destruction (2,25,27). One means of reducing synovitis may be to decrease the joint temperature using physiotherapy procedures. We suggest that treatments in which the intraarticular temperature is increased should be used with caution (28–30).

Short-wave diathermy, as well as ligno-paraffin, did increase intraarticular temperature and may therefore be potentially harmful in acute or subacute arthritis or secondary synovitis in osteoarthritis. Local application of ice chips and local application of nitrogen-cold air, which reduced the temperature in the joint cavity by 9.4°C and 4.1°C, respectively, in healthy subjects, are probably more suitable treatments for patients with inflammatory joint diseases. Further investigations on this issue, in patients with arthritis, are warranted.

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