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CLINICAL REPORT

Thermal Effects of Emollients on Facial Skin in the Cold

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Ointments are traditionally used in Finland for protection against facial frostbite. Recent epidemiological reports showed unexpectedly, however, that the use of ointments is a statistically considerable risk factor for frostbite of the face and ears. The effects of 4 different emollients on facial temperature were studied in 46 acute cold exposures. The voluntary test persons sat in a cold chamber after emollients were applied thickly on half of the face, while the other half acted as an untreated control. Thermistors and an infrared scanner were used to measure skin temperature of symmetrical areas of the face. The thermal sensations on the corresponding sites were also recorded. Test emollients more often had an objectively cooling than a warming effect on facial skin. However, white petrolatum often produced a subjectively warming skin sensation. "Protective" ointments may cause a false sensation of safety, leading to increased risk of frostbite due to neglect of other protective measures. ***Key words: creams; ointments; frostbite; cold injury.***

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At least one superficial frostbite of the head occurs in 47% of men in Finland by the age of 19 years (1). Unprotected areas of the head (i.e. the ears and face) are among the most common locations of frostbite in Finnish conscripts, forming 44% of 2,054 cold injuries needing medical attention in 1976–89 (2). During the past 12 months 22% of 2,081 reindeer herders, living and working under high risk of cold injury, have experienced frostbite, mostly on the face and ears (3). The risk of frostbite on facial skin depends on many climatic and physiological (4, 5) parameters and on the protection of the head (2, 6), primarily by clothing.

In Finland, ointments have traditionally been used to protect the facial skin against cold injuries. In Finnish conscripts, 21% had used cold protective ointments, mostly at school age or earlier (1). In 25% of their families another member (mostly women and children) had also used emollients to prevent cold injuries (1). According to conventional belief, waterless ointments give the best protection against cold. However, in a large prospective epidemiological study with 913, mostly mild, frostbites of the head and 2,478 uninjured controls (2), the use of protective ointments was unexpectedly shown to be associated with a considerably increased risk of frostbite on the face and ears. In a retrospective questionnaire study (1) there was also a statistical association of the cumulative incidence of facial frostbite with the habit of using protective ointments in the cold. No reports were found in the scientific literature confirming any protective characteristics of ointments against frostbite.

The effect of different emollients on human facial skin temperature and on subjective thermal sensation was analysed in this study in experimental cold conditions. The magnitude of the effect of non-medicated emollients was compared with thermal asymmetry of the face and with some known vasodilative and vasoconstrictive agents.

MATERIAL AND METHODS

Test subjects and cold exposure

Acute cold exposures were carried out in a climatic chamber (−15°C, 3 m/s wind against the face). After obtaining informed consent, 24 voluntary and healthy male test persons (mean age 26 years, range 19–48 years), mostly medical students, sat in the chamber in each test for 25–30 min. Test subjects wore a Finnish army winter cap with the ears covered and warm clothing (thermal insulation 2.7 clothing units = 0.42 m^2K/W). The ambient temperature and wind speed were registered during each test. During cold exposure the facial skin temperature decreased from +32–34°C to around +10°C. The same test persons were not used for experiments until at least 48 h after the previous test.

Ointments and their application

Four emollients were studied; an oil-in-water (o/w) emulsion cream A (Aqualan L®, Orion Pharma, Espoo, Finland) containing vegetable oils, 4.25% glycerol and 65% water, a water-in-oil (w/o) emulsion cream B (Neribase®, Leiras Co., Turku, Finland) containing white beeswax, liquid paraffin, white petrolatum, no humectant and 30% of water and 2 different waterless ointments, C and D; C (Ceridal® lipogel, Rhone-Poulenc Rorer Co., Helsinki, Finland) containing synthetic long chain hydrocarbons with cyclosiloxan, and D consisting totally of a mineral grease, white petrolatum (vaselinum album), manufactured *ad modum* Pharmaca Nordica in local pharmacy, Oulu, Finland. These non-medicated emollients were tested in 46 cold exposures (A in 16, of which 3 were started "late" = 1 h from its application, B in 9, C in 10 and D in 11 exposures). In addition, 6 tests were performed with no emollient on either side of the face, in order to obtain a quantitative estimation of normal thermal asymmetry of face and to validate the test arrangement.

Two vasodilative liniments (Trafuril®, Ciba-Geigy, Helsinki and Muskelan®, Lääkefarmos, Turku, Finland) with 1% nicotinate as the pharmacologically active agent were studied in 3 tests. Four tests were performed with strong topical corticosteroid creams; 2 with 0.05% clobetasol-17-propionate (Dermovat®, Glaxo, Helsinki, Finland) and 2 with 0.1% halcinonide (Halocort®, Orion Pharma, Espoo, Finland). Corticosteroids are known to have vasoconstrictive properties (7, 8).

Emollients and topical preparations were applied at room temperature on half the face. The other half was left untreated as a control. Left and right facial halves were used equally for application and control to avoid bias caused by possible asymmetry of the test conditions. The amount of application was 1 g/half face, approximately 50 g/m^2. This intentionally exceeds by about threefold the average application of 16 g/m^2 used in topical therapy (9, 10) to demonstrate even a small thermal effect. In a majority of experiments the test persons entered the cold chamber 2 min after the application of the emollient. Application was performed 1 h before the cold exposure in 3 tests with o/w cream A to let its water content evaporate at room temperature. This has been shown to occur in about 20 min (11). Vasodilator liniments were applied 4 min before entering the cold chamber. In tests with corticosteroids the cold exposure was started 4 h after first application in 1 test and 2.5 – 3 h after the last of repeated (once daily) applications on 2 – 3 days in 3 tests in order to quantify their effect when the vasoconstrictive influence was expected to be present (7, 8).

Measurement of skin temperature

The skin temperature of 4 symmetrical locations on the forehead and cheeks was measured once a minute by using thermistors (YSI 400 series, Yellow Springs Instruments Inc., Yellow Springs, USA) with an accuracy of about 0.1°C. The location of the sensors is presented in Fig. 1. The sensors were attached to the skin with a small strip of adhesive tape (Transpore®, 3M, USA) before the emollient was applied. All sensors were connected to a portable Squirrel 1200 data logger in the lap of the test subject. Thermal difference between facial halves was calculated (i) by summarizing the temperature comparisons on the left and right sides of the forehead and cheeks at 5, 10, 15, 20 and 25 min after the application, and (ii) by comparing the average temperatures on the applied side with the untreated side of the forehead and cheeks during time period 13 – 23 min, when the decreasing temperature curve was moving into a plateau phase.

In the first 7 tests there were no thermistors on the cheeks. The criteria for abandoning temperature values for sensor detachment or electrical contact failure were no reading at all or 0°C. The changes in facial temperature were also measured continuously using a thermal infra-red (IR) scanner (Inframetrics 600, Inframetrics Inc., Billerica, Massachusetts, USA). The scanner was adjusted to 0.93 emittance and −15°C background. The visual temperature scale consisted of 20 colours. During cold exposure the range of the scale was usually widened from 10 to 20°C. Therefore the resolution of the colour differences was either 1.0 or 0.5°C. The temperature region was regulated downwards to sustain its ability to discern temperatures (best discernible in the middle area of the scale) while the skin temperature lowered. The scanner measured the temperature of pointed areas or spots with an accuracy of 0.1°C. Thermographic results were recorded on VHS videotape for further analysis. IR results were achieved by combining the face-half comparisons in 3 modes of observations (see also Fig. 1): (i) IR image was frozen at 5 min intervals from the application (at the same moments when thermistor results were used for comparison) to "still pictures", and the skin temperatures on symmetrical square areas (about 2 × 2 cm) on the forehead and cheeks were compared simultaneously, (ii) temperature differences between face halves (visible areas of the forehead and cheeks in frontal image) were compared visually by 1 of the authors (E.L.) in infra-red videotape recordings from the same still pictures, and (iii) temperature levels of horizontal graphs on the forehead and cheeks were recorded on both sides and compared from these same still pictures.

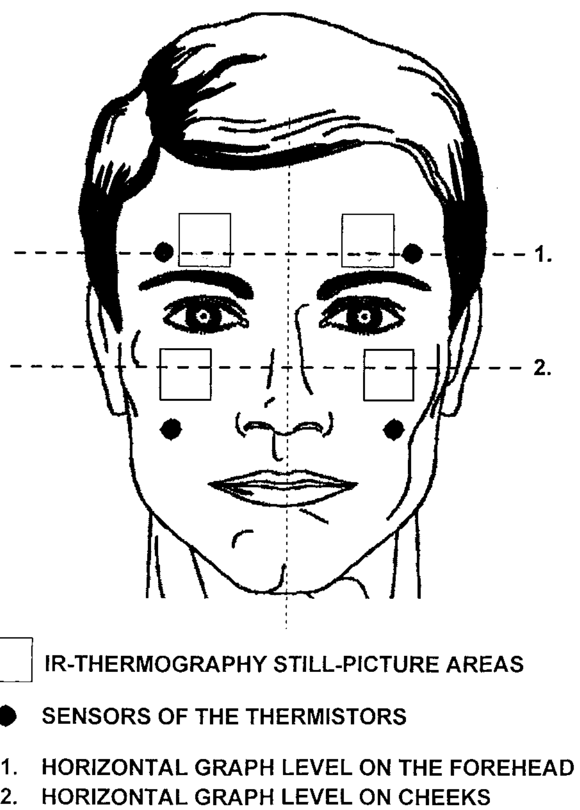

Fig. 1. The locations of thermistors, infra-red (IR) areas and horizontal graphs in the measurement of facial skin temperature.

Subjective thermal sensation

Test subjects were asked of their subjective thermal sensations in different facial locations. The perception of temperature difference between face halves was registered in the beginning, middle and at the end of each cold exposure (5, 15 and 25 min after the application). The location of the sensed difference was recorded.

Validation of methodology by tests without application

In the IR area registrations of 6 tests without application the mean thermal difference of the face halves was 0.7°C (0 – 2.2°C) on the forehead and 0.8°C (0 – 2.2°C) on the cheeks. This finding lead to a decision to regard only results ≥ 0.7°C as thermal differences in all calculations of objective results. In half (27/56) of the IR area registrations (4 – 5 observations per test separately on the forehead and cheeks) the temperature on both sides was equal. The right side was cooler in 11/56, the left in 18/56.

In thermistor measurements the average temperature difference of untreated facial halves was 1.2°C (0.1 – 3.7°C) on the forehead and 2.8°C (0.1 – 8.4°C) on the cheeks. In addition to 2 total detachments or electrical contact failures of thermistors, the half differences in 2 other thermistor measurements on the cheeks were so high that they lead the researchers to suspect partial sensor detachments on the cooler half. These numbers also had a remarkable influence on the average half difference.

A difference in skin temperature between face halves was sensed subjectively in 2/18 of comparisons without application. These 2 observations were both in the same test, only on cheeks, and the right side was cooler.

Statistics

For all proportions of summed results in Table I, a 95% confidence interval (95% CI) was calculated based on an assumption of a binomial distribution. The agreement of observed and expected distributions in proportion of cooling and warming effects of individual emollients was tested by using χ^2 test statistics.

RESULTS

Non-medicated emollients

Thermistor results. The detachment or electrical contact failure of 1 or both thermistors caused a rejection of 7/59

Table I. *Effect of all test emollients on facial skin temperature (T) in cold. Comparison of the applied half of the forehead and cheeks with the untreated half. Values ≥ 0.7°C were considered as thermal difference. Ambient temperature −15°C, wind 3 m/s against the face*

Method	Effect (sum of emollients A–D) Cooling n (%, 95% CI)	No effect n (%, 95% CI)	Warming n (%, 95% CI)	Observations n
Thermistors				
T at 5, 10, 15, 20 and 25 min (°C)	38 (51, 40–62)	16 (21, 12–30)	21 (28, 18–38)	75
Average T during period 13–23 min (°C)	37 (49, 38–60)	14 (19, 10–28)	24 (32, 21–43)	75
Infra-red scanner				
Area T at 5, 10, 15, 20 and 25 min (°C)	38 (41, 31–51)	43 (47, 37–57)	11 (12, 5–19)	92
Overall estimation at 5, 10, 15, 20 and 25 min (°C)	57 (62, 52–72)	20 (22, 13–30)	15 (16, 8–23)	92

comparisons on the forehead and 9/52 on cheeks, altogether. The different calculations of thermistor results are shown in Table I. In comparison between facial halves the application of tested emollients caused a cooling effect more often (in 49–51%) than a warming effect (in 28–32%). According to 95% CI values this indicates a significant finding. Different emollients showed variability in thermal responses, although this was not significant ($\chi^2 = 5.85$; degree of freedom = 8; $p > 0.50$). The cooling effect was most evident with emulsion cream B (12/17 of observations showed a cooling effect and 4/17 a warming effect) and A (11/24 a cooling effect and 6/24 a warming effect) in measurements at 5 min intervals. Lipogel C (6/15 cooling, 5/15 warming) and waterless white petrolatum D (9/19 cooling, 6/19 warming) were noted to have more thermoneutral effects, although still more often cooling than warming. After the water content of cream A had evaporated, it acted as thermoneutral (2/5 both cooling and warming). The comparisons of effects by individual emollients also showed consistent results in the second mode of calculation (average temperatures at period 13–23 min).

IR scanner results. The results of 2 modes of IR registrations are also shown in Table I. The skin temperature on the applied half was significantly more often cooler (41–62%) than on the untreated half (12–16%) following the results in thermistor registrations. Also this difference was significant when assessed by 95% CI values. In comparisons of horizontal graphs the applied half was cooler in 29/88 (33%) and warmer in 6/88 (7%). Creams A (15/32 of observations showed a cooling effect and 2/32 a warming effect) and B (7/18 cooling, 2/18 warming) together with lipogel C (9/20 cooling and 3/20 warming) had a cooling effect in a clear majority of comparisons in IR area measurements. White petrolatum D (7/22 cooling, 4/22 warming) had somewhat more thermoneutral effect (Fig. 2). Cream A acted still as cooling (3/6 cooling, 0/6 warming) after the evaporation of its water. The inter-emollient difference was not significant ($\chi^2 = 3.11$; degree of freedom = 8; $p > 0.50$). The responses of individual emollients were also similar in overall IR estimations and horizontal graphs.

Subjective thermal sensations. The thermal sensations of test subjects are specified with individual emollients in Table II. Test persons felt no thermal difference between facial halves in 51% of the tests. In the other half of the tests, the

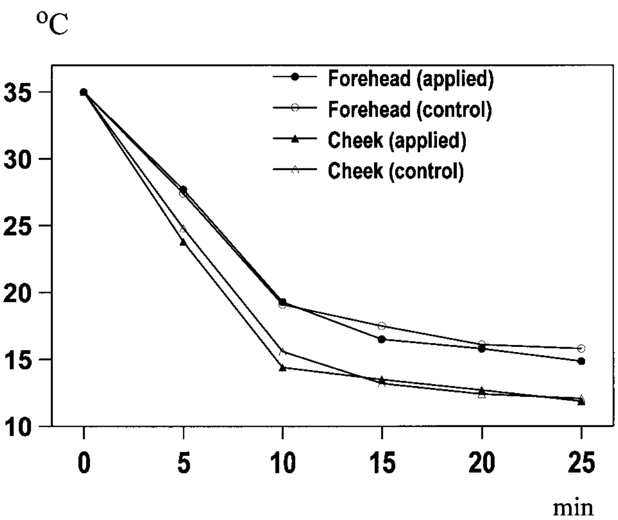

Fig. 2. The median skin temperatures on the applied (emollient D) and untreated halves of the forehead and cheeks during the acute cold exposures ($n = 11$) measured by infra-red scanner on symmetrical areas of about 2 × 2 cm. Ambient temperature −15°C, 3 m/s wind against the face.

applied side of the face was sensed as often as warmer as cooler. Cream A caused a cooler sensation much more often than a warming feeling, as well before as after the evaporation of its water content. White petrolatum differed significantly from the almost neutral effects of emollients B and C by causing a warming sensation more than twice as often as a cooling sensation. The inter-emollient difference was statistically almost significant ($\chi^2 = 18.1$; degree of freedom = 8; $p = 0.058$).

Pharmaceuticals

The pharmacologically active vasodilative liniments had a distinctive warming effect in IR area tests with an average difference of 3.8°C (0.4–5.6°C) on the forehead and 8.1°C (2.0–15.7°C) on cheeks between facial halves. Temporally the difference was maximal (6.2°C on average on the forehead and 13.7°C on cheeks) at 10 min after the application showing a diminishing tendency after that period. The warming effect of vasodilators was distinctly sensed by all test subjects. Topical corticosteroids lowered the skin temperature in IR-area comparisons on the average by 1.1°C on the cheeks, but

Table II. *The effect of individual test emollients A–D on the subjective sensation of facial skin temperature in cold. Comparison of the applied and untreated face halves at 5, 15 and 25 min after the application.*
Ambient temperature −15°C, wind 3 m/s against the face. Emollients were applied 2 min before cold exposure, except in tests marked A* in which cold exposure was started 1 h after the application to let the water content of cream A to evaporate first.

	Effect			
Emollient	Cooling (*n*)	Neutral (*n*)	Warming (*n*)	Total no. of observations
A	12	22	5	39
A*	4	5	–	9
B	5	15	7	27
C	7	16	7	30
D	6	12	15	33
All	34	70	34	138

had no significant effect on the forehead. In IR-area comparisons including both the cheeks and forehead the applied half was cooler in 3/8 and warmer in 2/8. Corticosteroid creams caused a subjectively cooling sensation in 6/12 and a warming feeling in 2/12 of observations.

DISCUSSION

The thermal effects of ointments in the cold can theoretically be based either on physical or physiological mechanisms. In a recent experimental study *in vitro,* emollients A–D did not physically show significant thermal protective effects even in a 10 times thicker layer than ordinarily used in topical therapy (11). The physiological effects of emollients could still influence the temperature of the living skin, e.g. by adjusting water permeability of the epidermis, blood circulation in the dermis, etc. If there is a real thermal effect on the skin, it should lead to a temperature difference between the applied and untreated symmetrical skin areas, as tested in this study. The experimental conditions resembled true conditions of cold injury, but were not continued to an actual risk of frostbite. Exposure to −15°C and 3 m/s wind produces a wind chill effect of 1186 kcal/m^2 h = 1377 W/m^2 (12) corresponding the cooling power of approximately −21°C in a calm environment and usually producing a "very cold" thermal sensation (13). The emulsion creams and waterless ointments chosen for testing represented a wide variety of emollients for getting an overview on the effects of this group. Objective measuring of the skin temperature is problematic, both theoretically and practically, when ointments are applied on the skin. When the sensors of thermistors are inside of the emollient layer, do they interfere with the ointment's thermal effect on this skin site? The sensors do not stick well on a greasy skin. A total of 17/208 (8%) of thermistor registrations in this study had to be rejected for the total detaching (or electrical contact failure) of the sensor, 9 of them on the applied side. Unconfirmed partial detachments of sensors were not rejected, in order to avoid bias of results by selection. However, this possibility made the IR results appear more reliable, although both methods gave usually consistent results. Emollients on the skin may also cause erroneous observations when measuring skin temperatures with IR thermography. On the applied side the scanner responds to thermal radiation from the surface of the ointment, not from the surface of the skin like the thermistors. However, according to an earlier study (11), the thermal insulative influence of even thick emollient layers is insignificant. Inframetrics 600 equipment scans IR emission with long wavelengths (8–12 μm) in over 95%, which makes the apparatus independent of the molecular structure on the surface of the measured object and gives comparable temperature values both to the skin and emollient layer. The applied half of the face was cooler significantly more often than warmer in side half comparisons with objective methods. The objective results (measured on the surface of the skin and emollients) and subjective sensations (perceived deeper in the skin) were often discrepant, especially when white petrolatum was used. This is a true skin sense, not merely a consequence of psychological awareness of protection, as this phenomenon was not noted when applying o/w cream A. The positive subjective experience of cold protectiveness by a great majority of ointment users (1) cannot therefore be trusted and may lead to a false sense of safety in the cold. The only consistent warming effect observed was caused by vasodilator liniments. For its short duration it is not likely to function successively in cold exposures lasting for hours. In addition to an effect on skin temperature, emollients may have other effects on skin increasing its risk of cold injury, such as moisturizing of the skin surface. The freezing temperature of the stratum corneum has been shown to rise with increased water content, both *in vitro* (14) and *in vivo* (15). This phenomenon could not be tested in this study, as the cold exposure did not lead to actual frostbite.

CONCLUSION

Tradition and subjective experience obtained from erroneous skin sensation seem to have formed the basis for the use of waterless commercial sports ointments, often consisting of petrolatum together with minor other ingredients, in prevention of facial cold injury. This sensation may lead to neglect of other preventive measures. The results of this study indicate that the emollients tested do not delay the cooling of facial skin temperature in cold. Together with epidemiological evidence of increased risk of frostbite in connection with emollient use (1, 2) and *in vitro* results of their lack of thermal insulation against cold even in thick application layers (11), the results in this study lead to a recommendation that the long-lived tradition to use "protective" ointments should be discouraged when cold exposure causes an actual risk of frostbite. Moisturizing of dry winter skin with emollients should be left to temperatures at which the risk of frostbite is absent, and preferably indoors.

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