**Original article**

Scand J Work Environ Health 1987;13(4):352-355

doi:10.5271/sjweh.2029

**Thermographic assessment of skin temperature during a cold provocation test.**

by Dupuis H

**Affiliation:** Institute of Occupational Health and Social Medicine, Johannes Gutenberg University, Mainz, Federal Republic of Germany.

This article in PubMed: [www.ncbi.nlm.nih.gov/pubmed/3433037](https://www.ncbi.nlm.nih.gov/pubmed/3433037)
Thermographic assessment of skin temperature during a cold provocation test

by Heinrich Dupuis, Prof Dr1

Since 1976 in Germany, vibration-induced white finger (VWF) has been included in the official list of occupational diseases, but there are yet no guidelines for the diagnostic methods to be used for this disorder. The Ministry of Research and Technology and the Central Association of the Industrial Injuries Insurance Institutes have financed research with the purpose of establishing diagnostic methods developed under laboratory conditions and tested in the field. However, for several reasons, there has been no attempt to obtain epidemiologically valid data. The results of this project will be used for the standardization of screening tests in occupational health examinations of vibration-exposed workers. The part of the project described in the present report concerns fingertip thermometry and infrared thermography on subjects with and without Raynaud’s phenomenon.

Subjects and methods

The investigation comprised a total of 317 subjects. Seventy-five of them were students [mean age 25.2 (SD 3.8) years], 10 were staff members of the Institute [mean age 29.2 (range 20–36) years], and 15 were lumberjacks [mean age 38.0 (SD 13.7) years] examined in the preliminary clinical study. Eighty-four lumberjacks [mean age 37.6 (SD 9.5) years], 65 grinders [mean age 34.5 (SD, 9.6) years], 62 metalworkers [mean age 37.9 (SD 8.5) years], and 6 stone cutters [mean age 40.3 (range 21–53) years] were studied in connection with the field occupational health examination. These workers were employed in steel, automobile, and brown-coal industries and in forestry. The total average vibration exposure time was 5 188 h for the lumberjacks and 13 329 h for the grinders, the times for the metalworkers and stone cutters varying greatly. Considering the heterogeneity in age, exposure time, and environmental factors of the study group and the small number of subjects, it was not appropriate (and not intended) to use the collected data for any epidemiologic research purposes.

In addition to other methods (general health examination, occupational history, anamneses on peripheral circulation and nervous function disturbances, nerve conduction velocity, vibration perception threshold, and temporary threshold shift) reported elsewhere (1), a cold provocation test was carried out, together with infrared thermography, and fingertip thermometry.

In a pilot study it was shown that water temperatures below 10°C gave rise to pain and therefore were not generally tolerated. A few subjects were excluded because of circulatory debility. At water temperatures above 10°C, a variation of 2°C did not influence the thermal reaction of the skin during the test. Doubling the time of hand immersion in the water led, however, to a prolongation of the rewarming time. For practical reasons it was desirable that the duration of the complete test not exceed 30 min. Therefore, in the field research, the conditions of the cold provocation test were standardized as follows: room temperature 22–24°C, acclimatization before the test 20 min, water temperature 15°C, immersion time 1 min, test duration 30 min.

The following two methods for measuring skin temperature were used simultaneously in all cases:

1. The skin temperature was measured during the test from a thermosensor attached to the volar surface of each finger-
The temperature was measured every 12 s, stored, computed, and recorded on a 6-color plotter. The fingertip thermometry system is shown in figure 1.

2. In order to obtain information on skin temperature not only at one point, but along the finger length and the hands, infrared thermography was also used. By way of temperature radiation, the system (as shown in figure 2) enables the recording of temperature images of the dorsal sides of both hands. Thus, during the test, 16 images could be recorded and stored in a computer. Special software allowed the analysis of temperature profiles along the finger and the drawing of rewarming curves for the measuring points on the fingertips (in figure 5 of the Results and Discussion section).

Results and discussion

The temperature measurements made on 90 fingers in a pilot study showed small differences between the volar and dorsal surfaces (mean 0.2°C, maximum 0.9°C). The results of the two thermometric methods did not differ very much in accuracy and always showed the same trend. The values of the fingertip thermometry sometimes tended to be lower than those measured with the infrared thermography, the reason possibly being the difficulty in thoroughly drying the skin of the area around the thermosensors after the cold provocation.

There is no absolute and generally agreed measure of "normal" and "pathological" reactions to guide the choice of the rewarming criterion. In principle it is, however, clear that fast rewarming is a sign of high dynamic activity of the muscles of the blood vessels, whereas delayed recovery is a symptom of weak dynamic activity. Different criteria may be used to follow this principle.

The background for the choice made in the present work was the following. Temperature recovery for healthy persons mostly showed exponential rewarming curves, ie, normally recovering peripheral vessels dilate some minutes after the end of the cold provocation.

Thus the skin temperature at the fingertips increases rapidly up to about 28°C or higher (curve 1 in figure 3). Further increase in skin temperature becomes continuously smaller and smaller however. Delayed recovery may be characterized by a temperature of < 28°C after 15 min (curves 2, 3, and 4 in figure 3). In this way the analysis of temperature recovery of 220 fingers of 222 subjects (lumberjacks, grinders, metalworkers, students) revealed the following three reaction types:

Normal recovery: Fingertip skin temperature of ≥ 28°C within 15 min
Figure 3. Examples of different recovery reactions after cold provocation in five fingers of one hand.

Figure 4. Recovery of fingertip temperature during a cold provocation test (mean, standard deviation, and significance for three groups with different types of recovery) — 222 subjects.

Moderate delay: Fingertip skin temperature of ≥ 28°C within 16—30 min

Strong delay: Fingertip skin temperature of < 28°C at end of test (30 min)

A more differentiated assessment did not seem justified. Both thermometric methods may be used for the evaluation of cold provocation tests.

For the initial evaluation of the reaction type of a subject the "worst" of the 10 fingers was decisive. If all 10 fingers showed normal recovery, the subject would be evaluated as normal. If one or more fingers showed moderate delay or strong delay, the subject was placed in the moderate-delay or strong-delay group, respectively. Figure 4 shows the summarized assessment of the skin temperature recovery of 220 subjects during the cold provocation test. It may be seen that at 15 min the mean skin temperature of the worst finger increased to 32.1°C in the normal group, to 24.5°C in the moderate-delay group, and only to 22.4°C in the strong-delay group. All group differences were statistically significant. At the end of the test (30th minute) the skin temperature of the normal group reached 32.7°C, that of the moderate-delay group 31.1°C, and that of the strong delay group 24.7°C. The differences between the normal and strong-delay groups and between the moderate-delay and strong-delay groups were statistically significant.

Within the normal group there was no statistically significant increase in skin temperature between the 15th and 30th minutes, ie, the recovery process was complete already at the 15th minute. The corresponding increase in the moderate-delay group was statistically significant, signifying that the main recovery took
place after the 15th minute. For subjects of the strong
delay group however, there was only a very small in-
crease in skin temperature. This finding demonstrates
a very low level of peripheral circulation. On the basis
of the statistical analysis made, it may be concluded
that an assessment according to three different reaction
types (normal, moderate delay, strong delay) is
justified.

In a recent study by Steeger (personal communica-
tion) on intraindividual variation in skin temperature
reaction with eight repetitions of the cold provocation
test on different days, a very high consistency (vari-
ation coefficient < 5%) in temperature recovery was
demonstrated for eight of nine healthy subjects. Varia-
tion in temperature reaction may reflect the different
physiological types (acrohomoiothermal, acropoikilo-
thermal) of Kliiken (2) (1964). Further research on
intraindividual variation between VWF patients in cold
provocation tests is needed.

The kind of evaluation of cold provocation tests with
fingertip thermometry or infrared thermography de-
scribed in this report is based on temperature measure-
ments from reference points of ten fingertips and,
therefore, allows a comparison of temperature re-
covery between all the fingers of a subject. This pro-
cedure proved to be very important since, in many
cases of VWF, the peripheral circulation disturbance
only concerns single fingers, mostly exposed to vibra-
tion and static forces. On the contrary, Raynaud's phe-
nomenon of constitutional origin generally shows
delayed temperature recovery for all fingers. A cold
provocation test of this kind therefore may be of dif-
ferential diagnostic value.

Infrared thermography, however, gives additional
information which may be used in a second step of
assessment. With this method it is possible to evaluate
circulation disturbances on the basis of spatial and
temporal changes in finger skin temperature.

Figure 5 shows the mean skin temperature at four
points along the fingers at 14 and 30 min of the test
(corresponding to the 13th and 29th minutes after the
end of the cold provocation). In the 1732 fingers
assessed as normal, the temperature was high at distal
points 2 and 3. In the two proximal points (1 and 0),
however, the temperature was 0.5—1.0°C lower at 14
min than at 30 min. In the 257 fingers given a
moderate-delay rating, the temperature distribution at

References
1. Dupuis, H. Untersuchung zu vibrationsbedingten Durch-
blutungsstörungen der Hände. Schriftenreihe des Haupt-
verbandes der Gewerblichen Berufsgenossenschaften,
Sankt Augustin 1986.
2. Kliiken, N. Regulationsmechanismen an den Akren. Bibl
Anat 4 (1964) 227—233.