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Cold provocation test results from a 1985 survey of hard-rock miners in Ontario

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PELMEUR PL, ROOS J, LEONG D, WONG L. Cold provocation test results from a 1985 survey of hard-rock miners in Ontario. *Scand J Work Environ Health* 13 (1987) 343–347. A total of 143 miners, 6 ex-miners, and 42 referents from five mines in northern Ontario were examined with a cold provocation test. The skin temperatures, measured by thermocouples at the tips of the fingers and thumbs were recorded at 5-s intervals throughout the immersion in cold water (10°C) for 10 min and during the recovery period. The finger skin temperature was followed until 99 % recovery had occurred as compared to the starting temperature. For the referents and the vibration-exposed subjects, the results by separate stage of the Taylor-Pelmeur scale for hand-arm vibration syndrome were compared. There were statistically significant differences in the mean finger temperature at the 50, 75, 90, and 95 % recovery times between stages 0, 0₁/0_N, and stages 1 through 3 combined, as well as significant differences between stages 1, 2, and 3. The mean temperature at 10 min and the mean hyperemia temperature for eight fingers combined were compared between the miners and referents. There were significant differences in the mean temperature at 10 min and in the hyperemia temperature between the referents and miners in stage 0₁/0_N, as well as between the referents and the miners in stages 1 through 3 combined. For the worst finger (defined as that with the lowest temperature at 10 min) there was an increasing trend towards a lower hyperemia temperature and delay in recovery time from stage 0 to stages 2 and 3 combined. Comparison of the positive predictive values of the cold provocation test results for the worst finger supports the use of a staging of blanched fingers based on social and work interference as the grade of severity, rather than the use of a blanching index rating.

Key terms: finger skin temperature, Raynaud's phenomenon.

Objective tests to confirm the presence of Raynaud's phenomenon and grade its severity are sorely needed by clinicians, particularly in field studies. The cold provocation test has been frequently used for such purposes, and the present investigation was carried out to evaluate this use.

Subjects

A total of 227 miners or ex-miners and 60 referents were examined from five mines in northern Ontario. Ninety-six subjects were rejected from the analysis because of a history of trauma, an abnormal medical history, or an unsatisfactory clinical state. A total of 143 miners, 6 ex-miners, and 42 referents remained (table 1). The mean age of the referents was 34.8 years, and that of the miners 35 years. The daily exposure to vibratory tools averaged 2.1 h. The prevalence of finger blanching by Taylor-Pelmeur stages 1, 2, and 3 of the hand-arm vibration syndrome (2) was 43 % among the miners, and the mean latency interval was 10.4 years.

Methods

As previously described (1), each subject was examined lying down with his body and legs completely wrapped in an elec-

tric blanket (heated to 45°C) and covered with a wool over-blanket except for the arm to be examined. Thermocouples were applied to the tips of the fingers and thumb with surgical tape and velcro straps, and one was placed in the armpit. When the body temperature measured by the armpit thermocouple was constant at 34–36°C, a sphygmomanometer was placed around the wrist and inflated to 30 mmHg (4 kPa) above the systolic blood pressure, and the hand was immersed in cold water. The water was maintained at a constant temperature of 10°C by thermostat control, and the room temperature for the study was maintained at 20–23°C. The skin temperatures, measured by thermocouples, at the tips of the fingers and thumb were recorded at 5-s intervals throughout the immersion for 10 min and during the recovery period. At 5 min of immersion, the pressure cuff was released. At 10 min, the hand was removed from the water and gently dried. The velcro straps were removed and replaced by dry ones. The hand was placed at rest in a horizontal position. The finger skin temperatures recorded on the tracer chart were followed until they were at 1 % of the starting skin temperature. The opposite hand was then examined in the same way.

Table 1. Surveyed population.

Group	Examined	Rejected	Accepted
Ex-miners	16	10	6
Miners	211	68	143
Referents	60	18	42 ^a
Total	287	96	191

^a Includes three cases of constitutional white finger which were excluded from the analysis of the results of the cold provocation test.

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Figure 1. Skin temperature response curves (A, B, and C) determined for the subjects.

Results and discussion

The mean values of the skin temperature measurements of the referents and miners, grouped as stage 0+0_T/0_N and stages 1–3 of the Taylor-Pelmeur scale, were compared (table 2). The differences between the groups were significant for the temperature at 10 min of immersion (T_{10}) and for the temperature at the time of hyperemia (T_H) ($P < 0.002$). In addition, the differences between the groups were significant ($P < 0.002$) for the length of the 50, 75, 90, and 95 % recovery times.

Likewise, between stages 1, 2, and 3 there were significant differences for T_{10} and T_H (table 3) and for the 75, 90, and 95 % recovery times (table 3).

During the cold provocation, three distinct skin temperature response curves were observed which were termed A, B, and C (figure 1). The temperature for curve type A did not go below 11°C. For curve type C it went below 11°C and remained there throughout the cold provocation. For curve type B the temperature went below 11°C but progressively rose with or without a hyperemic peak. It can be noted from table 4 that curve type A was the most common for all the groups but the mean of T_{10} was progressively lower from stage 0 to stage 2 of the Taylor-Pelmeur scale. Curve type C could be found in every group, but it was in-

Table 2. Results of the cold provocation test of the miners (grouped according to Taylor-Pelmeur stages of hand-arm vibration syndrome) and the reference group — All digits except the thumbs included.

Group	Number of digits	Skin temperature ^a (°C)						Recovery ^b (min)							
		T_5		T_H^c		T_{10}^c		50 % ^d		75 % ^d		90 % ^d		95 % ^d	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Miners															
Stage 0+0 _T /0 _N	696	12.2	1.3	17.1	4.1	16.5	4.1	9.3	1.9	12.8	3.1	14.8	4.6	15.9	5.1
Stages 1–3	448	12.2	1.5	6.0	4.1	15.4	4.2	10.3	2.9	14.2	5.1	16.3	6.1	17.5	6.5
Referents	312	12.3	1.6	18.4	4.0	17.6	3.9	8.9	1.8	11.7	1.6	13.4	2.3	14.5	2.8

^a T_5 = skin temperature at 5 min of cold provocation, T_H = skin temperature at the time of hyperemia, T_{10} = skin temperature at 10 min of cold provocation.

^b Time needed for the skin temperature after the cold provocation to recover to 50, 75, 90, and 95 % of the temperature before the provocation.

^c Differences between the groups at T_{10} and T_H were significant (all P values < 0.0002).

^d Differences between the groups were significant (all P values < 0.002).

Table 3. Results of the cold provocation test of the miners in Taylor-Pelmeur stages 1–3 of the hand-arm vibration syndrome — All digits except the thumbs included.

Stage of hand-arm vibration syndrome	Number of digits	Skin temperature ^a (°C)						Recovery ^b (min)							
		T_5		T_H^c		T_{10}^c		50% ^d		75 % ^d		90 % ^d		95 % ^d	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	240	12.2	1.5	17.2	4.2	16.6	4.2	9.5	2.5	12.4	2.6	14.2	3.7	15.4	4.3
2	200	12.2	1.5	14.7	3.6	14.1	3.7	11.2	3.1	16.0	6.3	18.3	7.3	19.6	7.6
3	8	12.0	1.2	11.7	1.3	11.1	1.4	11.3	1.5	23.1	4.7	26.1	4.6	27.4	4.8

^a T_5 = skin temperature at 5 min of cold provocation, T_H = skin temperature at the time of hyperemia, T_{10} = skin temperature at 10 min of cold provocation.

^b Time needed for the skin temperature after the cold provocation to recover to 50, 75, 90, and 95 % of the temperature before the provocation.

^c Differences were significant between stages 1, 2, and 3 (all P values < 0.0002).

^d Differences were significant between stages 1, 2, and 3 (all P values < 0.005).

dicative of latent, as well as actual, vasospastic disease and was more frequently associated with the exposed subjects.

A finger blanching index rating (1, 3, and 6 for blanching of the distal interphalangeal, middle interphalangeal, and metacarpophalangeal joints of the fingers, respectively) was used for all the miners in stages 1 through 3 of the Taylor-Pelmeur scale. This rating, when compared with the stage grading, could not differentiate stage 2 from stage 3. Table 5 compares the mean of the T_H and T_{10} of the miners with different ratings. Both the T_{10} and T_H decreased as the finger blanching index ratings increased, and significant differences were noted between ratings 0 and 3, 0 and 6, and 1 and 6. The recovery times increased with the index ratings (table 5) at 75, 90, and 95 %

Table 4. Mean of the skin temperatures of the miners in Taylor-Pelmeur stages 0, 0_{7/10N}, 1, and 2 of the hand-arm vibration syndrome and the reference group after 10 min of cold provocation (T_{10}) according to the type of response curve — All digits except the thumbs included.

Group	Response curve ^a					
	Type A		Type B		Type C	
	Percentage of group	T_{10}	Percentage of group	T_{10}	Percentage of group	T_{10}
Miners						
Stage 0	85	17.2	11	15.2	4	10.4
Stage 0 _{7/10N}	76	17.4	16	13.5	8	10.3
Stage 1	82	17.4	10	15.5	8	10.5
Stage 2	61	16.1	9	12.8	30	10.5
Referents	85	18.0	14	15.7	1	10.5

^a Type A = temperature did not go below 11°C, type B = temperature went below 11°C but progressively rose with or without a hyperemic peak, type C = temperature went below 11°C and remained there.

Table 5. Results of the cold provocation test of the miners in Taylor-Pelmeur stages 1—3 of the hand-arm vibration syndrome according to their finger blanching index rating — All digits except the thumbs included.

Finger blanching ^a	Number of fingers	Skin temperature ^a (°C)						Recovery ^b (min)							
		T_5		T_H^c		T_{10}^d		50 % ^e		75 % ^e		90 % ^e		95 % ^e	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0	173	12.2	1.6	16.8	4.3	16.2	4.3	9.7	2.7	13.0	3.4	15.1	4.5	16.3	5.1
1	71	12.5	1.6	16.2	4.0	15.6	4.2	10.7	3.5	14.3	5.0	16.1	5.8	17.2	6.0
3	125	12.1	1.3	15.5	3.8	15.0	3.8	10.5	2.7	14.8	6.3	17.0	7.6	18.3	7.9
6	79	12.2	1.2	14.9	4.0	14.2	4.1	10.9	2.9	15.8	5.7	17.9	6.5	19.0	6.8

^a 0 = no blanching, 1 = blanching of the distal interphalangeal joint, 3 = blanching of the middle interphalangeal joint, 6 = blanching of the metacarpophalangeal joint.

^b Time needed for the skin temperature after the cold provocation to recover to 50, 75, 90, and 95 % of the temperature before the provocation.

^c T_5 = skin temperature after 5 min of cold provocation, T_H = skin temperature at the time of hyperemia, T_{10} = skin temperature after 10 min of cold provocation.

^d Differences were significant between ratings 0—3, 0—6, and 1—6 (all P values < 0.05).

^e Differences were significant between ratings 0—3 and between 0—6 (all P values < 0.02).

of skin temperature recovery, and the differences were significant between the 0 and 3 and the 0 and 6 ratings.

The results of the cold provocation test, grouped by the Taylor-Pelmeur stage of hand-arm vibration syndrome and by the finger blanching index rating, were further analyzed with reference to the worst finger, defined as that with the lowest T_{10} . The mean temperatures for the worst finger are compared in table 6 by stage, and a progressive lowering of temperatures for T_{10} and T_H can be noted by stage. Included in table 6 are reference means for temperatures by stage, derived by rounding the figures to the nearest 0.5°C and incorporating appropriate limits to differentiate the stages. Table 7 similarly shows the mean temperatures and reference means for skin temperature at the 50 and 75 % recovery times. The mean temperatures and reference means for the worst finger with respect to the extent of finger blanching (ie, the blanching index) were determined and are shown in table 8, along with the mean skin temperatures for the 50 and 75 % recovery times. It can be seen that there was a progressive decrease in temperature for T_{10} and T_H , but the increases in recovery times were less consistent.

Table 6. Results for the "worst" finger, ie, that with the lowest temperature at 10 min of cold provocation (T_{10}), of the miners (grouped by Taylor-Pelmeur stage of the hand-arm vibration syndrome) and the reference group in comparison to reference values (derived by rounding the figures to the nearest 0.5°C and incorporating appropriate limits to differentiate the various stages of the syndrome).

Group	Number of workers	Skin temperature (°C)				Reference mean (°C)
		T_H^a		T_{10}		
		Mean	SD	Mean	SD	
Miners						
Stage 0	58	13.8	2.4	13.0	2.1	13.5
Stage 0 _{7/0_N}	29	13.9	3.0	13.3	3.0	
Stage 1	30	13.6	2.6	13.0	2.1	
Stage 2	25	11.7	1.7	11.2	1.7	11.0
Stage 3	1	10.2	.	10.0	.	10.0
Referents	39	15.0	2.8	14.2	2.6	14.5

^a Skin temperature at the time of hyperemia.

The reference means by the Taylor-Pelmeur stage of the hand-arm vibration syndrome and by the finger blanching index were used to determine the sensitivity and specificity of the cold provocation test. The sensitivity refers to the proportion of individuals with the hand-arm vibration syndrome, according to the Tay-

Table 7. Time needed after cold provocation for 50 and 75 % recovery of the skin temperature recorded before the test of the miners (grouped by the Taylor-Pelmeur stage of hand-arm vibration syndrome) and the reference group, as well as the reference values (derived by rounding the figures to the nearest 0.5°C and incorporating appropriate limits to differentiate the various stages of the syndrome).

Group	Number of workers	50 % recovery (min)			75 % recovery (min)		
		Mean	SD	Reference mean	Mean	SD	Reference mean
Miners							
Stage 0	58	10.6	1.2	10.5	13.1	2.8	14.0
Stage 0 _{T/0_N}	29	10.6	1.3		14.2	4.9	
Stage 1	30	11.0	1.2	11.0	12.7	2.4	
Stage 2	25	13.3	3.7	13.5	19.7	7.8	20.0
Stage 3	1	10.3			26.2		26.0
Referents	39	10.0	1.3	10.0	12.2	1.6	

Table 8. Skin temperatures during, and recovery times of the skin temperature after, the cold provocation test, as well as the reference values for skin temperatures during the test, according to the finger blanching index ratings — Results for the “worst” finger, ie, that with the lowest temperature after 10 min of cold provocation (T_{10}).

Finger blanching ^a	Number of workers	Skin temperature (°C)					50 % recovery time (min)		75 % recovery time (min)	
		T_H^b		T_{10}		Reference ^c mean	Mean	SD	Mean	SD
		Mean	SD	Mean	SD					
0	19	13.4	2.9	12.7	2.3	13.5	11.2	1.6	13.9	3.9
1	12	13.0	2.1	12.3	2.2	12.5	12.7	4.0	17.1	7.2
3	15	12.6	1.9	12.1	2.0	12.0	12.1	3.1	16.3	8.7
6	10	11.2	1.8	10.9	1.5	11.0	12.5	2.7	18.7	6.1

^a 0 = no blanching, 1 = blanching of the distal interphalangeal joint, 3 = blanching of the middle interphalangeal joint, 6 = blanching of the metacarpophalangeal joint.

^b Skin temperature at the time of hyperemia.

^c Derived by rounding the figures to the nearest 0.5°C and incorporating appropriate limits to differentiate the various stages.

Table 9. Validity of the cold provocation test by stages 1 and 2 + 3 of the Taylor-Pelmeur scale for the hand-arm vibration syndrome.

	H (%)	T_{10} (%)	50 % recovery time (%)	75 % recovery time (%)
Comparison with exposed workers				
Sensitivity ^a	68	70	39	38
Specificity ^b	46	37	84	72
Positive predictive value ^c	46	43	63	48
Comparison with all workers				
Sensitivity ^a	68	70	39	38
Specificity ^b	53	43	85	76
Positive predictive value ^c	40	36	55	42

^a Proportion of individuals with the hand-arm vibration syndrome who are properly classified as having the syndrome according to the cold provocation test (true positives divided by the sum of true positives and false negatives).

^b Proportion of individuals without the syndrome who are properly classified as not having the syndrome according to the cold provocation test (true negatives divided by the sum of the false positives and true negatives).

^c Proportion of individuals with a positive test result for the cold provocation test who actually have the syndrome (true positives divided by the sum of the true positives and false positives).

Table 10. Validity of the cold provocation test by the finger blanching index ratings 1 and 3 + 6.^a

	H (%)	T_{10} (%)	50 % recovery time (%)	75 % recovery time (%)
Comparison with exposed workers				
Sensitivity ^b	73	76	35	46
Specificity ^c	45	38	89	76
Positive predictive value ^d	33	31	54	41
Comparison with all workers				
Sensitivity ^b	73	76	35	46
Specificity ^c	52	43	92	79
Positive predictive value ^d	28	26	54	37

^a See table 5 for a definition of the ratings.

^b Proportion of individuals with the hand-arm vibration syndrome who are properly classified as having the syndrome according to the cold provocation test (true positives divided by the sum of true positives and false negatives).

^c Proportion of individuals without the syndrome who are properly classified as not having the syndrome according to the cold provocation test (true negatives divided by the sum of the false positives and true negatives).

^d Proportion of individuals with a positive test result for the cold provocation test who actually have the syndrome (true positives divided by the sum of the true positives and false positives).

lor-Pelmeur classification, who are properly classified as having the syndrome according to the cold provocation test (true positives divided by the sum of true positives and false negatives). The specificity refers to the proportion of individuals without the syndrome who are properly classified as not having the syndrome

according to the cold provocation test (true negatives divided by the sum of the false positives and true negatives). The positive predictive value refers to the proportion of individuals with a positive test result for the cold provocation test who actually have the syndrome (true positives divided by the sum of the true

positives and false positives). The results have been tabulated by stage in table 9 and by finger blanching index in table 10. The comparisons are made both for the exposed workers and for all the workers combined. It shows that the cold provocation test is sensitive and specific enough to verify vasospastic disease, as well as finger blanching. However, the positive predictive values for grouping by stage (36—46 % for immersion reference temperatures, 42—63 % for recovery times) are somewhat better than grouping by blanching index (26—33 % for immersion reference temperature and 37—54 % for recovery times).

Conclusions

The cold provocation test, as described and used in this investigation, has proved to be a feasible and practical test for use in field surveys of vibration-exposed workers.

In assessments of the results of a cold provocation test, the T_H and T_{10} of the worker's worst finger and the times at 50 and 75 % of skin temperature recovery should be compared with reference means. The test results will help to confirm the diagnosis of Raynaud's phenomenon and the verification of the stage of the hand-arm vibration syndrome. Since the positive predictive value of the cold provocation test is lower with the blanching index, grading the severity of the hand-arm vibration syndrome by such means as the Taylor-Pelmear scale used in the present study is preferable.

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