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DIAGNOSTIC VALUE OF FINGER THERMOMETRY IN ASSESSMENT OF HAND–ARM VIBRATION SYNDROME

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Finger thermometry and cold provocation test were performed in 90 chain-saw workers and 58 healthy controls. The workers were grouped according to the Taylor–Pelmear scale of hand–arm vibration syndrome into subgroups 0, 1, 2, 3. The recovery rate reflected passive vasodilative ability. According to the results of the study, the test could differentiate the subjects with clinically manifest vibration–induced white fingers (stages 1, 2 and 3) from the controls. The discriminating threshold of recovery rate with regard to Raynaud's phenomenon was 90%. With that diagnostic limit the above method was sensitive and specific enough to verify vibration–induced vasospastic disorders and therefore could be recommended for their surveillance.

Key terms: chain-saw workers, finger skin temperature, peripheral circulatory disturbance, Raynaud's phenomenon, recovery rate, vibration–exposed workers, vibration–induced white finger

Damage to the peripheral circulation, nervous system, muscles, bones and joints, induced by occupational exposure to hand transmitted vibration is, by international agreement, called hand–arm vibration syndrome (1). Vascular symptoms are known as traumatic vasospastic disease, Raynaud's phenomenon of occupational origin or vibration-induced white finger (VWF). Today such health disturbances have become widespread in many industries, and methods are needed for their objective verification. A case history and a questionnaire are not always the best means for assessing functional vascular disorders, especially when industrial injuries benefit may be involved. Therefore, various tests (2–15) have been developed to objectively assess peripheral circulatory disturbances. However, no single method has yet been generally accepted for screening or diagnosing occupational Raynaud's phenomenon (6, 7, 13, 16–18).

The thermometric method evaluates peripheral vascular reactivity based on the fact that finger skin temperature depends on the rate of blood flow through the skin (19). Since the occurrence of white finger is secondary to an isolated decrease in skin circulation rather than to hyperreactivity of the main digital arteries (20), finger thermometry can be used to objectively assess these changes in finger skin. Therefore, skin temperature measurements after cold water immersion are recommended as a screening test for VWF (8, 19). However, the method has not been fully recognized. This simple and low cost test, easy to perform even in field conditions, is considered useful on a group basis (7, 14). Many variations of the test have been presented and the evaluation of the results has been variable (7, 8, 10). For this reason, this paper presents finger skin temperature recordings in vibration exposed workers and aims to evaluate the suitability of the test for verification of VWF.

SUBJECTS AND METHODS

The study was carried out in 90 male chain-saw workers aged 26–58 years (mean 47) who were referred to the hospital because of coldness, white finger, weakness, pain, numbness or tingling in the hands. They had operated chain-saws from 6 to 37 years (mean 23). Depending on the severity of the symptoms, the subjects were classified according to the Taylor–Pelmear scale (1) into four subgroups: 0, 1, 2, 3. A group of 58 healthy men, aged 23–58 years (mean 46), without exposure to vibrating tools and with no symptoms of finger blanching, constituted a control group. None of them were receiving any cardiovascular medication or had a history of any disease related to Raynaud's phenomenon. The groups did not differ statistically with regard to age (Table 1). The number of current smokers and right-handers was equal in both groups.

Table 1. *Some relevant parameters in the study groups*

Group	Number of subjects	Age* (years)	Chain-saw usage* (years)
Chain-saw workers	90	47.6±7.8 (26–58)	23.0±8.1 (6–37)
stage 0	24	47.2±8.1 (36–57)	19.6±8.8 (10–35)
1	21	50.2±2.9 (39–58)	18.8±7.8 (12–37)
2	25	45.3±8.3 (28–57)	28.5±4.9 (8–30)
3	20	47.5±6.4 (36–55)	25.1±5.1 (15–30)
Controls	58	45.4±7.2(23–58)	–

*Mean ± Standard deviation (Range)

The subjects, wearing light clothes, were examined in a sitting position with the arms held at the midsternum level, without moving and after 30 minutes adaptation. Smoking was prohibited for at least one hour before the test. The room temperature ranged from 20 to 24 °C and noise and air currents were reduced to a minimum. Skin temperature was recorded before the cold provocation test, at the end of the test and after a 10 minute rest at room temperature (19). Cold provocation was provided by immersing the hand up to the wrist in cold water at 10 °C for 10 minutes and after immersion the hand was dried by light towelling (14, 19, 21). The test was carried out in winter when vascular symptoms of vibration syndrome were more marked.

Skin temperature was measured with a contact digital thermometer. The test finger was the one in which the most severe attacks of white finger had occurred in chain-saw workers and the middle finger of the right hand in controls. A probe with a NiCrNi thermocouple was placed on the volar side of the distal phalanx of the test finger.

The authors analysed skin temperature before and at the end of the cold provocation test and 10 minutes after the test. The rewarming response was expressed as the recovery rate (13):

$$\text{Recovery rate (\%)} = \frac{T_{10} - T_C}{T_B - T_C} \times 100$$

where T_{10} was the skin temperature 10 minutes after the end of the cold provocation test, T_B was the skin temperature before the cold test and T_C the temperature at the end of the test.

For statistical analysis Student's t-test was used, and both the sensitivity and specificity of the method were also calculated.

RESULTS

The chain-saw workers had significantly lower values of all examined temperature variables than the controls (Table 2). Initial temperature discriminated subgroups 2 and 3 (P<0.01) from the controls. Skin temperature immediately after the test was lower in all subgroups. The temperature 10 minutes after the test distinguished subgroups 1 (P<0.05), 2 and 3 (P<0.01) in relation to the controls. The recovery rate differed significantly in subgroups 1, 2 and 3 (P<0.01) in relation to the controls.

Table 2. *Skin temperature before and after cold provocation test in chain-saw workers grouped according to the Taylor–Pelmear scale and in a control group*

Group	Skin temperature (°C)+			Recovery rate (%)
	Before test	Immediately after test	Ten minutes after test	
Chain-saw workers	29.3±3.7**	13.4±3.1**	26.2±4.8**	77.0±19.9**
Stage 0	30.5±2.1	14.4±2.1**	29.1±2.8	85.5±19.1
1	30.5±3.6	15.8±3.4**	27.9±5.3*	78.2±20.3**
2	27.8±3.2**	12.3±2.1**	23.7±3.5**	65.4±18.8**
3	28.1±4.9**	12.1±2.9**	23.7±4.5**	61.9±22.0**
Controls	30.9±1.8	18.3±3.9	29.5±3.6	91.9±28.1

+Mean ± Standard deviation
*P<0.05; **P<0.01 (t-test, compared with controls)

Table 3. *Sensitivity and specificity of the recovery rate for diagnosing VWF with regard to the history of finger blanching (stages 1, 2, 3 of the Taylor–Pelmear scale)*

Limit	Comparison with exposed workers		Comparison with all subjects	
	Sensitivity	Specificity	Sensitivity	Specificity
< 90%*	75	79	75	83
< 75%	50	69	50	72

Values expressed as percentages
*Lower normal limits (mean ± 2 standard error) from controls

Table 3 presents the sensitivity and specificity of the temperature recovery rate for assessing VWF. The sensitivity is expressed as the incidence of true positive test results in subjects with VWF, according to the Taylor-Pelmear classification. The specificity is expressed as the incidence of the true negative test results in subjects without VWF (10, 12). Comparisons were made for the exposed workers as well as for all the examined subjects. The lower normal limit was the mean ± 2 standard errors of the control group. However, the sensitivity and specificity were also calculated for other possible limits to choose the best options for diagnosing VWF.

DISCUSSION

Besides the theory of the hyper-response of vessels to cold, there is also the hypothesis that the pathophysiological defect in VWF is the failure to recover from cold stimulus (22). The majority of VWF studies have concentrated on the examination of vasoconstriction, whereas damage to passive or active vasodilative function has received less attention (14). Therefore, in the present investigation skin temperature was recorded not only before and immediately after the test, but also ten minutes after the rewarming, and the recovery rate was then calculated. Our results show lower fingertip temperature before, at the end of the cold stress and after rewarming time in chain-saw workers than in controls. These results corroborate the reports of other authors (19, 20, 23, 24). However, after dividing the group of chain-saw workers into subgroups according to Taylor-Pelmear stages, it is evident that the skin temperature before the test cannot discriminate subgroups 0 and 1 from controls. That means that this thermometric parameter is not suitable for verification of VWF in the early stages of the disease. On the contrary, the skin temperature taken immediately after the cold test differentiated all subgroups in relation to the control group.

The temperature values, however, cannot serve as indicator of rewarming (14). According to the present study the temperature measured ten minutes after the cold test and the recovery rate could distinguish chain-saw workers with clinically manifested VWF from controls and therefore were considered satisfactory for assessing persistent digital vasospasm and passive vasodilative function. The recovery rate as a relative expression of temperature recovery fitted better the dynamic nature of the function test and is more suitable for practical use. A lower recovery rate (13, 25) and rewarming or recovery time (3, 7, 14, 20, 23, 26) in vibration exposed workers were also reported in earlier studies.

In our investigation, the sensitivity and specificity of the recovery rate were calculated to discriminate the thresholds of 75% and 90%. The discriminating threshold of 90% for the recovery rate determined, with regard to a positive history of VWH, the sensitivity of 75% and the specificity of 83%. *Virokannas and Rintamaki* (14) reported very similar values for the sensitivity (67%) and specificity (70%) of the rewarming rate. According to *Bovenzi* (7) temperature recovery had a sensitivity of 60% and a specificity of 92%; the respective percentages as quoted by *Pelmear and co-workers* (10) were 38 and 76. Despite the fact that finger skin temperature depends on individual factors and environmental parameters, our results demonstrate that the thermometric method shows satisfactory sensitivity and specificity for surveying VWF. Moreover, the method may be of interest for evaluation of vasodilatory therapy and prognosis of the reversibility of vasospastic disorders.

CONCLUSION

The vascular response to cold provocation in the fingers shows considerable variation, making it difficult to exactly define the border between normal and pathological reactions. No single test, when applied on an individual basis, can distinguish with certainty between vibration-exposed and control subjects (16, 27).

The present study represents a simple, non-invasive and inexpensive diagnostic procedure which reflects the degree of vasodilative ability and detects digital vasospastic disorders. Surveys of chain-saw workers are frequently carried out in the field and require a simple objective test. Therefore, finger skin thermometry can be considered useful in health surveillance of vibration exposed workers.

REFERENCES

1. *Pelmear PL, Taylor W.* Hand-arm vibration syndrome: Clinical evaluation and prevention. J Occup Med 1991;33:1144–9.
2. *Welsh CL.* The effect of vibration on digital blood flow. Br J Surg 1980;67:708–10.
3. *Juul C, Nielsen SL.* Locally induced digital vasospasm detected by delayed rewarming in Raynaud's phenomenon of occupational origin. Br J Ind Med 1981;38:87–90.
4. *Futatsuka M, Pyykko I, Farkkila M, Korhonen O, Starck JP.* Blood pressure, flow, and peripheral resistance of digital arteries in vibration syndrome. Br J Ind Med 1983;40:434–41.
5. *Cooke ED, Bowcock SA, Smith AT.* Photoplethysmography of the digital pulp in the assessment of the vasospastic hand. Angiology 1985;65:33–40.
6. *Ekenvall L, Lindblad LE.* Vibration white finger and digital systolic pressure during cooling. Br J Ind Med 1986;43:280–3.
7. *Bovenzi M.* Finger thermometry in the assessment of subjects with vibration-induced white finger. Scand J Work Environ Health 1987;13:348–51.
8. *Matoba T, Sakurai T.* Physiological methods used in Japan for the diagnosis of suspected hand-arm vibration syndrome. Scand J Work Environ Health 1987;13:334–6.
9. *Matsumoto T.* Tests employed in Japan for the investigation of peripheral circulatory disturbances due to hand-arm vibration exposure. Scand J Work Environ Health 1987;13:356–7.
10. *Pelmear 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 1987;13:343–7.
11. *Bovenzi M.* Finger systolic pressure during local cooling in normal subjects aged 20 to 60 years: reference values for the assessment of digital vasospasm in Raynaud's phenomenon of occupational origin. Int Arch Occup Environ Health 1988;61:179–81.
12. *Olsen N.* Diagnostic tests in Raynaud's phenomena in workers exposed to vibration: a comparative study. Br J Ind Med 1988;45:426–30.
13. *Kurozawa Y, Nasu Y, Nose T.* Diagnostic value of finger systolic blood pressure in the assessment of vasospastic reactions in the finger skin of vibration-exposed subjects after finger and body cooling. Scand J Work Environ Health 1991;17:184–9.
14. *Virokannas H, Rintamaki H.* Finger blood pressure and rewarming rate for screening and diagnosis of Raynaud's phenomenon in workers exposed to vibration. Br J Ind Med 1991;48:480–4.
15. *Bogadi-Šare A, Zavalić M.* Digital photoplethysmography in the diagnosis of traumatic vasospastic disease. Arh hig rada toksikol 1992;43:303–11.
16. *Taylor JS.* Vibration syndrome in industry: dermatological viewpoint. A missed diagnosis. Am J Ind Med 1985;8:415–32.
17. *Harada N, Matsumoto T.* Validity of various function tests performed in Japan as a screening test for vibration syndrome. Int Arch Occup Environ Health 1984;54:283–93.
18. *Hellstrom B, Myhre K.* A comparison of some methods of diagnosing Raynaud phenomena of occupational origin. Br J Ind Med 1971;28:272–9.

19. *Kurumatani N, Hirata K, Moriyama T, Satoh M, Arai T.* Usefulness of fingertip skin temperature for examining peripheral circulatory disturbances of vibrating tool operators. Scand J Work Environ Health 1986;12:245–8.
20. *Arneklo-Nobin B, Johansen K, Sjoberg T.* The objective diagnosis of vibration-induced vascular injury. Scand J Work Environ Health 1987;13:337–42.
21. *Niioka T, Kojima Y, Kaji H, Saito K.* Diagnostic method for the vibration syndrome with special reference to finger skin temperature and vibratory sense threshold. Scand J Work Environ Health 1986;12:251–3.
22. *Grigg MH, Wolfe JHN.* Raynaud's syndrome and similar conditions. Br Med J 1991;303:913–6.
23. *Bovenzi M, Franzinelli A, Strambi F.* Prevalence of vibration-induced white finger and assessment of vibration exposure among travertine workers in Italy. Int Arch Occup Environ Health 1988;61:25–34.
24. *Caramaschi P, Codella O, Poli G et al.* Use of computerized digital thermometry for diagnosis of Raynaud's phenomenon. Angiology 1989;40:863–71.
25. *Miyashita K, Shiomi S, Itoh N, Kasamatsu T, Iwata H.* Epidemiological study of vibration syndrome in response to total hand-tool operating time. Br J Ind Med 1983;40:92–8.
26. *Welsh CL.* Digital rewarming time in the assessment of vibration-induced white finger. Scand J Work Environ Health 1986;12:249–50.
27. *Laroche GP.* Vibration syndrome: Legal aspects and staging. Vascular Surgery 1990;35:579–86.

Sažetak

VRIJEDNOST DIGITALNE TERMOMETRIJE U DIJAGNOSTICI VIBRACIJSKE BOLESTI

Mjerenje kožne temperature kontaktnom termometrijskom metodom uz primjenu termalnog testa provedeno je u 90 sjekača motornom pilom, grupiranih prema Taylor-Pelmearovoj skali, i 58 muškaraca kontrolne skupine. Indeks oporavka prikazuje sposobnost pasivne vazodilatacije. Prema rezultatima ovog rada, u sjekača motornom pilom utvrđene su niže vrijednosti svih vrijednosti kožnih temperatura tijekom testa, a indeks oporavka razlikuje sjekače s klinički prisutnim simptomima vazospastičke bolesti od kontrolne skupine. Predložena je vrijednost za indeks oporavka od 90% kao dijagnostička granica za razlikovanje normalne od vazospastičke reakcije, a metoda je preporučena za zdravstveni nadzor radnika izloženih djelovanju vibracija.

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Ključne riječi: bijeli prsti izazvani vibracijama, indeks oporavka, poremećaj perifernog krvotoka, radnici izloženi vibracijama, Raynaudov fenomen, sjekači motornom pilom, temperatura kože prstiju