

HAND-ARM VIBRATION EXPOSURE AND THE DEVELOPMENT OF VIBRATION SYNDROME

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ABSTRACT

To evaluate the circulatory disturbances, sensory disturbances and damage to muscles and joints by chain saw vibration exposure, the process of the deterioration of the symptoms with chain saw operating time was studied. Subjects were classified into eight groups according to TOT (Total Operating Time): Group 0, 46 controls; Group A, 39 operators (<2,000 hours); Group B, 53 operators (2,000–4,000 hours); Group C, 45 operators (4,000–6,000 hours); Group D, 29 operators (6,000–8,000 hours); Group E, 31 operators (8,000–10,000 hours); Group F, 35 operators (10,000–15,000 hours); and Group G, 34 operators (>15,000 hours). The subjective symptoms and clinical findings due to operating chain saws were divided into three main categories of peripheral circulatory disturbances, sensory disturbances and damage to muscles and joints. According to the criteria, the total score of each disturbance was calculated per individual in Group 0 and Groups A through G, respectively. The scores for the three (circulatory, sensory, muscles and joints) disturbances increased significantly with the increase of TOT. The scores for circulatory disturbances increased significantly in Group A and B, as compared with those in its previous Group, respectively. The scores for sensory disturbances increased significantly in Groups A, B and F. The scores for damage to muscles and joints increased significantly in Group B.

Key Words: Hand-arm vibration, Vibration syndrome, Raynaud's phenomenon, Dose-response relationship

INTRODUCTION

Workers occupationally exposed to vibration often complain of symptoms of peripheral circulatory disturbances, peripheral nerve disturbances and bone and joint disorders. Many cross-sectional and longitudinal investigations have been performed, and dose-response relationships have been derived from epidemiological data.¹⁻³⁾ In some papers, the response has been assessed only by the prevalence rate of a symptom or a finding, and Raynaud's phenomenon is often used as a response. To evaluate vibration syndrome with complex symptoms, a comprehensive or quantitative evaluation of the symptoms combined with clinical findings is needed. In this study, to evaluate circulatory disturbances, sensory disturbances and damage to muscles and joints by chain saw vibration exposure, a scoring method is introduced and the process of deterioration of the symptoms with chain saw operating time was studied.

SUBJECTS AND METHODS

Subjects were 266 workers professionally exposed to chain saw hand-arm vibration, and 46 controls, forestry workers never exposed to vibration. The subjects were all male and in age

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group 40 to 59 years of age to eliminate the effects of sex and age.

In order to determine the vibration exposure dose for an individual, total operating time (TOT) was calculated from the full occupational history using the following equation: chain saw operating time/day \times days/year \times years. Subjects were classified into eight groups according to TOT as follows: Group 0, 46 controls never exposed occupational hand-arm vibration; Group A, 39 operators with less than 2,000 hours exposure; Group B, 53 operators with 2,000–4,000 hours exposure; Group C, 45 operators with 4,000–6,000 hours exposure; Group D, 29 operators with 6,000–8,000 hours exposure; Group E, 31 operators with 8,000–10,000 hours exposure; Group F, 35 operators with 10,000–15,000 hours exposure; and Group G, 34 operators with over 15,000 hours exposure. Table 1 shows the subjects by TOT groups.

Subjective symptoms were obtained by clinical interview from all subjects with reference to the pain and/or numbness or tingling of hands and forearm or upper arms and restriction of joint movement. Clinical examinations consisted of peripheral circulatory function tests, sensory function tests and motor function tests combined with cold water immersion tests. Raynaud's phenomenon was identified by a medical doctor by detailed interview.

The subjective symptoms and clinical findings due to operating chain saws were divided into three main categories of peripheral circulatory disturbances, sensory disturbances and damage to muscles and joints. Circulatory disturbances included Raynaud's phenomenon, skin temperature, hyperemia time of the nail, tingling or numbness of hand and arm and some subjective symptoms. Sensory disturbances included loss of pain and vibratory sense, hypesthesia of touch sense, tingling or numbness of hand and arms and some subjective symptoms. Damage to muscles and joints included lowering of grip force and pinch power of finger, restriction of joint mobility, muscle pain, joint pain and some subjective symptoms.

Subjective symptoms and findings of medical examinations were scored 25 points in total in each category according to their severity, as shown in Table 2. According to the criteria, the total score of each disturbance was calculated per individual in Group 0 and in Groups A through G, respectively, and the mean scores were compared with Group 0 and the operators groups. The correlation coefficients between total operating time and scores of operator groups were also studied.

Significance of scores in each group and correlation coefficients were statistically tested by Student t-test.

Table 1. Number of subjects by the total operating time (TOT)

Group	TOT	n
0	—	46
A	0 ~ 2000	39
B	2000 ~ 4000	53
C	4000 ~ 6000	45
D	6000 ~ 8000	29
E	8000 ~ 10000	31
F	10000 ~ 15000	35
G	15000 ~	34

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Table 2. Criteria for scoring of symptoms and findings

(a) Circulatory disturbances			
Symptoms or examinations		Score	Criteria for minimum score
Skin temperature	measurement before immersion test*	1 - 3	below 31.5 °C
	recovery rate**	1 - 3	below 60.6 %
Hyperemia time of the nail	measurement before immersion test*	over 1.5 sec	
	measurement at 5 min after immersion test*	over 2.0 sec	
Raynaud's phenomenon		5	more than 1 finger
Tingling or numbness	in fingers or hands	2 - 3	in either side
	in forearm	2 - 3	in either side
Subjective symptoms	hypesthesia for warm and cold	1	
	stiffness of fingers	1	
(b) Sensory disturbances			
Pain sense	measurement before immersion test*	1 - 3	over 2gr by weighted needle
	measurement at 5 min after immersion test*	1 - 3	over 2gr by weighted needle
Vibratory sense	measurement before immersion test*	1 - 3	over 10 dB
	measurement at 5 min after immersion test*	1 - 3	over 20 dB
Tingling or numbness	in fingers or hands	2 - 3	in either side
	in forearm	2 - 3	in either side
Subjective symptoms	five subjective symptoms on hypesthesia of hands and arms	1 each	
(C) Damage to muscles and joints			
Grip strength	on dominant side	1 - 2	below 40 Kg
Pinch power	measurement between thumb and forefinger on dominant side	1 - 2	below 5.5 Kg
Muscle pain	in hand, forearm and upper arm	1 each	
Joint pain	in wrist, elbow and shoulder joints	1 each	
Restriction of joint mobility	wrist and shoulder joints	1 - 2 each	
	elbow joint	1 - 3	
Muscle atrophy of hand		5	
Subjective symptoms	three subjective symptoms on inability to perform fine tasks	1 each	

*Either hand is immersed into 10 °C water for 10 minutes

**Recovery rate is the percent obtained from skin temperature at 10 min after immersion / skin temperature before immersion

RESULTS

The mean scores in peripheral circulatory disturbances, sensory disturbances and damage to muscles and joints were shown for each group (Fig. 1). The scores for circulatory disturbances was much, as well as those for sensory disturbances. The scores for damage to muscles and joints were less than for the other two disturbances. The scores for the three (circulatory, sensory, muscles and joints) disturbances increased significantly with the increase of TOT ($p < 0.01$). The scores for circulatory disturbances increased significantly in Groups A and B as compared with those in the previous groups, respectively. The scores for sensory disturbances increased significantly in Groups A, B and F. The scores for damage to muscles and joints increased significantly in Group B.

Fig. 2 showed the prevalence rates of Raynaud's phenomenon and numbness of hands and

arms by group. The prevalence rate of Raynaud's phenomenon showed a straight-line elevation with TOT and significantly increased in Group B as compared with Group 0, and in Group E as compared with Group B. The prevalence rate of numbness showed an arch shaped elevation with TOT and significantly increased in Groups A and B as compared with Groups 0 and A, respectively, and showed a slight increase in Groups B through G.

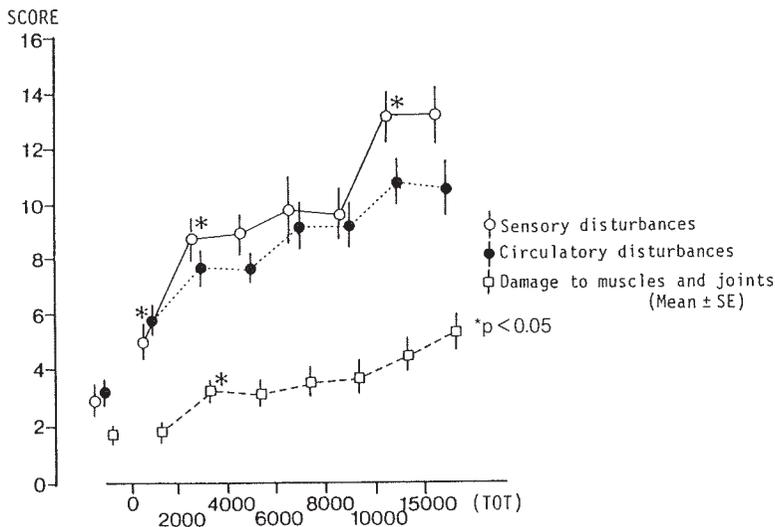


Fig. 1. The scores in circulatory disturbances, sensory disturbances and damage to muscles and joints by the groups divided according to TOT.

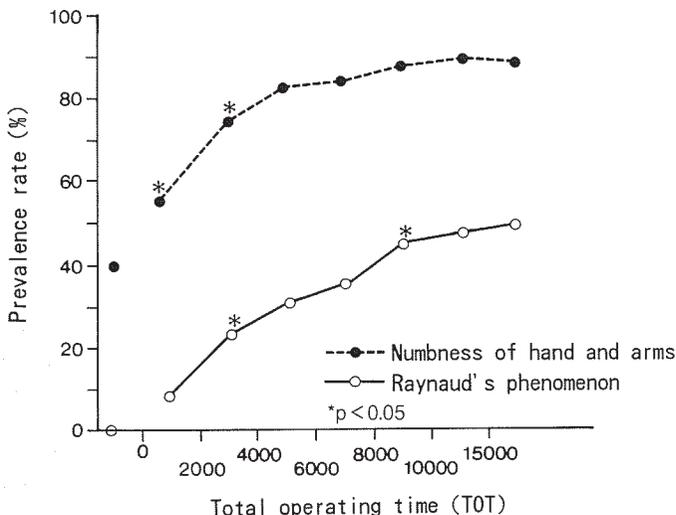


Fig. 2. Prevalence rate of Raynaud's phenomenon and numbness of hand and arms among chain saw operators.

DISCUSSION

In our previous study,^{1,3)} we investigated the vibration exposure time-response relationship among chain saw operators by the prevalence rates of various symptoms. In the group with less than 2,000 hours exposure, the findings were characteristic of the early stage of the syndrome such as tingling or numbness, pain in hand and arm. In the group with less than 5,000 hours exposure, peripheral circulatory and nerve disturbances were observed from not only subjective symptoms but also clinical aspects such as prolonged recovery of finger skin temperature after cold water immersion or hypesthesia of pain and vibratory sense. Raynaud's phenomenon was observed among about 30% of operators. Muscles, bone and joints were affected, and a weakness of grip strength appeared. With longer exposure of less than 8,000 hours, there was a steady progression of symptoms. Raynaud's phenomenon occurred more frequently and was more severe. Both circulatory and nerve functions were more severely affected, and the prevalence of muscles disturbance, along with pain in the joints and bones, increased. The majority of symptoms in this group were considered to be functional changes, although, in some cases, organic changes were involved. In the group with operating time in excess of 8,000 hours or so, the prevalence of Raynaud's phenomenon was 50%, and the area of finger blanching enlarged. Circulatory as well as nerve disturbances progressed, giving rise to a typical pathological condition seen in a severe stage of vibration syndrome. Occasionally, this severe stage was combined with damage to bones and joints, evidencing further organic change.

In the present study, the scoring method was introduced for the evaluation of the severity of vibration syndrome. This method involved subjective symptoms and clinical findings for peripheral circulatory disturbances, sensory disturbances and damage to bones and joints, which were scored according to the criteria. Development of vibration syndrome was quantitatively assessed by the scoring method. According to the criteria, the total score for each disturbance was calculated per individual in Group 0 and in Groups A through G, respectively. The mean score in each category showed a significant elevation with the increase of TOT. This confirmed the dose-response relationship in vibration syndrome. In the curves of circulatory disturbances and sensory disturbances, there was a marked elevation at 0–2,000 hours, 2,000–4,000 hours and 8,000–10,000 hours. These were considered to be important points in the development of vibration syndrome over time.

However, the prevalence rate of Raynaud's phenomenon showed a straight-line elevation with TOT, and the prevalence rate of numbness showed an arch-shaped elevation with TOT. The former was considered to be the symptom combined with circulatory and sensory disturbances, and the latter is associated with manifest circulatory disturbances. Judging from the prevalence, Raynaud's phenomenon could be a better indication of the dose-response relationship or the staging in vibration syndrome, as used in some stage classifications or models.^{6–8)}

CONCLUSION

According to the scoring methods for the symptoms of vibration syndrome, circulatory disturbances, sensory disturbances and damage to muscles and joints among chain saw operators deteriorated with total chain saw operating hours. The dose-response relationship in vibration syndrome was quantitatively confirmed.

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