Vibration and Its Effects on the Body

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Key Words

Hand-transmitted vibration · Vibration-induced white finger · Whole-body vibration

Abstract

Objectives: To assess the effects of machine-induced vibration on workers and to determine effective precautions for vibration-induced trauma. **Subjects and Methods:** The study group consisted of 114 workers who were randomly selected: 50 rock drill workers and 64 truck heavy vehicle operators. Fifty-four office workers were designed as controls. The study and control groups were age-matched. All subjects were interviewed to determine subjective symptoms using a 38-item questionnaire designed by the Medical Committee of Vibration Disease, Japanese Association of Industrial Health. **Results:** The complaints of pain in the fingers, sensitivity to cold, numbness and pain of fingers at night, weakness of static position, wrist-elbow pain, difficulty in bending and stretching elbow, pain in shoulder when holding up arms, lower back pain, sleeping disturbance and hearing difficulty were significantly higher in rock drillers than heavy vehicle operators and office workers ($p < 0.05$ – 0.01). **Conclusion:** Permanent vibration exposures cause negative physical effects that may lead to occupational diseases. In order to be protected against whole-body and hand-arm vibrations, technical and medical measures must be taken into account.

Introduction

Vibration is a physical factor that acts on the human body by transmission of mechanical energy from sources of oscillation. Workers in various industries are subjected to vibration from machinery they work with. This vibration may be divided into two types: (a) general or whole-body vibration that acts on the body of a sitting or standing person through supporting surfaces and (b) local vibration that is mainly transmitted to the hands and arms by motion such as drilling. Hand-held power tools used in manufacturing, quarrying, public utilities, mining and construction, agriculture and forestry [1] have given rise to peripheral circulatory disturbances of peripheral nerves, muscles, bones and joints. In addition, a wide variety of disturbances may arise from the succession of physical blows impacting on a hand holding a vibrating tool [2–6].

Some tools are known to produce vibration, which after a period of time causes cumulative trauma disorders that eventually lead to conditions such as white finger, Raynaud's phenomenon, carpal tunnel syndrome and peripheral neuropathies [2–6]. The pathologic mechanisms causing these disorders are not yet known and furthermore, there are limited valid objective tests available to measure them.

This study investigated stages in the development of vibration syndrome in workers who used vibrating hand tools and heavy vehicles for road construction and repair.

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Table 1. Questioning form used for the study

		Complaint within 1 year		
		frequently	seldom	never
1	Raynaud's phenomenon	☐	☐	☐
2	Cold fingers	☐	☐	☐
3	Pain in fingers	☐	☐	☐
4	Sensitivity to cold	☐	☐	☐
5	Numbness and pain of fingers at night	☐	☐	☐
6	Numbness of fingers	☐	☐	☐
7	Decreased sensitivity of hands to hot stimulation	☐	☐	☐
8	Decreased sensitivity of hands to cold stimulation	☐	☐	☐
9	Hypaesthesia in stick sensation of hands	☐	☐	☐
10	Hypaesthesia in touch sensation of hands	☐	☐	☐
11	Hypaesthesia in pain sensation of hands	☐	☐	☐
12	Difficulty in buttoning clothes	☐	☐	☐
13	Hand tremor	☐	☐	☐
14	Difficulty in fine finger coordination	☐	☐	☐
15	Drop things easily	☐	☐	☐
16	Weakened hand grip force	☐	☐	☐
17	Tiredness in holding up arms for long period	☐	☐	☐
18	Wrist pain	☐	☐	☐
19	Elbow pain	☐	☐	☐
20	Difficulty in bending and stretching elbow	☐	☐	☐
21	Pain in shoulder when holding up arms	☐	☐	☐
22	Neck pain when turning head	☐	☐	☐
23	Lower back pain	☐	☐	☐
24	Headache or heaviness of head	☐	☐	☐
25	Dizziness	☐	☐	☐
26	Increased irritability	☐	☐	☐
27	Forgetfulness	☐	☐	☐
28	Wakefulness	☐	☐	☐
29	Sleep disturbances	☐	☐	☐
30	General fatigue	☐	☐	☐
31	Getting tired easily	☐	☐	☐
32	Shoulder stiffness	☐	☐	☐
33	Tinnitus	☐	☐	☐
34	Hearing difficulty	☐	☐	☐
35	Falling off of appetite	☐	☐	☐
36	Gastroenteric trouble	☐	☐	☐
37	Shortness of breath when doing heavy work	☐	☐	☐
38	Decline of vigour	☐	☐	☐

The effect of different types of vibration on various parts of the body and the effectiveness of preventive measures are described.

Subjects and Method

A total of 168 workers were studied. The subjects were 50 rock-drilling operators (group 1) exposed to hand-transmitted vibration, 64 heavy vehicle operators (group 2) working in road construction who were exposed to whole-body vibration, and 54 office workers

(group 3) as the control group. The general health status of prospective subjects was assessed, and those under medical treatment and with disease causing primary and secondary disorders in all systems (prominent visceral disease such as heart, lung, kidney insufficiency, insulin-dependent diabetes, uncontrolled hypertension, systemic collagenous disease, infections or malignancy, severe vascular disease) were excluded from the study. All of the subjects were interviewed by using a 38-item questionnaire designed by Medical Committee of Vibration Disease of the Japanese Association of Industrial Health (table 1) [7]. The questionnaire, which was administered face to face, inquired aspects of subjects' lives that included daily working hours, educational status, working period, previous job, brand names of

Table 2. Prevalence rate of complaints

Complaints	G1		G2		G3		Two-tailed significance ¹		
	n	%	n	%	n	%	G1-G2	G2-G3	G1-G3
Raynaud's phenomenon	2	4	2	3.1	0	0	NS	NS	NS
White fingers	2	4	2	3.1	0	0	NS	NS	NS
Pain in fingers	34	68	10	15.6	5	9.2	***	NS	***
Sensitivity to cold	30	60	11	17.1	5	9.2	***	NS	***
Numbness and pain of fingers at night	16	32	8	12.5	4	7.4	*	NS	**
Decreased sensitivity to hot-cold stimulation	4	8	2	3.1	0	0	NS	NS	NS
Hypaesthesia in touch and pain sensation	6	12	5	5.7	2	3.7	NS	NS	NS
Difficulty of finger movements	4	8	6	9.3	2	3.7	NS	NS	NS
Hand tremor	8	16	6	9.3	2	3.7	NS	NS	NS
Difficulty in fine finger coordination	4	8	3	4.6	0	0	NS	NS	NS
Weakness of hands	5	10	4	6.2	2	3.7	NS	NS	NS
Weakness in static position	13	26	6	9.3	4	7.4	*	NS	NS
Wrist-elbow pain	37	74	12	18.7	9	16.6	***	NS	***
Difficulty in bending and stretching elbow	25	50	10	15.6	0	0	***	**	***
Pain in shoulder when holding up arms	27	54	25	39	15	27.7	NS	NS	*
Neck pain when turning head	13	26	14	21.8	8	14.8	NS	NS	NS
Lower back pain	35	70	27	42.1	20	37	**	NS	**
Headache	10	20	12	18.7	11	20.3	NS	NS	NS
Dizziness	8	16	9	14	7	12.9	NS	NS	NS
Increased irritability	15	30	25	39	10	18.5	NS	*	NS
Forgetfulness	8	16	5	7.8	6	11.1	NS	*	NS
Sleep disturbances	30	60	20	31.2	15	27.7	**	NS	**
General fatigue	10	20	11	17	4	7.4	NS	NS	NS
Shoulder stiffness	12	24	12	18.7	8	14.8	NS	NS	NS
Tinnitus	15	30	10	15.6	4	7.4	NS	NS	**
Hearing difficulty	25	50	11	17.1	3	5.5	**	NS	***
Shortness of breath doing heavy work	18	26	12	18.7	22	40.7	NS	*	NS
Decline of vigour	10	20	7	10.9	5	9.2	NS	NS	NS

NS = Non-significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Group 1 (G1) = Rock drill workers; group 2 (G2) = heavy vehicle operators; group 3 (G3) = office workers.

¹ Comparison of two proportions.

equipment used, previously diagnosed disease, ongoing usage of drugs, cigarette smoking and alcohol abuse, and history of circulatory disorders and disease causing primary and secondary disorders in all systems. In scoring the items in the questionnaire, the following ordinary scale for rating the frequency of each complaint within 1 year was used: 'frequently' was given a score of 2, whereas 'never' or 'seldom' was given a score of 1. Prediagnoses were made according to the results of the questionnaire. Clinical symptoms were unified due to small sample size; uncertain cases and industrial injury were referred to specialists or physiatrists for definitive diagnosis. However, since some of the complaints were not consistent with clinical evaluation, physiatrist evaluations marked 'yes' or 'maybe' were accepted as positive. Results were statistically analysed using z test (comparison of two proportions) and one-way ANOVA test.

Results

The mean employment period was 7.74 ± 2.76 years for rock drillers, 9.00 ± 5.72 years for heavy vehicle operators and 9.59 ± 6.43 years for office workers. The average age of the workers was 36.18 ± 11.53 , 40.85 ± 16.11 and 35.96 ± 7.65 years for rock drillers, heavy vehicle operators and office workers, respectively. There was no statistically significant difference between the groups in both employment period and age ($p > 0.05$). Prevalence rate of complaints and comparisons among the groups are listed in table 2.

The complaints of pain in fingers, sensitivity to cold, numbness and pain of fingers at night, weakness of static position, wrist-elbow pain, difficulty in bending and

stretching elbow, pain in shoulder when holding up arms, lower back pain, sleeping disturbance and hearing difficulty were significantly higher in rock drillers than heavy vehicle operators and office workers ($p < 0.05$ – 0.001). There was a significant difference between rock drillers and heavy vehicle operators but not with office workers in complaints of weakness in static position ($p < 0.05$). Three other differences were observed between heavy vehicle operators and office workers and these were increased irritability, forgetfulness and shortness of breath ($p < 0.05$). Two other significant differences (pain in the shoulder when holding up arms and tinnitus) were observed between rock drillers and office workers ($p < 0.01$ – 0.01). These differences are important indicators of negative effects of vibrating tools on the body.

Discussion

In order to comprehend the negative effects of vibration on the body, five physical application properties should be assessed: application area, frequency, acceleration of vibration, duration and resonance [1, 8, 9].

Although cumulative traumatic diseases may include the whole upper extremities and cervical zones, they are likely to occur particularly in wrists and hands [10]. The most obvious cause for cumulative traumatic disorders in workers who use vibrating tools is hand-transmitted vibration [11]. The findings of the present study (table 2) are consistent with this report [11] as the complaints of hands and arms of rock drillers were significantly higher than those of either heavy vehicle operations or office workers ($p < 0.05$).

It is well known that hand-arm vibration syndrome caused by using manual vibrating tools can be found in many occupations [1]. A lot of surveys have confirmed the relationship between the vibration of hand-held tools and disturbances in the peripheral circulation, nerves, muscles, bones and joints [1]. The most prominent component of hand-arm vibration syndrome is the periodic ischaemic attack affecting the fingers, known as vibration-induced white finger. Peripheral nerve symptoms such as numbness, paraesthesia, and pain in arms and hands have also been reported [12–17]. In this study, although the incidence of white finger was low as seen in both rock drillers (4.0%) and heavy equipment operators (3.1%), 68% of the rock drillers complained of pain in the fingers.

It is known that occupational exposures to whole-body vibration mainly occur in transport but at times in

association with other industrial processes. Prolonged exposure causes undue stress and discomfort. The discomfort caused by vibration acceleration depends on the vibration frequency and direction, the point of touch with the body and the duration of the exposure. In the whole-body resonance frequency, there is a maximum displacement between the organs and the skeletal structure and thus, this is the vibration frequency that should be minimized in the workplace and elsewhere [18]. Short-term whole-body vibration exposure can affect visual performance depending on the vibration frequency and the sitting posture [19]. The visual acuity and self-rated assessment of visual disturbances may be influenced by the resonance frequency of the eyeball [19]. Low back pain is a common problem among the working adults as observed in this study particularly among rock drill workers (70%). Occupational risk factors for low back pain include forceful lifting, bending and twisting of the trunk, whole-body vibration and heavy manual labour [20]. There are strong indications that whole-body vibrations are involved in the pathophysiology of different spinal aberrations known or assumed to generate back pain and sciatica. It is known that whole-body vibration causes various symptoms without the existence of any known pathology. Vibration resonance in internal organs can be measured; yet, it is hard to diagnose any disease as resulting from vibrating resonance throughout the whole body. Therefore, harmful effects of vibration are of different types and mechanisms [21].

Vibration-exposed workers may have complaints of muscular weakness and pains in hands and arms. Besides the complaints caused by hand-transmitted vibration in upper extremities, other physical disorders were observed. Disturbances due to lack of sleeping, hearing impairments and ringing in the ear were significantly higher in rock drill operators than vehicle operators and office workers ($p < 0.05$). The workers using vibrating tools were exposed to vibration as well as loud noise. Industrial hearing impairments occurring in rock drill operators because of loud noise are as important as damage taking place in extremities. Although the complaint of hand numbness was evaluated subjectively, the finding does imply that vascular structures, peripheral and most probably autonomic nervous systems could be affected.

Since vibrating tool operators are continuously exposed to hand-arm vibration and heavy vehicle drivers to whole-body vibration, and permanent vibration exposures cause physical harm that may lead to occupational diseases, preventive measures (both technical and medical) must be taken against the harmful effect of both hand-

arm and whole-body vibration. Some technical measures include better tool design that incorporates the engineering principles of vibration, damping and isolation; anti-vibration gloves made of special viscoelastic materials to damp a broad spectrum of vibration [22] and also keep the hands warm and prevent cuts and lacerations; design that minimizes whole-body vibration, seats with good attenuation, and ergonomic design that provides good posture. Some medical measures include pre-employment screening, periodic medical checks and medical surveillance, advice about the consequences of exposures, seeking medical advice if symptoms appear, shortening working period or changing working environment and informing the employer about relevant disorders.

Conclusion

Permanent vibration exposures cause physical harmful effects that may lead to occupational diseases. Complaints of finger numbness and pain at night, wrist-elbow pain, shoulder pain when holding up arms, lower back pain, sleeping disturbances and hearing difficulty were more pronounced in rock drillers than heavy vehicle operators and office workers. Technical and medical measures must be considered in order to prevent negative impacts of hand-arm and whole-body vibrations.

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