

OPERATING HAND-HELD VIBRATING TOOLS AND PREVALENCE OF WHITE FINGERS

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ABSTRACT

Hand-transmitted vibration levels (HTVLs) and the prevalence of vibration-induced white finger (VWF) and numbness of the hands were investigated in eight groups of subjects operating various hand-held vibrating tools. The prevalence rates of Raynaud's phenomenon (RP) and numbness of the hands in 1,027 males and 1,301 females not occupationally exposed to vibration were compared to those of the exposed subjects. The prevalence of VWF was in the range of 0.0–4.8% in subjects exposed to HTVLs of between 1.1 to 2.5 m/s² and reached 9.6% in a group of workers exposed to HTVLs of 2.7–5.1 m/s². The latter group showed a significant difference ($P < 0.05$) in the prevalence of VWF compared to the 2.7% prevalence of RP in male subjects of the general population. The prevalence of VWF in female subjects exposed to vibration (4.3%) was not significant compared to the prevalence of RP in females of the general population (3.4%). The prevalence rates of numbness of the hands were between 6.5% and 30.4% in the exposed groups and in the range of 13.4–29.5% in the general population. It was concluded that in decisions concerning quantitative recommendations for vibration exposure, the prevalence of VWF should be employed. To decrease the risk of developing VWF, estimated vibration safety values for 4 h and 2 h daily exposures are discussed.

Key Words: General population, Hand-held vibrating tools, Hand-transmitted vibration level, Vibration exposure, Raynaud's phenomenon.

INTRODUCTION

It is well established that prolonged exposure to hand-arm vibration can be the cause of disturbances in the peripheral circulatory, peripheral nerves, muscles, bones, and joints of the hands and arms.¹⁾ These disorders are called hand-arm vibration syndrome (HAVS). The most prominent component in HAVS is a secondary form of Raynaud's phenomenon (RP), which is called vibration-induced white finger (VWF). In workers suffering from VWF, circulatory disorders result in stiff, painful fingers with diminished tactile sensation.

In Japan, HAVS has been recognized as an occupational disease for many years, but a documentation for the general risk assessment of frequency-weighted vibration exposure is still lacking. It should be noted that only for a group of workers exposed to hand-arm vibration, i.e., chain saw operators in the state forests of Japan, improvements have been made in their working condition since 1978. For instance, their daily maximum exposure time has been considerably reduced to 2 h and age restriction of 55 years has been imposed.²⁾

The objectives of this study are as follows: (a) to investigate the prevalence of subjective symptoms, particularly finger blanching and numbness of the hands in various groups of workers exposed to hand-arm vibration and in the general population not occupationally exposed to vibration and (b) to use the most appropriate syndrome in decisions concerning quantitative recommendations for exposure limitations.

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MATERIALS AND METHODS

Subjects not operating vibrating tools

From a large group of people attending the annual health examination in different health centers in Gifu City, Japan, 1,208 males and 1,946 females not occupationally exposed to vibration were questioned as to whether they had any experience of finger blanching. This part of the survey was conducted using a questionnaire and when, possible, medical interviews. To eliminate the effect of age on the prevalence of RP, 1,027 males and 1,301 females in the range of 30–59 years of age were considered for this study. These subjects were classified into three subgroups according to their ages, i.e., 30s, 40s, and 50s; and the prevalence of RP was then assessed for each subgroup.

Subjects operating vibrating tools

The hand-transmitted vibration levels (HTVLs) and the prevalence of VWF, numbness, pain or stiffness in the upper and lower extremities were investigated in eight groups of subjects operating various hand-held vibrating tools. These groups were as follows: 164 male dental technicians (group A), 54 male orthopaedists (group B), 256 male technicians of the aircraft industry (group C), 79 male digging laborers (group D), 27 male workers using hand-held grinders in a precision machine industry (group E), 46 female sewing machine operators (group F), 23 male workers using tea harvesters (group G), and 272 male chain saw operators (group H). These subjects were aged 30 to 59 years, except group (E), whose ages ranged from 19 to 57 years.

By means of a questionnaire, interviews, field visits, or during the annual health examination, we gathered detailed information on operating career (years), daily vibration exposure (h/day), various types of vibrating hand tools used on the job, and subjective symptoms. The considered subjective symptoms were: VWF, numbness of the hands, pain in the fingers, stiffness in the hands and/or fingers, and pain in the wrists, arms, shoulders, and lumbar region. These symptoms were classified into 3 categories, i.e., always, sometimes, or rare. In data analysis, selection of “always” or “sometimes” was taken to indicate the presence of a symptom.

The subjects in group A to H have used various types of vibrating tools on their jobs. These tools could be summarized as follows: subjects in Group A mainly use electrically driven grinding and polishing tools; subjects in group B mostly operate plaster saws, power drills, reciprocating saws, and multi-head drills (small or large sized); subjects in group C principally use all types of vibrating tools; subjects in group D use various percussive tools; subjects in group E use chiefly hand-held grinders; subjects in group F operate sewing machines; subjects in group G largely use tea harvesting machines; and subjects in group H often use anti-vibration chain saws.

Vibration measurements

The frequency-weighted HTVL values ($L_{h,w})_{eq,t}$ while operating vibrating tools were measured on the right or left hand during actual job processes. The measurements were made using a vibration dosimeter — type VB-03 (Rion Co., Tokyo). The dosimeter was connected to an accelerometer — type PV-90 H (Rion Co.) using an extension cable of about 115 cm length. The accelerometer has a weighting filter conforming to the guidelines of International Organization for Standardization (ISO 5349).³ The vibration pick-up is a small sized (i.e. weight = 6 g, and outward size = $16\phi \times 8$ mm) uni-directional (X-axis) accelerometer. Detailed information on the vibration dosimeter was reported elsewhere.^{4–6} The accelerometer was fixed in a small pick-up case and then mounted on the back of the hand using a simple palm band, such as an athletic wrist supporter, with a weight of about 15 g. This technique permitted the monitoring of the ($L_{h,w})_{eq,t}$ while the subject was holding a vibrating tool. Moreover, fewer complaints have

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been received by subjects when the accelerometer was mounted on the back of the hand.⁶⁾ Also, this technique prevents chattering, which may occur by mounting the accelerometer on the palm while the subject is holding a tool.

Statistical methods

The prevalence rates of all symptoms were computed for the groups of subjects exposed to vibration. As for the general population, the prevalence rate of RP and its 95% confidence interval (95%CI) were derived and compared to the prevalence of VWF in the exposed groups. To test levels of significance, Student's t-test and χ^2 test were used. The level of significance was set at $P < 0.05$.

RESULTS

Prevalence of RP in the general population

The prevalence of RP by sex and age in the general population not occupationally exposed to vibration are listed in Table 1. In general, the prevalence of RP tended to be lower in the male group than in the female group. The highest prevalence of RP was noticed among females aged from 30 to 39 years (4%, 95%CI=1.8–6.2%). Males in their 40s showed a slightly higher prevalence rate of RP (3.1%, 95%CI=1.4–4.8%) compared to the other male subgroups. However, no significant differences ($P > 0.05$) could be observed, either between males and females or between the subgroups. On the whole, prevalence rate of RP was noticed at a rate of 2.7% (95%CI=1.7–3.7%) in male subjects and 3.4% (95%CI=2.4–4.4%) in female subjects ($P > 0.05$).

Operating career and prevalence of subjective symptoms in subjects operating vibrating tools

Table 2 shows age, operating career, and operating hours per day for the different groups of subjects. As can be seen, there was a large variation in the subjects' daily exposure time; and subjects in group (B) where reported to use vibrating tools less than the other subjects (0.3 ± 0.2

Table 1. PREVALENCE of RAYNAUD'S PHENOMENON (RP) by SEX and AGE in the GENERAL POPULATION not OCCUPATIONALLY EXPOSED to SEGMENTAL VIBRATION. (95% CI = 95% CONFIDENCE INTERVAL)					
MALE	Age (years)			Total (N = 1,027)	
	30 - 39 (N = 254)	40 - 49 (N = 392)	50 - 59 (N = 381)		
	Prevalence of RP	6 (2.4 %)	12 (3.1 %)	10 (2.6 %)	28 (2.7 %)
	95% CI	0.5 - 4.3 %	1.4 - 4.8 %	1.0 - 4.2 %	1.7 - 3.7 %
FEMALE	Age (years)			Total (N = 1,301)	
	30 - 39 (N = 297)	40 - 49 (N = 491)	50 - 59 (N = 513)		
	Prevalence of RP	12 (4.0 %)	17 (3.5 %)	15 (2.9 %)	44 (3.4 %)
	95% CI	1.8 - 6.2 %	1.9 - 5.1 %	1.5 - 4.3 %	2.4 - 4.4 %
(NS: not significant)					

Table 2. The MEAN and STANDARD DEVIATION of AGE, OPERATING PERIOD and DAILY EXPOSURE TIME in EIGHT GROUPS of SUBJECTS EXPOSED to HAND-TRANSMITTED VIBRATION.

GROUP	No. of subjects	Age * (years)	Exposure period (years)	Daily exposure time (h/day)
(A) Dental technicians	164	38.8 ± 6.3	12.8 ± 6.0 (2 - 29)	4.1 ± 2.2 (0.5 - 8.0)
(B) Orthopaedists	54	43.3 ± 7.6	18.1 ± 8.9 (5 - 30)	0.3 ± 0.2 (0.1 - 1.0)
(C) Aircraft factory technicians	256	39.7 ± 7.1	17.4 ± 5.6 (4 - 27)	3.9 ± 1.4 (0.2 - 5.0)
(D) Digging laborers	79	42.8 ± 6.2	21.9 ± 8.2 (1 - 29)	4.5 ± 1.8 (2.0 - 6.0)
(E) Operators of grinders	27	37.5 ± 14.1	15.9 ± 12.5 (1 - 33)	2.6 ± 1.1 (1.0 - 5.0)
(F) Sewing machine operators	46	50.2 ± 6.1	21.3 ± 7.2 (1 - 27)	--- (4.0 - 5.0)
(G) Operators of tea pluckers	23	53.5 ± 3.8	26.6 ± 9.2 (10 - 40)	6.8 ± 2.3 (3.0 - 8.0)
(H) Chain saw operators	272	52.8 ± 4.9	18.9 ± 7.5 (1 - 35)	3.0 ± 2.0 (0.5 - 5.0)

*: All subjects aged from 30 to 59 years, except group (E) whose ages ranged from 19 to 57 years.

h/day). In contrast, the mean daily exposure times of workers in groups (D) and (G) were found to be higher than in the other workers (4.5 ± 1.8 and 6.8 ± 2.3 h/day, respectively). Subjects in group (G) tended to be older (53.5 ± 3.8 years), and have had longer experience using vibrating tools (26.6 ± 9.2 years).

The prevalence rates of the investigated symptoms are illustrated in Fig. 1. Of the symptoms, VWF had the lowest percentage prevalence, compared to the other symptoms. As shown among the 8 groups, there were great variations in the prevalence rates of subjective symptoms. Pain in the arms, shoulders, and lumbar region were frequent complaints. For the three mentioned symptoms as well as numbness of the hands, workers in group (G) showed high prevalence rates, although none of these subjects ($n=23$) had VWF.

The prevalence rates of VWF or RP and numbness of the hands are shown in Fig. 2. These results together with the prevalence of pain in the hands, significant differences, and vibration exposure levels are listed up in Table 3. VWF, one of the most typical symptoms in vibration syndrome, was observed at a rate of 0.0–4.6% in groups A–G. Even if subjects in group (A) showed a slightly higher prevalence of VWF, nevertheless among the mentioned groups the difference in the VWF prevalence rates was not significant. The prevalence rate of VWF was significantly ($P < 0.05$) higher in group (H) than in group (C) or group (D). Of the subjects, only those in group (H) had significant difference in the prevalence of VWF compared to the prevalence rate of RP in males of the general population (9.6% vs. 2.7%, $P < 0.05$).

The prevalence rate of numbness of the hands was observed in 6.5–30.4% of the exposed groups. The differences among the groups were significant at the 5% level (shown in Table 3). Regarding the general population, numbness of the hands occurred in 13.4% of males (85 out of 635 subjects) and complaints increased to 29.5% in females (141 out of 478 subjects), the difference being significant at the 5% level. The prevalence of numbness of the hands in male subjects of the general population was almost the same as in groups A–D and H. Female

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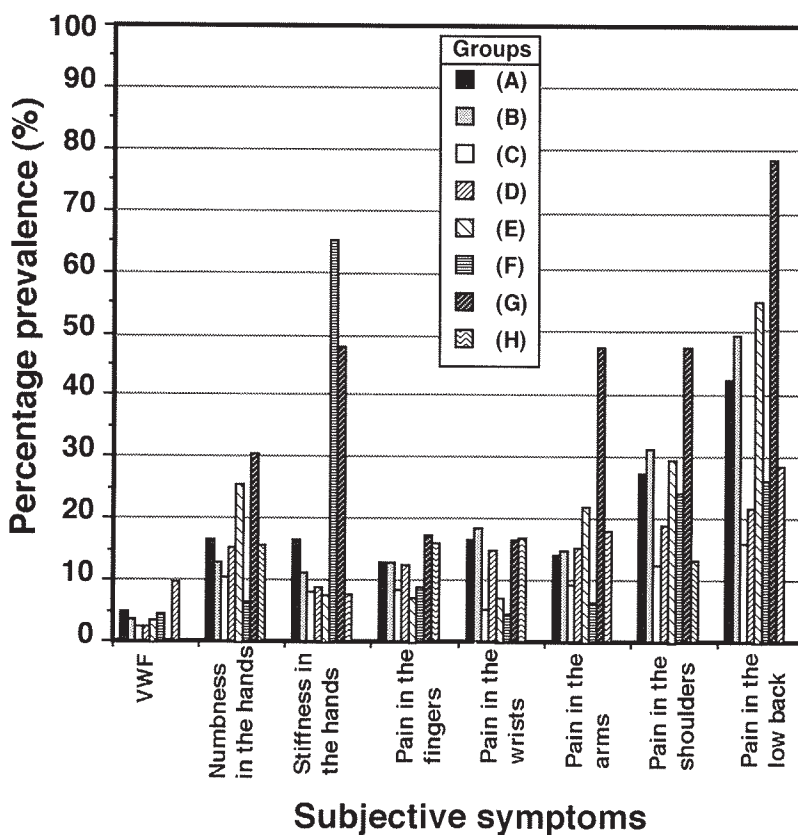


Fig. 1. Prevalence rate of subjective symptoms in subjects (8 groups) exposed to hand-transmitted vibration.

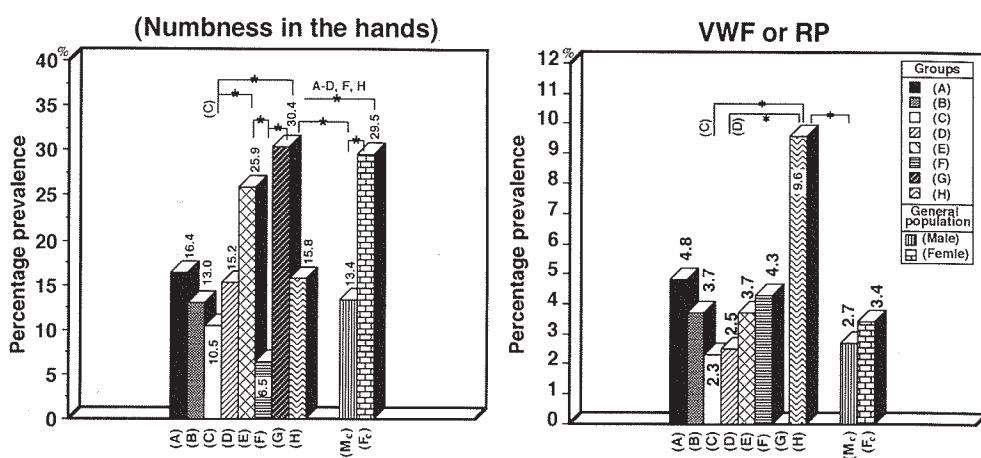


Fig. 2. Prevalence rates of VWF or RP and numbness of the hands in subjects operating vibrating tools and in the general population not occupationally exposed to vibration. (*: P < 0.05)

Table 3. PREVALENCE RATES of VIBRATION-INDUCED WHITE FINGER (VWF), NUMBNESS of the HANDS, and PAIN in the HANDS in the VIBRATION EXPOSED GROUPS together with the PREVALENCE of RAYNAD'S PHENOMENON (RP) in the GENERAL POPULATION not OCCUPATIONALLY EXPOSED to SEGMENTAL VIBRATION.

Group	Number of subjects	VWF/RP (%)	Numbness (%)	Pain in the hands (%)	Exposure time (h/day) (Mean \pm SD, range)	Frequency-weighted acceleration (m/s^2)
(A) Male dental technicians	164	8 (4.8 %)	27 (16.4 %)	21 (12.8 %)	4.1 \pm 2.2 (0.5 - 8.0)	1.7
(B) Male orthopaedists	54	2 (3.7 %)	7 (12.9 %)	7 (12.9 %)	0.3 \pm 0.2 (0.1 - 1.0)	1.0 - 2.4
(C) Male aircraft factory technicians	256	6 (2.3 %)	27 (10.5 %)	22 (8.6 %)	3.8 \pm 1.4 (0.2 - 5.0)	2.3 - 2.5
(D) Male digglin laborers	79	2 (2.5 %)	12 (15.2 %)	10 (12.6 %)	4.5 \pm 1.8 (2.0 - 6.0)	1.6 - 2.1
(E) Male operators of grinders	27	1 (3.7 %)	7 (25.9 %)	2 (7.4 %)	2.6 \pm 1.1 (1.0 - 5.0)	1.2 - 2.0
(F) Female sewing machine operators	46	2 (4.3 %)	3 (6.5 %)	4 (8.7 %)	-- (4.0 - 5.0)	1.6
(G) Male operators of tea pluckers	23	0.0	7 (30.4 %)	4 (17.4 %)	6.8 \pm 2.3 (3.0 - 8.0)	1.1 - 2.3
(H) Male chain saw operators	272	26 (9.6 %)	43 (15.8 %)	44 (16.2 %)	3.0 \pm 2.0 (0.5 - 5.0)	2.7 - 5.1
(M _g) Male general population	1,027	28 (2.7 %)	85 (13.4 %) [n = 635]	--	--	--
(F _g) Female general population	1,301	44 (3.4 %)	141 (29.5 %) [n = 478]	--	--	--

(*; Significant difference at $P < 0.05$)

subjects of the general population complained more frequently than did those in the other groups (except group G). There was also a significant sex difference in the prevalence of the aforementioned symptom between female sewing machine operators (group F) and female subjects of the general population (6.5% vs. 29.5%, $P < 0.05$).

Pain in the hands was observed in 8.6% of group C, in 7.4% of group E and in 8.6% of group F, but the rates showed a rise to 12.6–17.4% among the other groups. The prevalence of this symptom was significantly ($P < 0.05$) higher in group H as compared with that in group C. The rates were not significant among the other groups.

Vibration exposure

The results of frequency-weighted HTVL (Table 3) showed that subjects in groups A to G are exposed to segmental vibration [$(L_{h,w})_{eq,t}$] at levels between 1.1 and 2.5 m/s^2 , but the measured values in chain saw operators (group H) increased to 2.7–5.1 m/s^2 .

DISCUSSION

Vibratory tool operation is a recognized cause of vibration syndrome in many industrial settings. In Japan, it has been estimated that about 1.3 million workers are exposed to vibration.⁷⁾

For the limitation of exposure and hazards of segmental vibration exposure, a number of standards have been established in several countries. For instance, in the United Kingdom,⁸⁾ a safety value of 4 m/s^2 during 4 h daily for 8 years is supposed to result in 10% prevalence of VWF. In Denmark,⁹⁾ a recommendation has been made to reduce exposure to less than 3.1 m/s^2 , a level said to result in 10% prevalence of VWF with a daily 4-h exposure for 10 years. Most of these safety values are based on criteria published by the International Organization for Standardization (ISO 5349).³⁾

In Japan, the ISO guidelines 5349 have mostly been used for the assessment of risk due to hand-arm vibration. However, because of differences in climatic conditions, physical extent,

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Author's name and year of publication	RP	
	Male	Female
Miyashita, <i>et al.</i> [1992]	2.3 % (44)	—
Harada, <i>et al.</i> [1991]	1.2 % (1875)	2.2 % (1998)
Inaba, <i>et al.</i> [1989]	1.3 % (149)	1.5 % (256)
Iwata, <i>et al.</i> [1987]	2.5 % (635)	4.6 % (835)
Futatsuka, <i>et al.</i> [1986]	0.5–2.0 %	—
Futatsuka, <i>et al.</i> [1985]	2.3–2.4 % (44 and 42)	—
Present study	2.7 % (1027)	3.4 % (1301)

The numbers in parenthesis show the total number of subjects reported in each survey.

tolerance of working with hand-held vibrating tools, and the prevalence rates of RP in the general population, a vibration-dose limit for Japanese workers is imperative. Such guidelines would be beneficial to achieve compatibility with standards of other countries. Hence, the present study was designed with particular attention to the prevalence of white finger in workers exposed to vibration and in the general Japanese population not using vibrating tools.

The results indicated that there were no significant differences in the prevalence rates of RP in male and female subjects divided into three subgroups. These results were almost similar to those reported^{10–15}) in some investigations conducted in Japan (Table 4). The prevalence of RP in male subjects did not differ significantly from that reported¹⁶⁾ in 256 Chinese male workers not exposed to vibration (1.6%, 95%CI=0.1–3.1%).

A comparison of the prevalence rates of RP in the above-mentioned surveys with those of studies with Caucasian subjects shows that the prevalence rates for Japanese and Chinese males and females are lower than those for Caucasians. For instance, Silaman *et al.*¹⁷⁾ reported that the prevalence rates were 11.0% in males and 19.0% in females. Walker *et al.*¹⁸⁾ showed 9.5% prevalence in the male population not exposed to vibration, and Bovenzi *et al.*^{19,20)} reported prevalence rates of 6.6% and 8.3% among males not using vibrating tools. Leppert *et al.*²¹⁾ showed a prevalence rate of 15.6% in the female population. Hellström *et al.*²²⁾ reported 14.0% in forest workers not exposed to vibration and 9.0% in male indoor workers not exposed to vibration. On the other hand, Weinrich *et al.*²³⁾ reported that the prevalence rates were 2.8% in males and 3.8% in females of South Carolina residents. The reason for the difference between Weinrich's report and others is not apparent. However, it should be noted that most of the other studies have been performed in countries colder than South Carolina, and it would not be surprising that a higher number of Raynaud's phenomenon patients could be detected because of

more frequent exposure to cold, the triggering stimulus.

Regarding the discussed materials, it may be concluded that the prevalence rates of RP among Japanese and Chinese are lower than in Caucasians. This difference between the prevalence rates for Japanese and Caucasians suggests that in the Japanese vibration exposure guidelines, the difference in the prevalence of Raynaud's phenomenon between the races should be taken into account. This means that in some European countries, for instance, the documentation may provide safety levels that would result in 10% VWF after several years' vibration exposure. But in Japan, sufficient evidence is available at this time⁵⁾ (i.e., a lower prevalence of VWF compared to those in 1970s) that this level of VWF is considered as the actual occurrence of HAVS in the exposed workers.

We demonstrated that when the values of HTVLs were about ≤ 2.5 m/s², the prevalence of VWF in the exposed subjects (groups A–G) did not differ significantly from the prevalence rates of RP in male and female subjects of the Japanese general population. However, subjects in group H (HTLVs of 2.7–5.1 m/s²) showed a significant difference in the prevalence of VWF as compared to the prevalence rate of RP in male subjects of the general population. It should be mentioned that the HTVL values were obtained in the X-axis (on the back of the hand), which in some cases may be lower than that of combined components (X, Y, and Z). The differences at vibration magnitude of up to 4.8 m/s² have been shown²⁴⁾ to be about 1.2 m/s². Therefore, we speculate that if the HTVLs are about 2.5 ± 1.2 m/s², the risk of developing VWF in the exposed subjects may be decreased to some extent.

The fact that the mean daily exposure of these subjects (except group G) was about 4 h/day leads one to infer that the proposed vibration-dose limit should be considered for 4 h total daily exposure. As already pointed out, in some Japanese industrial sectors, the maximum daily vibration exposure has been reduced to 2 h/day; therefore it is necessary to present a vibration-dose limit for 2 h daily vibration exposure.

A review of the literature was conducted on available publications from Japan and China which contain useful information on the relationship between exposure and response, i.e., between vibration magnitude and duration of exposure and the occurrence of VWF. Among numerous reports, only publications in which the daily exposure time of workers had been cited to be ≤ 2 h/day were carefully selected.^{15,25,26)} On the basis of the data collected, the prevalence rates of VWF were plotted against the frequency-weighted acceleration levels (Fig. 3). There was a significant correlation ($p < 0.05$) between the prevalence of VWF and the vibration dose ($y = -18.5 + 4.6x$, $R^2 = 0.8$). By using the equation, it may be speculated that the prevalence of VWF in workers using vibrating tools would be within the prevalence of RP of the Japanese general population, if vibration magnitude is below about 4.5 ± 1.2 m/s². This value was considered as the vibration-dose limit during 2 h daily segmental vibration exposure. However, the possible application of this value remains to be investigated.

Numbness in the hands in the unexposed female subjects was significantly higher than in those of some groups using vibrating tools (Fig. 2). However, in the male subjects not using vibrating tools, this symptom was less prone to occur as compared to the female subjects; the prevalence rate was comparable to that in the exposed groups (except groups E and G). For instance, the prevalence of numbness in subjects of group H who had used chain saws for the past several years and had to work in cold climate, was 15.8%, compared to the 13.4% in the male subjects not exposed to vibration. These findings indicate that in some subjects hand-arm vibration exposure does not necessarily coincide with numbness, and such cases cannot be properly classified with the proposed scale.²⁷⁾ Also, it may be concluded that nerve disturbances should not be employed in the scale for the classification of VWF.²⁸⁾ We suggest that when investigating (or grading) the neurological symptoms in vibration-exposed persons, it is necessary to include a

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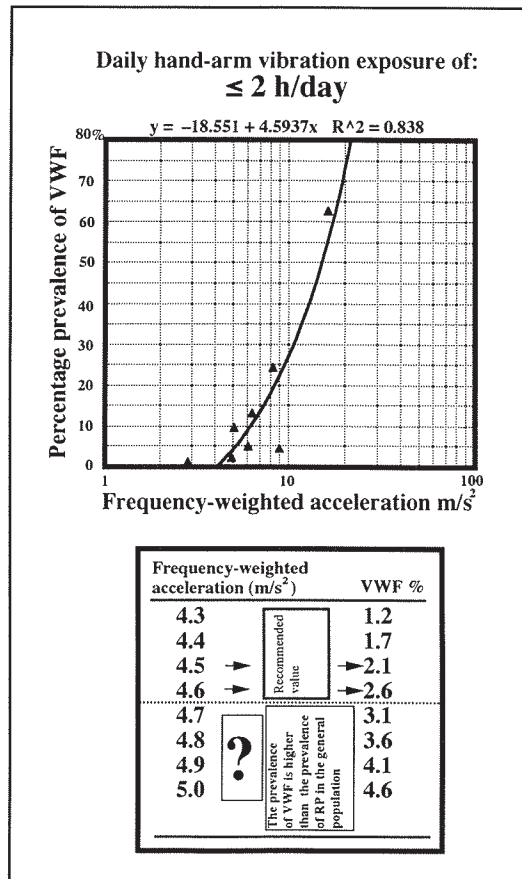


Fig. 3. Relation between the prevalence rate of VWF and the frequency-weighted acceleration level in various groups of subjects with ≤ 2 h/day segmental vibration exposure (data from Ref. 15, 25, 26). The predicted prevalence rates of VWF at different vibration dose levels are also presented.

reference group not exposed to vibration in such a survey.

Among occupationally vibration-exposed workers, a common complaint in the hand-arm locomotor is pain in the upper extremities. The increased prevalence rates of these complaints in some groups provide strong evidence for a dominant work related aetiology in development of these symptoms. For instance, workers in group G showed higher prevalence rates of various subjective symptoms compared to other subjects. This might be attributed to the small number of subjects in group G ($n=23$), their ages (i.e., older than other groups), and their operating career (i.e., longer experience and longer daily exposure time).

In contrast to high prevalence rates of subjective symptoms in group G, no one of these subjects suffered from VWF. To find out a possible reason for this particular symptom, we reviewed all information on these subjects' operating career. It was noticed that the annual outdoor activities of these subjects are mostly concentrated in the period between April and August, when the mean outdoor air temperature on their job is often between 14°C and 27°C . Also, it should be mentioned that anti-vibration materials have been equipped on the handles of all tea harvesting machines (tea pruners and tea pluckers) used by these workers. This technique reduces, to

some extent, the transmission of vibration to the hands. The mentioned factors besides low HTVLs could be considered as the main elements to reduce the risk of developing VWF in subjects of group G.

The higher prevalence rates of low back pain observed in the exposed groups are most probably due to incorrect ergonomic posture and not to vibration exposure. This means that by ergonomic adaptations and/or ergonomic training on the job, the prevalence of subjective symptoms may be decreased among the exposed subjects.

Regarding the proposed vibration-dose limits in this study, it should be mentioned that at this time no firm guidelines can be established regarding maximum no-effect vibration exposure levels. We concur, however, that common sense dictates that extensive vibration exposure tasks be minimized to the extent possible. Tool and job redesign may be required in many situations to accomplish the preventive measures. In addition to appropriate reductions in risk factors, medical surveillance is required and will allow greater appreciation of the extent of vibration syndrome, as well as ongoing assessment of the efficacy of preventive intervention.

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