Nagoya J. Med. Sci. **57 (Suppl.)**. 229 ~ 234, 1994

IMPROVEMENT OF CHAIN SAW AND CHANGES OF SYMPTOMS IN THE OPERATORS

HIDEYOSHI SUZUKI

Institute of Public Health of Kohchi Prefecture, Kohchi, Japan

ABSTRACT

The average maximum acceleration levels of chain saws by the one-third octave band analyzer decreased considerably from 5.1 G (range: 2.5 to 8.0 G) during 1965–1975 to 1.7 G (range: 1.0 to 2.5 G) during 1976–1988. The effects of this reduced vibration level on the prevalence of vibration syndrome were studied by comparing two groups of male chain-saw workers: 285 who started to use chain saws before 1976 and were examined in 1975–1976; and 230 who started chain-saw work after 1976 and were examined during 1985 to 1988. As compared with the pre-1976 group, the prevalence of white fingers among the post-1976 group was one-seventh in chain-saw use of less than 5 years, about one-eighth in that from 5–9 years, and less than one-tenth in that of 10 or more years. Complaints of numbness or coldness in fingers or hands, and pain in hands or arms also decreased considerably from about one-fourth to less than one-tenth. This considerable reduction in the prevalence of vibration syndrome is attributable, above all, to a marked reduction in the acceleration levels of chain saws since about 1976, and secondarily to decreased total hours-per-year of vibration exposure due to improvements in general working conditions.

Key Words: Vibration, Chain saw, Acceleration level, Vibration syndrome

INTRODUCTION

Vibration acceleration levels of chain saws has decreased gradually since the early 1970s, and more rapidly since the late 1970s in Japan. The present study aims to evaluate the effects of this improvement in chain saws on the prevalence of vibration syndrome in chain saw users.

MATERIALS AND METHODS

We compared the prevalence of vibration syndrome between two groups of male chain-saw workers, 285 of whom started to use chain saws before 1976 and were examined in 1975–1976 (the pre-1976 group), and 230 of whom started chain-saw operation after 1976 and were examined during 1985–1988 (the post-1976 group). All workers were employed in private enterprises in Fukushima Prefecture, Japan. Following each annual health examination for vibration syndrome, they were interviewed about health and working conditions.

Statistical evaluations were carried out by Student's t-test for mean and SD values, and by chi-square test or Fisher's exact probability test for frequency values.

RESULTS

Mean age and vibration exposure time in the two groups are shown in Table 1 according to

Correspondence: Dr. Hideyoshi Suzuki, Institute of Public Health of Kohchi Prefecture, 2-4-1, Marunouchi, Kohchi 780, Japan

duration of chain-saw work. Working days-per-year and hours-per-day significantly decreased in the post-1976 group in comparison with the pre-1976 group ($p<0.05$ or $p<0.01$) except for those engaged in chain-saw work from 10–12 years.

Average vibration exposure time according to age is shown in Table 2. Working days-per-year and hours-per-day were less in the post-1976 group than in the pre-1976 group ($p<0.05$ or $p<0.01$), except for workers in their thirties and those 60 and above.

Frequency and percent of Raynaud's phenomenon according to years of duration of chain-saw operation by age are exhibited in Table 3. A remarkable reduction in the prevalence of Raynaud's phenomenon in the post-1976 group was observed in chain-saw use of over 5 years, especially in the 10–12 year range ($p<0.001$).

Table 4 shows that complaints of vibration syndrome such as numbness or paresthesia, coldness in fingers or hands, pain in hands or arms and dullness in arms were significantly reduced in the post-1976 group. There were statistically significant differences ($p<0.01$ or $p<0.001$) between the two groups in each period of chain-saw operation.

Table 1. Age and vibration exposure time by years of chain saw operation

Years of operation	Group	N	Age (Years)	Operating days/year	Operating hours/day
<5	A	44	45.6+13.2	142.0+89.5	3.47+1.44
	B	79	42.4+12.2	109.8+61.9*	2.73+1.29**
5–9	A	146	45.1+ 9.3	159.5+69.9	3.80+1.36
	B	101	46.2+11.1	123.0+65.3**	3.15+1.32**
10–12	A	95	48.2+ 8.1	150.3+70.5	3.64+1.29
	B	50	51.8+ 7.7	123.0+59.8*	3.24+1.28
Total	A	285	46.2+ 9.8	153.7+73.7	3.70+1.35
	B	230	46.1+11.4	118.5+63.3**	3.02+1.32**

N: number of workers; A: workers examines during 1975 to 1976; B: workers who started to operate chain saws after 1976 and were examined 1985 to 1988.

* $p<0.05$, ** $p<0.01$, statistical significance between group A and B by Student's t-test

Table 2. Vibration exposure time by age.

Age	Group	N	Years of operation	Operating days/year	Operating hours/day
–30	A	23	5.57+2.04	176.7+78.1	4.13+1.51
	B	22	3.63+2.57	92.3+49.3**	2.67+1.07**
30–39	A	40	6.98+2.72	149.9+75.4	3.42+1.36
	B	51	5.29+2.90	124.6+68.5	3.03+1.25
40–49	A	114	8.02+2.64	154.0+72.4	3.66+1.26
	B	52	6.56+3.06	126.3+59.0*	2.95+1.30**
50–59	A	84	7.55+2.98	153.4+71.8	3.87+1.33
	B	76	7.29+2.80	117.5+61.4**	3.22+1.39**
60–	A	24	6.92+3.11	138.3+74.5	3.30+1.46
	B	29	6.64+3.66	116.8+69.9	2.91+1.36

N, A, B: see Table 1.

* $p<0.05$, ** $p<0.01$, statistical significance between A and B by Student's t-test

Table 3. Frequency (%) of Raynaud's phenomenon by vibration exposure time in various age categories.

Age	Group	Years of operation				
		−2	2−4	5−9	10−12	Total
		n (%)	n (%)	n (%)	n (%)	n (%)
−30	A	−	0/8(0.0)	0/13(0.0)	2/2(100)	2/23(8.7)
	B	0/7(0.0)	0/8(0.0)	0/7(0.0)	−	0/22(0.0)
30−39	A	−	1/6(16.7)	3/25(12.0)	3/9(33.3)	7/40(17.5)
	B	0/8(0.0)	0/12(0.0)	0/27(0.0)	0/4(0.0)	0/51(0.0)**
40−49	A	−	0/11(0.0)	13/59(22.0)	10/44(22.7)	23/114(20.2)
	B	0/3(0.0)	0/15(0.0)	1/21(4.8)	0/13(0.0)	1/52(1.9)**
50−59	A	−	3/13(23.1)	14/38(36.8)	14/33(42.4)	31/84(36.9)
	B	0/1(0.0)	1/16(6.3)	2/35(5.7)**	0/24(0.0)**	3/76(3.9)**
60−	A	0/1(0.0)	0/5(0.0)	4/11(36.4)	2/7(28.6)	6/24(25.0)
	B	0/2(0.0)	0/7(0.0)	0/11(0.0)*	0/9(0.0)	0/29(0.0)**
Total	A	0/1(0.0)	4/43(9.3)	34/146(23.3)	31/95(32.6)	69/285(24.2)
	B	0/21(0.0)	1/58(1.7)	3/101(3.0)**	0/50(0.0)**	4/230(1.7)**

A, B: see Table 1.
* $p<0.05$, ** $p<0.01$, statistical significance between A and B by Fisher's exact probability test or Chi-square test

Table 4. Frequency (%) of principal complaints by vibration exposure time.

Symptom	Group	N	Years of operation		
			<5	5−9	10−12
			n (%)	n (%)	n (%)
White fingers	A	285	4(9.1)	34(23.3)	36(37.9)
	B	230	1(1.3)	3(3.0)**	0(0.0)**
Numbness in fingers or hands	A	285	11(25.0)	55(37.7)	44(46.3)
	B	230	6(7.6)**	13(12.9)**	3(6.0)**
Coldness in fingers or hands	A	285	9(20.5)	44(30.1)	45(47.4)
	B	230	2(2.5)**	6(5.9)**	4(8.0)**
Pain in hands or arms	A	285	9(20.5)	36(24.7)	32(33.7)
	B	230	2(2.5)**	3(3.0)**	0(0.0)**
Dullness in arms	A	285	6(13.6)	40(27.4)	31(32.6)
	B	230	6(7.6)	6(5.9)**	1(2.0)**

N, A, B: see Table 1.
** $p<0.01$, statistical significance between A and B by Fisher's exact probability test or Chi-square test

IMPROVEMENT OF CHAIN SAWS

Changes in the vibration acceleration level of chain saws were evaluated by using the data published by the Japanese Forestry Agency[1,2] from 1974 to 1977 and the Japanese Association for Mechanization of Forestry Work[3−5] from 1978 to 1988. These data were systematically

analysed from 10 to 500 Hz by a one-third octave band analyser.

The average of and standard deviation (SD) from the maximum vibration acceleration level of chain saws were 8.8 ± 3.4 G (86.2 ± 33.3 m/s^2) in 1974, 5.7 ± 2.8 G (55.9 ± 27.4 m/s^2) in 1975, 2.4 ± 1.1 G (23.5 ± 10.8 m/s^2) in 1976–77, 1.7 ± 0.7 G (16.7 ± 6.9 m/s^2) in 1980, and 1.7 ± 0.6 G (16.7 ± 5.9 m/s^2) in 1988. From these data it can be estimated that the average maximum acceleration levels of chain saws decreased considerably from 7.3 G (71.5 m/s^2) between 1965 and 1975 to 1.9 G (18.6 m/s^2) between 1976 and 1988.

DISCUSSION

In the present study, the prevalence of hand-arm vibration syndrome increased with years of vibration exposure time in chain saw users who began to operate chain saws before 1976. But, the trend of increase according to years of operation was not as clear among workers who began chain-saw work after 1976. In fact, the prevalence of vibration syndrome decreased remarkably among most of them. As mentioned above, average vibration levels have been considerably reduced from 7.3 G (71.5 m/s^2) between 1965 and 1975 to 1.9 G (18.6 m/s^2) between 1976 and 1988. Therefore, it is safe to say that the marked reduction in the prevalence of vibration syndrome in workers who started to operate chain saws after 1976 may be attributed to the marked decrease in the vibration intensity of chain saws.

Watanabe et al.[6] measured vibration levels of 13 kinds of chain saws from seven makers during log cutting. Using a one-third octave band analyser, they demonstrated the vibration spectra of the tools in 1970. They showed that the maximum vibration levels of chain saws with antivibration rubber on the handles were very nearly 4 G at 125 Hz in almost all tools measured. They found that these chain saws were not improved enough to diminish the hazardous effects of hand-arm vibration on chain-saw operators.

Sakurai[7] examined vibration levels of both old and new types of eight and six chain saws, respectively, and reported in 1991 that the maximum vibration acceleration on the handles of chain saws used in the 1970s ranged between 100–356 m/s^2 (10.2–36.2 G), whereas chain-saw acceleration has been reduced to about one-fifth of that over the last 20 years, ranging from 28.2 to 70.8 m/s^2 (2.9–7.2 G).

According to the systematically analyzed data of the Japanese Forestry Agency[1,2] from 1974 to 1977, and the Japanese Association for Mechanization of Forestry Work[3–5] from 1978 to 1988, the vibration level after 1980 is approximately one-fourth that of the early 1970s. In addition, both average vibration exposure time and working days-per-year and hours-per-day showed reductions of 22.9% and 18.4%, respectively.

Though the data of one-third octave band analysis lacked frequencies above 500 Hz, such frequencies could have little effect on the calculations in consequence of the frequency weighting which was absolutely too small to influence the result at a higher frequency. Therefore, applying the multifying factor '2' of Draft International Standard 5349.1 (1979) and the frequency weighting defined in British Standard Institution (1987b) for the calculation of the frequency-weighted 4-hour energy-equivalent acceleration,[8] two mean values of 5.6 m/s^2 (r.m.s) and 1.4 m/s^2 (r.m.s) may be obtained from five randomly selected tools of five manufacturers and four randomly selected tools of three manufacturers, respectively. The former tools showed 6.8 to 7.3 G at 125 Hz as the maximum acceleration frequency. The latter tools showed 1.6 G at 125 Hz as the maximum acceleration frequency. It may be estimated that the former is the approximate value of the frequency-weighted 4-hour energy-equivalent acceleration to which workers were probably exposed between the late 1960s and the early 1970s, whereas the latter is the

value to which workers were exposed from the late 1970s to the early 1980s.

If the relationship between the frequency-weighted 4-hour energy-equivalent acceleration and vibration exposure time before onset of finger blanching according to the ISO 5349 (1986b) is applied to evaluate the effect of the acceleration of 5.6 m/s^2 (r.m.s.) on the prevalence of finger blanching, the relationship corresponds very closely to that of the ISO: 9.1% in less than 5 years of vibration exposure time, 23.3% in 5 to 9 years, and 37.9% in 10 to 12 years in the present study refer approximately to 10% between 5 and 6 years, 20% between 7 and 8 years, 30% between 8 and 9 years, and 40% between 11 and 12 years from the ISO, respectively. Furthermore, in the case of 1.4 m/s^2 (r.m.s), we would not expect the finger blanching rate to reach 10% within 15 years. It seems likely that the multiplying factor of DIS 5349.1 must be taken into consideration in order to evaluate the effect of vibration on finger blanching.

The prevalence of white fingers in the post-1976 group in contrast to that in the pre-1976 group was one-seventh among those with less than 5 years of exposure time, about one-eighth among those with 5 to 9 years of exposure time, and less than one-tenth among those with 10 and more years of exposure time. There were no cases of finger blanching among workers exposed less than 2 years. This was in line with the recent reduction in chain-saw vibration, and tended to especially benefit the workers examined after 1976. Complaints of numbness or coldness in fingers or hands, and pain in hands or arms also decreased remarkably from about one-fourth to less than one-tenth among workers who started after 1976.

Futatsuka et al.[9] were convinced from a follow-up study of vibration-induced white finger in chain-saw workers that a reduction of Raynaud's phenomenon among forestry workers was due to considerable decreases in vibration strength and exposure time. It may be said that the principal complaints of vibration syndrome such as finger blanching, numbness or coldness in fingers or hands, and pain in hands or arms, induced by hand-arm vibration[10–12] derive mainly from vibration acceleration, although a variety of conditions may modify the signs and symptoms.

We concluded that the considerable decrease in the prevalence of vibration syndrome was attributable principally to the marked reduction in acceleration levels of chain saws after about 1976, and secondarily to a decrease in total exposure hours-per-year to vibration as a consequence of improvements in general working conditions.

REFERENCES

1) The Division of Mechanization for Forestry of Forestry Experiment Station of Forestry Agency of Japan: The vibration acceleration levels of holding machines in forestry. Report No.1, Forestry Agency of Japan (1974).
2) The Division of Mechanization for Forestry of Forestry Experiment Station of Forestry Agency of Japan: The vibration acceleration levels of holding machines in forestry. Report No.2, Forestry Agency of Japan (1975).
3) Japanese Association for Mechanization of Forestry Work: A list of the vibration acceleration and noise levels of chain saws and mowing machines on sale at present. *Mechanized Forestry,* No.300, 75–89 (1978).
4) Japanese Association for Mechanization of Forestry Work: A list of the vibration acceleration and noise levels of chain saws and mowing machines on sale at present. *Mechanized Forestry,* No.376, 54–61 (1985).
5) Japanese Association for Mechanization of Forestry Work: A list of the vibration acceleration and noise levels of chain saws and mowing machines on sale at present. *Safety in Forestry and Timber Work,* No.481, 33–39 (1989).
6) Watanabe, S. and Yamakawa, M.: Comparison of vibration of chain-saws. *Jpn. J. Ind. Health,* 12(7), 350–351 (1970).
7) Sakurai, T.: Vibration and noise induced by chain-saws and the transmission of vibration to the operator's body from chain-saw handles. *J. Sci. Labour,* 67(3), 109–124 (1991).
8) Griffin, M.J.: *Handbook of human vibration* (1990), Academic Press, London.
9) Futatsuka, M. and Ueno, T.: A follow-up study of vibration-induced white finger due to chain-saw operators. Scand. *J. Environ. Health,* 12, 304–306 (1986).

10) Taylor, W., Pearson, J., Kell, R.L. and Keighley, G.D.: Vibration syndrome in forestry commission chain saw operators. *Br. J. Ind. Med.,* 28, 83–89 (1972).
11) Suzuki, H.: Vibration syndrome among workers in private enterprises in Fukushima Prefecture. *Jpn. J. Ind. Health,* 21, 442–455 (1979).
12) Suzuki, H. and Iwasaki, S.: An analysis of relationships among the items of the special examination for the diagnosis of vibration syndrome and the relationship between the items and the subjective symptoms. *Jpn. J. Ind. Health,* 25, 387–398 (1983).