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VIBRATION EXPOSURE AND PREVENTION IN FINLAND

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ABSTRACT

The number of annually compensated occupational diseases due to exposure to hand-arm vibration (HAV) has decreased during the last 15 years. The number of exposed workers has been declining in Finland, especially in forestry work, as harvesters have increasingly replaced manual chain saw operations. During the entire 1970s, forest work caused more cases of vibration-induced occupational diseases than all industrial branches together. The decrease is mainly due to the technical development of chain saws, but also to the effective health care services in Finland. Other factors such as warm transport, warm rest cabins in which to take pauses at work, warm meals, adequate protective clothing, and vocationally adjusted early medical rehabilitation have helped to cut down health hazards, especially in forest work. The number of new cases has been decreasing in Finland not only in forestry but also in other industries. In Finland a considerable amount of research has been conducted to hand-arm vibration, resulting in the increased awareness of the health risks related to certain occupations. This has helped to carry out the Primary Health Care Act (1972) followed by the Occupational Health Care Act (1979) which obligates employers to arrange occupational health care for their employees. We believe that the research activity has contributed significantly to achieving the present health in Finnish work places. The purpose of the present paper is to describe the cases of occupational exposure to HAV, and the effectiveness of different preventive measures in Finland.

Key Words: Forest workers, Grip force, Impulse vibration, Pedestal grinding, Shipyard workers

INTRODUCTION

The number of workers exposed to hand-arm vibration (HAV) has been decreasing in Finland during the past 20 years. Increased automation has decreased the need for manual operations. In mines, hand-held rock drills are used only occasionally, as most of the drilling is done with automatically fed multidrilling machines. In forestry, harvesters have increasingly replaced manual chain saw operations. In shipyards, automatic welding has lessened the need to operate with scaling hammers and grinding machines in the welding of joints.

There are presently about 50,000 employees occupationally exposed to hand-arm vibration. Forest workers are still the biggest group. Their number has fallen from about 65,000 in 1974 to 10,000 in 1990. The other prominent groups exposed to HAV are workers in the metal industry, particularly shipyard workers.

The purpose of the present paper is to describe the cases of occupational exposure to HAV, and the effectiveness of different preventive measures. The results are related to the annually observed and compensated new cases of vibration disease. The paper reviews studies conducted in Finland during the last twenty years.

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MEASURING METHODS

Vibration measurements were taken in field conditions during normal operations with hand-held power tools. As the purpose of the hygienic measurements was more comprehensive than merely to follow the standard requirements, a more advanced measuring and analysing system was developed for the field measurements.[1)] The system applied a digital sampling technique to ensure that the dynamic range is as large as possible. This was considered necessary in impulse vibration measurements. In our measuring system the dynamic range was 72 dB. The sampling rate was 40,000 Hz allowing frequency analyses up to 20,000 Hz.

In the frequency analyses, a fast Fourier transform was applied to the samples in the time domain, resulting in 1/3-octave bands from 8 to 12500 Hz. Frequency weighted acceleration was analysed from the samples, according to Standard ISO 5349.[2)]

In addition to the standardised parameters we wanted to evaluate the properties of vibration acceleration signals more in detail also in the time domain. To measure differences in wave forms, we described the impulsiveness of vibration by the crest factor method.[3)] For this purpose we calculated the difference of peak and RMS levels of the vibration signal. This parameter, defined as impulsiveness, is independent of the signal level, but describes the wave form characteristics. The higher the crest factor, the shorter the impulse. Vibration with a crest factor varying time was analysed by averaging the difference between peak and RMS levels over the sampling periods.

The ISO Standard 5349 is intended for general use. However, the physical characteristics of vibration, other properties of tools, application forces and environmental factors can influence the genesis of vibration hazards, and can differ greatly depending on the tool and work tasks. Examples of vibration signals measured from different hand-held power tools demonstrate the problem illustrated by the samples in the time domain (Fig. 1) taken for chain saw, grinding

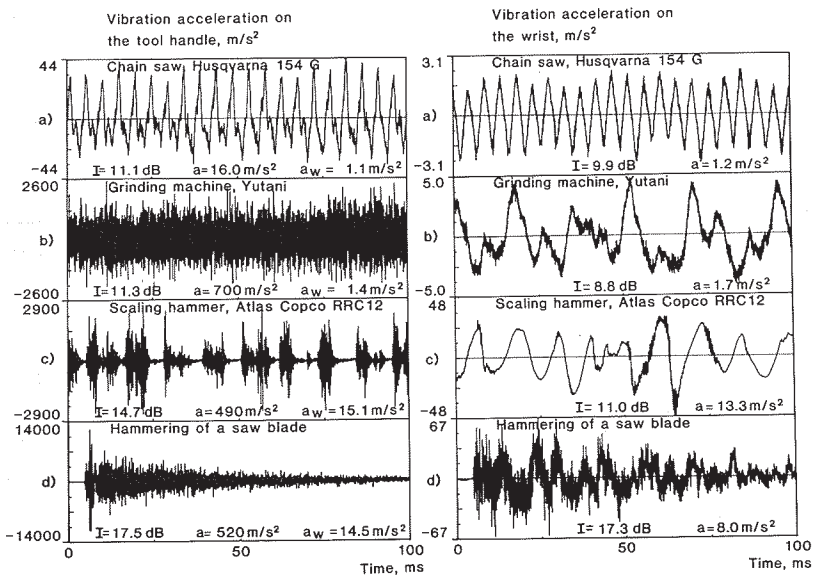

Fig. 1. Time functions of vibration acceleration signals measured in the handle of some tools and the corresponding wrist of the operator.
I=impulsiveness, a=unweighted vibration acceleration, a_w=weighted vibration acceleration.

machine, scaling hammer and in the hammering of a saw blade. The properties in the time domain differ greatly in these samples. In addition to the vibration of the tool the figure also shows simultaneously recorded samples of vibration in the wrist of the operator. These time functions demonstrate that only low frequencies have passed through the finger-palm area to the wrist. Comparison of the parameters displayed shows great relative differences between the standardised parameters and other analysed parameters as impulsiveness and unweighted acceleration. The curves and calculated parameters lead us to conclude that in hygienic assessment it may be necessary to describe also the impulsiveness and the transmission of vibration from the tool handle to the hand.

The high frequency components of acceleration signal are related to high values of impulsiveness, as the high peaks represent high frequencies. These high frequency components will not be considered in the measurements taken according to ISO 5349. The upper frequency limit is the 1 kHz octave band where the attenuation of the signal is 40 dB due to the weighting filter.

STUDY GROUPS

Forest workers

The exposure of forest workers to chain saw vibration was followed in a longitudinal study in 1972–1990.[4,5] The study comprised the medical examinations and evaluations of the working conditions of 118–205 forest workers employed by the National Board of Forestry in north-eastern Finland, in connection with the annual compulsory health examinations. The hygienic measurements of the chain saws were carried out during the field examinations for the chain saw types commonly used by the subjects before and during the follow-up study. During the course of the study four different chain saw generations were taken into use by professional forest workers. The oldest chain saw was manufactured in 1958. This chain saw type was commonly used until the late 1960s. It was included in the hygienic evaluations as, it comprised a prominent proportion of the forest workers' total exposure to HAV in the beginning of the follow-up. This first generation chain saw had no antivibrating elements between the handle of the chain saw and the frame. The daily operation time was only from 1 to 2 hours, as it was used mainly for felling and cutting, and only very little for branching, as these chain saws were rather heavy and clumsy to use.

Table 1. Technical specifications of the chain saws in the course of their professional use. M=mass (kg), CYL=cylinder volume (cm^3), RS=running speed (S^{-1})

Type	Year	M (kg)	CYL (cm^3)	RS (s^{-1})
Homelite	1958	11.6	82	102
Partner	1972	9.2	55	200
Raket	1982	5.2	49	215
Husqvarna	1986	6.3	54	230

The first chain saws supplied with antivibrating elements came into professional use in the early 1970s. The daily operation time rose to 4–5 hours, as they weighed less and were easier to handle. A chain saw manufactured in 1972 was included in the measurements as an example of the second chain saw generation. The chain saws became still lighter in the 1970s. A chain saw manufactured in 1978 was measured to describe the vibration characteristics and the workers' exposure to vibration at that time. The final chain saw included in the study was manufactured in 1986, and was very similar to that manufactured in 1978.

Three important changes have occurred during the development of chain saws. The weight of the saws has been reduced by more than 50%. The stroke volume of the cylinder has decreased by about 50%. Simultaneously the rotating speed of the engine has increased by about 100%. The changes have increased the dominant frequency of vibration by about one octave and allowed more effective attenuation. The lighter of weight has led to prolonged daily operation times of about one hour to five hours.

The chain saw without any antivibrating elements had clearly the highest weighted acceleration value of 14 m/s^2 and 9 m/s^2 as the effect of time weighting was considered according to ISO 5349. In the later generations the corresponding acceleration was about 2 m/s^2. The wave form of the vibration signal was less impulsive in all antivibrating chain saws, as the impulse index value decreased during the course of the study from 19 dB to 11 dB (Fig. 2). During the course of different chain saw generations, acceleration components over 1000 Hz have been attenuated most effectively (Fig. 3).

Fig. 4 illustrates the role of hand-grip force (HGF) in the etiology of the development of vibration-induced white finger (VWF). The forest workers with VWF used greater HGF than those who did not have VWF. The difference was statistically significant.[6)]

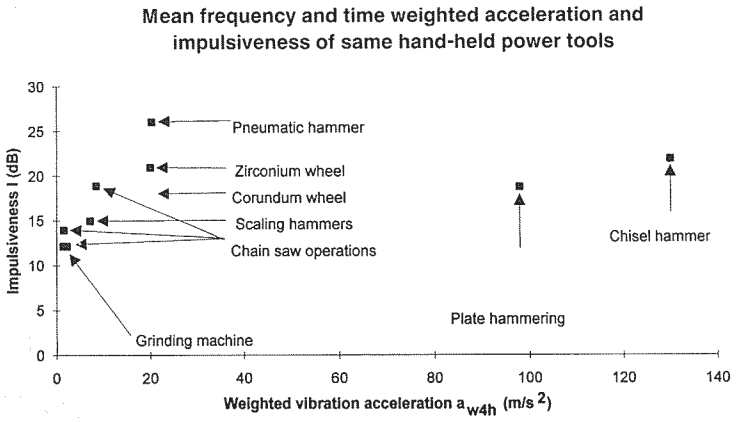

Fig. 2. Mean frequency and time-weighted acceleration (a_{w4h}) and impulsiveness (I) of some hand-held power tools.

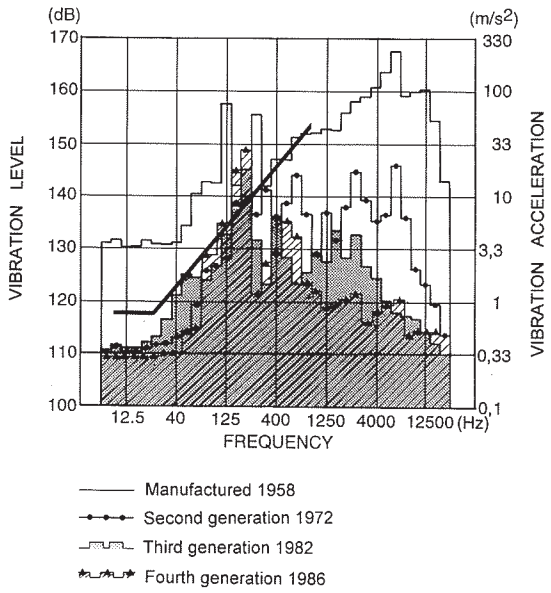

Fig. 3. Vibration acceleration of four different chain saw generations analysed in 1/3-octave bands with reference to ISO 5349 frequency-weighted limit for daily exposure of 4—8 h duration.

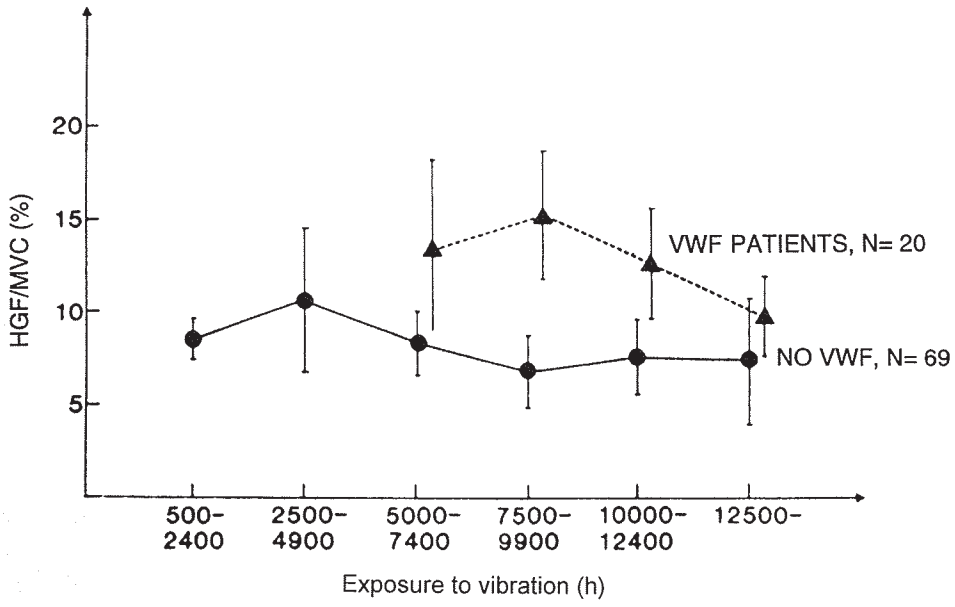

Fig. 4. Ratio of the hand grip force (HGF) and maximal voluntary contraction (MVC) measured during operation at the front handle of the chain saw in 20 forest workers with and 69 without VWF displayed by the mean and standard error of the mean.

Shipyard workers

In the metal industry, shipyard workers are the largest uniform group of workers exposed to HAV in Finland. The number of workers has been declining also in this branch. At present, about 5,000 workers use at least occasionally a hand-held power tool.

In the recent study in a shipyard assembly hall, 171 shipyard workers used different kinds of pneumatic power tools regularly in their work.[7] The measurements comprised 48 different hand-held power tools commonly used by platers, welders, and grinders. The tools included in the measurements were grinding machines (Atlas Copco 6000, Ytani YGS/GC), scaling hammers (Atlas Copco RRC 12), and riveting hammers (Atlas Copco RRC 32). The operation time was on average 2 h per day. The weighted acceleration for different kinds of grinding machines (N=15) was on average 1.5 m/s^2 with variation ranging between 0.4 and 6 m/s^2. Scaling hammers and other pneumatic hammers (N=15) generated clearly higher weighted acceleration, on average 14 m/s^2 with a variation of 6 to 130 m/s^2. Impulsiveness was about 12 dB for grinding machines and 15 dB for pneumatic hammers (Fig. 2). The prevalence of VWF among platers, welders and grinders was 2.9% with an average latency of 16 years.

Pedestal grinders

Pedestal grinding is common in metal work. In a Finnish foundry producing different kinds of small castings, in cleaning pedestal grinding was applied in cleaning. In this foundry, new wheels made of zirconium replaced softer corundum wheels. Simultaneously, the pedestal grinding machines were replaced by more effective grinding machines which allowed higher operating forces by the worker, resulting in a roughly 20% increase in working efficiency. After about one year, all the workers using the new pedestal grinding machines started to suffer from VWF. This finding led us to investigate the quality and quantity of vibration exposure in the work with the new machines as compared to that with the old machines.[8] Different kinds of operations with both new and old machines were evaluated. We found that the weighted acceleration remained on average the same, but the impulsiveness was increased by 3 dB when the new zirconium wheels were used. The increase in impulsiveness was mainly due to the generation of wave form on the surface of the wheel during operation which could not be removed in sharpening of the wheel. The drastic outbreak of VWF was explained to be due to an increase of impulsiveness and operating force causing the transmission of impulse vibration to the finger-palm area to a greater extent when cleaning castings with new wheels than with old wheels. This suggestion led to the use of the old type of wheels, and recent observations in the plant have shown that the symptoms of VWF have been disappearing also because of the regular interruptions in pedestal grinding work.

DISCUSSION

Statistics on the compensation for an occupational disease due to HAV have been collected since 1964 in Finland. The number of annual observed cases has been falling during the last 15 years. These numbers of annually observed cases can not be compared without considering the changes that have taken place in the entire system of health care services and occupational health care in Finland during the period covered by the statistics. In Finland, the Primary Health Care Act came into force in 1972 to take care of working-aged people, to give health education, to ensure medical rehabilitation, and improve environmental health too. Awareness of the health risks of HAV has increased, and with better knowledge of the vibration disease acquired through increased research activity since the early 1970s, it is easier to diagnose and find new

cases. At the same time, antivibrating chain saws were taken into professional use. These were the main reasons for finding new cases, and for turning the development rate of new cases to a decline. In the 1970s, forest workers have been the target of most research.

The coverage of occupational health care has increased gradually to the present level of 85% of all workers but in our studies it has been 100%. This fact accentuated the decrease in the numbers of observed cases in the course of the study.

The decline in HAV exposure has been the greatest among forest workers (Fig. 5). It should be noted that forest workers were the first professional group to be taken into the scope of vocationally adjusted early medical rehabilitation in Finland in the early 1980s. In the annual mandatory medical examination arranged by occupational health care, a group of forest workers was chosen for treatment in a specialized rehabilitation center. The intensive course lasted several weeks, including training in chain saw operation, with correct handling and work positions. The treatment involved physical tests and intensive physical training. Personal guidance and instructions were given in accordance to the test results to continue the rehabilitation at home. The expenses were paid by the Social Insurance Institution.

When the follow-up study was started in 1972, the prevalence of VWF was 40%.[9] Earlier studies showed even higher prevalence rates in the late 1960s.[10] These prevalences corresponded to the findings in other Scandinavian countries, and also in England and Australia.[11–13] During the course of our follow-up, the prevalence has fallen to 5%. The observed prevalence seems to be in good agreement with the official statistics on occupational diseases (Fig. 5). Thus the follow-up study confirms the reliability of the statistics, as the coverage and practices of occupational health care can be considered to be equal in different occupational branches in Finland.

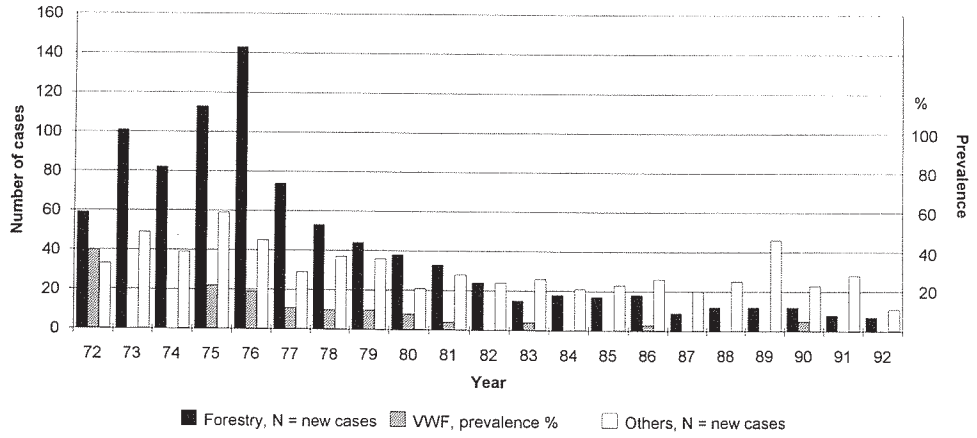

Fig. 5. Number of cases of vibration disease verified as an occupational disease in different years in forestry and other industries compared to the observed prevalence of VWF in the follow-up study.

During the 1970s forest work caused more cases of vibration-induced occupational disease than all industrial branches together. The decrease is mainly due to the technical development of chain saws. The working conditions of forest workers have also improved considerably. Warm transport from home to work place was arranged by the employer in the mid-1970s. At the same time warm rest cabins were taken into use, and facilities for having warm meals were set

up. Employers also started to pay more attention to adequate clothing, training in proper working methods, and physical education. However, it is not possible to determine precisely the prophylactic effect of these controlling measures.

The number of new cases of VWF has been on the decline during the past 15 years in Finland, not only in forestry work, but also in other industries. This is due to the structural changes in work life, but also to the increased awareness of the health risks related to certain occupations, and the increased motivation for healthier working methods. In Finland considerable research has been conducted on hand-arm vibration. We believe that the research activity has also significantly contributed to achieving the present health state in Finnish work places.

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