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Abstracts

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Preface

This is the eighth International Conference on Hand-Arm Vibration and is held in Umeå. The first conference was held in Dundee in 1972 followed by Cincinnatti (1975), Ottawa (1981), Helsinki (1985), Kanazawa (1989), Bonn (1992) and Prague in 1995. I have had the opportunity to attend the last four conferences and I believe that this series of conferences has become an important meeting point for all of us who have an interest to learn more about different aspects associated with occupational exposure to hand-arm vibration.

One major advantage with these conferences, at least in my point of view, is not only the possibility for scientists and experts to meet and exchange information within the area of their particular interest, but also the possibility to collect and exchange knowledge from other areas. As human response to vibration clearly is a multi-disciplinary problem it is of course of utmost importance that people from all disciplines can get an opportunity to meet. I think a multi-disciplinary approach is essential for better understanding of the relation between vibration exposure and related injuries. I am sure that this series of international conferences, which includes sessions of both technical and medical nature, plays an important role in this respect.

This conference is organized under the auspieces of:

- Intenational Commission on Occupational Health (ICOH), Scientific Committee Vibration and Noise (SCVN)
- International Advisory Committee of International Conferences on Hand-Arm Vibration
- European Research Network on Detection and Prevention of Injuries due to Occupational Vibration Exposures.

On behalf of the National Organizing Committee, the International Advisory Committee, the National Institute for Working Life, the Västerbotten County, the City of Umeå and my co-editors for this book of abstracts I wish to express my gratitude to the contributing authors, session chairmen, participants who presented papers, exhibitors and sponsors for making this conference feasible.

Finally, I would like to mention that without enthusiastic work by members of the National Organizing Committee, Conference secretariat, staff at NIWL's Department of Technical Hygiene and KONFERERA Conference Bureau, this meeting would not have been possible to realize.

Umeå, Sweden, 5 June 1998

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Session 1.1
VIBRATION AND ERGONOMIC EXPOSURE

Upper limb disorders associated with manual work and vibration

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Introduction

Hand-arm vibration syndrome, HAVS, may include both vascular and sensorineural impairments. Vascular impairments are mainly associated with vibration exposure, while the sensorineural impairments also may be associated with ergonomic factors. Ergonomic factors include repeated and sustained exertions, forceful exertions, contact stress, stressful postures and low temperature (2). In addition, these factors are also associated with fatigue, muscle disorders, tendon disorders and non-specific pain.

Contribution of ergonomic factors

A growing body of literature (2) supports the contribution of these factors. Most recently, Latko et al. (7) examined the relationship between non-specific discomfort, tendinitis and carpal tunnel syndrome, CTS, and three levels of repetition. Repetition was rated on a scale of 0 to 10. Independent health assessments were then performed on 352 workers. The results summarized in Table1 exhibit a dose-response relationship.

Table 1:Hand and wrist symptoms, Sx, versus repetition in a cross-sectional study.

Symptoms, Sx	Low (2.4)	Medium (5.4)	High (8.0)	p
Discomfort, Sx	22%	27%	46%	<0.0001
Tendinitis, Sx	4%	8%	14%	0.04
CTS Sx	7%	15%	17%	0.01
CTS Sx + Electrical findings	3%	5%	8%	0.06

The risk associated with repetition is increased when combined with other factors, e.g., force or force and vibration. Cannon et al. (5) and Wieslander et al. (11) found a significantly higher use of vibrating tools among patients with CTS than among age and gender matched controls. Significant relationships with repetitive work absent of vibration also were found. Armstrong et al. (1) reported that the risk of CTS among persons performing high repetition-forceful work with vibration was twice that among those performing the same kind of work with no vibration.

Repeated and sustained exertions

Sustained and repeated exertions required to hold and use tools can result in significant localized fatigue. Byström et al. (4) reported average force thresholds for fatigue to be 17% of maximum strength for intermittent work and 10% for continuous work. Other investigators suggested that there is not be an acceptable force limit for continuous static work. Fatigue may be a precursor to chronic muscle disorders and pain (2).

In addition to supporting the weight of tools, workers also must resist the reaction forces of tools as they start and stop (6,10). Armstrong et al. (3) found that subjects exerted as much as 80% of their maximum strength to resist torques of 2.5 Nm and that reducing the torque build-up time from 450 ms to 50 ms had the same effect as doubling torque.

Other factors affecting force include handle size, shape and material, tool balance, mechanical assists, air line attachments, gloves and work methods. Also, control of the process will influence how much work grinding or chipping is required.

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Contact stress

Contact stresses are related to the grip force and the area of contact and produce loads on underlying tissues (9). Use of bucking bars and rivet guns often result in grip forces being concentrated on the base of the palm and the sides of the fingers.

Posture stresses

Posture stresses result when the wrist is flexed or deviated from a neutral posture. Wrist flexion/extensions causes elevated carpal canal pressure and tendons to impinge on adjacent anatomical structures (2). Forced flexion is used as a provocative test for CTS.

Low vibration exposure does not mean low ergonomic stress

Many jobs involve stressful tasks in addition to those that result in vibration exposure. Lifshitz (8) studied the relationship between work activities and musculoskeletal disorders in the chassis department of an auto assembly plant. Tool use ranged from 0-19% of the time; the rest of time was spent holding tools, getting parts or assembling. The total incidence of non-specific, tendon and nerve disorders was 48.5 cases/200,000 hours.

Summary

Vibration exposure is inevitably accompanied by one or more physical stresses. It is essential that studies of upper limb disorders and vibration also consider other physical work stresses. Additionally, it is advisable that both vibration and physical work stresses be considered in the management of workers with upper limb disorders.

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Aspects on hand-arm vibration

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Introduction

There has always been a lot of problems concerning hand-arm vibrations. First of all the attempt to measure the correct amount of acceleration or vibration velocity and then quantify the exposure-response in comparison with the risk of damage. I will give a short revue on the subject of measurements.

Sensor

The type of sensors that have been used for a number of years are sensors that converts mechanical energy to electrical energy. Normally people have preferred accelerometers instead of vibration velocity sensors for hand-arm vibration measurements. There are two different types of accelerometers in connection with hand-arm vibrations:
- Piezoresistive
- Piezoelectrical

A piezoresistive sensor have a design not unlike a strain gauge sensor but the sensing material is a semi- conductor with much higher sensitivity.

The piezoelectric sensor is designed with a crystal of ceramic material which generates a charge when a force is applied to the crystal. The charge is proportional to the acceleration. The first piezoelectric accelerometers were of compression type. This type of accelerometer produced undesired signals from base bending and temperature transients. A very serious drawback of the compression design is that they do not mechanically isolate the piezoelectric element from non-vibration-related forces. The newer designs were therefore piezoelectric elements which were exposed to shear forces instead of compression forces. The next step for sensor design was to produce accelerometers with built-in amplification and/or accelerometers using constant current supply, in general named ICP- accelerometers.

Mounting

More than 20 years ago there were much research and investigations carried out in the world on how to correctly measure the vibrations transmitted to the hands from a vibrating tool. A main question was:
- How to get the sensor to measure exactly what is transmitted to the hand.

At that time almost all measurements on handheld tools should be done in three directions. The sensors had to be very small and lightweight. The sensitivity was therefore very low. Low sensitive accelerometers may cause more problems with external noise and environmental factors.

One of the investigations in Sweden pointed out a very small sensor device which should be located between the handle of the machine and the hand. The sensor device included a triaxial (3 x 0,5 grams) accelerometer array. The triaxial accelerometer array was glued to a rather small curved steel-plate that was adopted to the handle bar radius. The array was glued to the steel-plate. When measuring with this device the triaxial accelerometer array was meant to be placed between the fingers in the middle of the hand.

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One important question is: How much does the device in fact disturb the normal handforce and use of the machine? How much will any temperature changes and movements of the cable to the accelerometer influence the signal. In fact nobody knows, therefore the people working with the ISO standardisation choose another way.

In practice a lot of hand-arm measurements on vibrating machine are done with the accelerometers mounted upon the handle, covered by rubber, with a tiny tubeclamp.

During the 80´s there were possibilities to use a new device, the Laser Doppler Vibrometer was constructed. With this kind of instrument you were able to make measurements both on the machine, the machine tool and on the outside of the vibrating hand without any additional mass or local stiffness. The Laser Doppler Vibrometer do not have any cross axis sensitivity. Most accelerometers have about 5%. But as always there are limitations. The first instruments were rather heavy and big. The laser beam needed to have a reflecting surface and during the measurement the machine needed to be quite still in the axis you wanted to measure. The operator was therefore limited in his use of the machine. If the working operation of the machine caused dust flows, it could disturb the laser beam. In order to get a good signal the distance to the subject should be rather short.

Signal conditioning

Signal conditioning is mainly an optimisation of the frequency content and the amplitude of the signals. A usual trap you may fall in is that a lowpass filtered signal from an overloaded amplifier seems to be very nice and correct.

In the 60´s most instruments had a total dynamic range of about 50 dB. I order to get relevant measurements you very often needed to use the whole range. The instrumentations of today normally have a dynamic range of more than 80 dB so many times you are not aware of problems you may have. Sometimes you are analysing the amplified noise floor. If you then do present the acceleration signals as integrated velocity the results in 1/3-octave bands at low frequencies will decrease very smooth with increasing frequency.

If you desire to measure vibration on any kind of hammer-machines you will have a problem with the accelerometer. The signal spikes will normally have a huge amplitude at high frequencies above 1500 Hz. Both the accelerometer and the charge amplifier could be overloaded. In order to get a more adapted signal range for hand-arm vibration measurements you need to use a mechanical filter between the machine and the accelerometer.

Operation condition

The ISO-standard group 8662 say that the measurements on machines should be done with a group of professional operators and the working task should be as normal as possible. My opinion is that this is very important because the difference in measurement results between an inexperienced operator and a professional could be in the range of 2 - 3 times or 6 - 10 dB.

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The vibration pattern of pneumatic hammers

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Background

Pneumatic hammers are routinely used in a wide spectrum of working environments ranging from road construction to mining. Indeed, it is not uncommon to find workers whose unique source of occupational exposure to hand-transmitted vibration is a tool of this kind. Because of their typical vibration spectrum dominated by frequencies above 100 Hz, pneumatic hammers are good candidates to test the effects on the hand and arm of long-term exposures to large levels (several tens of ms^{-2}) of acceleration at high-frequency.

The motivation for our work is twofold: there are indications (1) that pneumatic hammers may be more "gentle" than predicted, possibly reflecting an inadequate relative weighting of high and low frequencies. Moreover, although the draft revision of ISO 5349 (2) advocates the use of the weighted acceleration sum as a predictor of potential hazard, studies of power absorbed by the hand - arm system (3) indicate a large dependence on vibration axis.

Objective

The purpose of this paper is to understand the basic vibrational pattern of pneumatic rock drilling hammers. We search for hypothetical deviations from left/right symmetry, axisymmetry, and for typical values of the weighted-sum-to-strongest-axis ratios. We also look for correlation between acceleration and noise level and between acceleration and tool age and mass. Acceleration data are then used to calculate daily exposures.

Similar work is in progress for other hand - held tools. All these results will be combined in a forthcoming paper with the outcome of a medical survey in an effort to establish correlation between long-term exposure to vibration and pathologies of the hand - arm system.

Methodology

The r.m.s. accelerations of 26 pneumatic hammers of 12 different models have been measured along each axis of two cartesian basicentric reference frames, one for each hand. Axes are oriented according to the ISO standard 8662-3 (4). This sample represents approximately 50 % of the total population of 57 hammers currently in use in the travertine quarries of Tivoli / Guidonia, the third largest in Italy.

The equipment used includes two Brüel & Kjær accelerometers type 4374 mounted on a Brüel & Kjær adaptor type UA0894, a four-channel digital recorder Sony PC204A, and a real time dual channel frequency analyser Brüel & Kjær 2144 providing a frequency range extending up to 11.2 kHz.

Two measurements have been taken on each of the handles resulting in a redundant measurement of acceleration along the handle longitudinal axis. Travertine is a fairly tender stone, which limits drilling times to about 60 s., the hole depth would otherwise exceed the length of the hammer spike. Typical measurement durations are therefore of order 30 ÷ 45 seconds. All hammers have been measured in situ, while operated by those same workers with everyday experience in their use.

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Results

No statistically significant deviation from left/right symmetry has been found. Fore-aft acceleration is higher than left-to right acceleration by about 20 %. This inequality is statistically significant ($p < 0.05$), providing some evidence for deviations from axisymmetry.

Ergonomic hammers have much smaller overall acceleration than traditional hammers, mostly because of a drastic cut in the vertical component. The vertical acceleration is larger that the average horizontal acceleration by about a factor of 3 in traditional hammers, by a factor of 1.5 ÷ 2 in ergonomic hammers. This translates to average ratios of weighted acceleration sum to strongest-axis acceleration of 1.12 and 1.30 respectively, in excellent agreement with previous more general results (5).

Correlation with noise levels is reasonably good (possibly non-linear ?) provided sound-proofed tools are not included. Manufacturer declared noise levels closely match the lower envelope of measured values, in line with expectations. Separate analyses of light ($m \leq 20$ Kg) and heavy ($m > 20$ Kg) traditional hammers provide good evidence for the latter having larger acceleration. A study of 8 hammers of the same model does not reveal any significant difference between young (age ≤ 2 years) and old (age > 2 years) tools.

Good agreement has been found with previous measurements (6) on a limited common sample of three hammers. Manufacturer declared acceleration values tend to be on the lower side of the measured values, in line with expectations, as well as with studies of other hand - held tools (7).

Preliminary calculations based on employer - declared working times of 40 ÷ 210 minutes a day, give daily exposures A(8) ranging from 4.5 up to 17 ms^{-2}. These values are all largely in excess of both current (e.g. 2.8 ms^{-2}, HSE (8)) and proposed (2.5 ms^{-2}, EU Directive) action levels.

Conclusions

The vibrational pattern of pneumatic hammers shows the expected prominence of vertical motions, but not the expected axisymmetry. There appears to be a significant correlation with noise levels, and some dependence on mass. Daily exposures are very large.

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The influence of shock-type vibration on the absorption of mechanical energy in the hand and arm

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Introduction

Risk assessment for hand-transmitted vibrations is in most countries based on the International Standard ISO 5349 (4). The standard applies to periodic and random, or non-periodic, vibration. Provisionally, this standard may also be applied to repeated shock-type excitation. The knowledge of the effect of shock-type excitation is, however, limited.

Shock-type vibration is often generated by different kinds of percussive tools (chipping hammers, impact wrenches, impact drills, concrete breakers) and is characterized by repetitive impacts, usually with low levels of acceleration at low frequencies, i.e. below 100 Hz, and high levels of acceleration at higher frequencies. Each stroke generates an initial transient with very high peak acceleration.

A possible method of measuring the influence of shock-type vibration on humans could be to determine the quantity of the energy transmitted to and absorbed by the hand (5,6). The assumption is that a higher quantity of absorbed energy per unit time (power) represents an increased risk of vibration injuries or reduction in comfort (3). The quantity of absorbed energy is not only influenced by vibration intensity but also by several other factors, such as frequency, transmission direction, grip and feed forces, hand-arm postures, and individual factors (1,2).

The purpose of the present investigation is to compare the influence of shock-type vibration compared with non-impulsive vibration on the absorption of vibration energy in the human hand and on the grip and feed forces applied by the subjects.

Methods

The technique used to determine the quantity of absorbed energy in the hand-arm system was based on measurements, made as close as possible to the surface of the hand, of vibration force, velocity, and the phase between these parameters. These were obtained by using a specially-designed handle (2) mounted on an electrodynamic shaker. The grip and feed forces applied by the subject to the handle were measured simultaneously.

The vibrations which affect the subjects through the handle were measured and recorded from one hand-held chipping hammer under practical working conditions. From the signals recorded, one typical stroke was chosen. Using a computer program, a random non-impulsive vibration signal was created. The created signal consists of added sinusoidal signals of different frequencies together with a random component. Both the shock-type and the non-impulsive signals had almost the same frequency spectrum. Due to limitations in the shaker the frequency range used was 4 to 2500 Hz.

The study was carried out on 10 healthy right-handed subjects and two different frequency weighted acceleration levels were used. Every subject participated in four experiments and each exposure took about 12 minutes to conduct.

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Results

The outcome showed that the vibration exposure levels made a significant contribution to the vibration absorption as well as to the strength of the grip and feed forces. Moreover, it was found that the hand forces decrease while the absorption of energy increases during the experiment. Furthermore, the influence of shock-type exposure gave a significantly higher hand forces and absorption of energy compared with the non-impulsive exposure.

Discussion

The total quantity of absorbed mechanical energy in the human hand and arm is dependent upon whether the exposure is of shock-type or non-impulsive type. The difference in absorption between the two vibration exposures was about 10%. With regard to the unsubstantiated premise that a higher quantity of absorbed energy represents an increased risk of vibration injuries, one could therefore state that shock-type vibrations increase the risk of vibration injuries compared to non-impact vibrations. Since the hand forces were also higher during exposure to shock-type vibration compared with non-impulsive vibration, it could be speculated whether observed differences in the absorption are due to the changes in the hand forces.

Conclusions

It could be concluded that the vibration response characteristics of the hand and arm differ, depending upon whether the exposure is of shock or non-impulsive type. Moreover, it could be concluded that the international standard ISO 5349 in future should only provisionally be used for evaluation of shock-type vibration until more knowledge are available.

Acknowledgement

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Energy flow in Human - Tool - Base System (HTBS) and its experimental verification

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Introduction

In this paper a theory of energy flow in Human - Tool - Base System (HTBS) and the results of its experimental verification are presented. Theoretical and experimental investigations have been carried out for a prototype of vibration-safe and ergonomic pneumatic MP chipping hammer in which a vibro-isolation WoSSO subsystem is applied. A hydraulic meter of impact energy has been used as the base in this investigation. A physical model of energy flow, its transformation and conversion has been elaborated for this dynamic structure - see fig. 1.

Methods

The First Principle of Energy Flow in Mechanical System defined by the author has been used for theoretical describing of energy flow in the HTB System (1,2). This Principle has been formulated accordance with First Principle of Thermodynamics. This defined Principle can applied for every level of analysis of energy flow, that is for an element, subsystem, system and metasystem. The Principle is also true for every degree of freedom of the dynamic model of investigated HTB System. This property gives a possibility of theoretical analysis of energy flow in mechanical systems with multi-degree of freedom and can be carried out as a computer digital simulation. An experimental method of the energy flow and its results are also presented. The results confirm correctness of the energy flow model of HTB system and the elaborated theory (2,3,4).

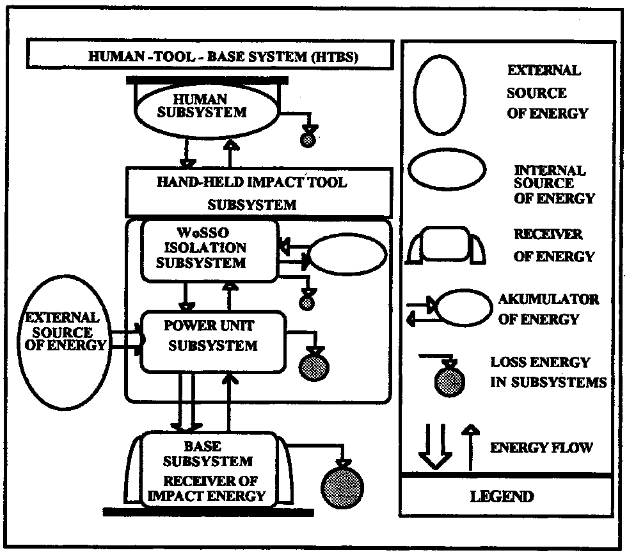

Figure 1. Dynamic structure of HTB System and the energy flow model into system (2,4).

Results

The main result of applied method of the energy flow analysis in HTB System is an assignation of structure energy flow and a calculation of main energy streams into which an input energy stream supplied from an external source of energy is divided. The calculation has been carried out for vibration-safe and ergonomic pneumatic MP chipping hammer in which the WoSSO anti-vibration subsystem was applied. The final result of this investigation is presented in fig.2. The experimental investigation confirming

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correctness of the theoretical describing has been carried out on a lab. stand in Lab. of Dynamics & Ergonomics of Man - Tool Systems (3,4).

Discussion

The energy flow analysis in HTB System with application of WoSSO anti-vibration subsystem proves that the input energy divides into following three main streams: an useful energy stream played to the base, an energy stream played to the man-operator and an energy stream of losses. As it has been proved in these investigations, the useful stream of energy makes 42% of the input energy to the HTB system, the energy stream played to the human-operator makes 0,08% of input energy and the energy stream of losses makes 52% of input energy.

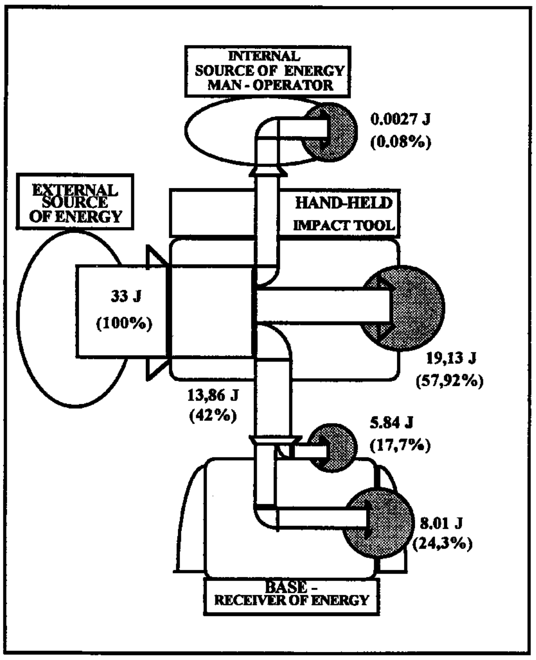

Figure 2. Energy flow in Human - Tool - Base System (HTBS) for vibration-safe and ergonomic pneumatic MP chipping hammer with WoSSO anti-shock subsystem during one work period (4).

Conclusions

The investigations carried out have proved the possibility of the theoretical describing and analysis of an influence of hand-held tools on human health of human in energy flow domain. For this aim the physical model of the energy flow in full HTB System and the simulation computer program have been elaborated.

The obtained results of energy flow have proved a good efficiency of anti-vibration WoSSO subsystem applied into MP chipping hammer for energy isolation and protection of human against vibration energy. WoSSO subsystem makes the control of energy flow in HTB System possible so that the dose of energy played to human-operator is minimal. This result has proved sense of purpose of applying WoSSO subsystem for the effective protection of human-operator against vibration energy. Experimental investigation carried out simultaneously has confirmed the obtained theoretical results.

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Vibration energy transmission to different parts of the human hand-arm system

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Introduction

The International Standard ISO 5349 used for measurements and risk assessment of hand-arm transmitted vibrations in the frequency range 5-1500 can only temporally be used for risk assessment of high frequency vibrations (4). The standard risk assessment shows no clear relation between the frequency weighted acceleration and injuries. A possible measurement method for studying the influence from high frequency vibrations on the human hand-arm system could be to determine the amount of energy absorbed and transmitted to the hand. Studies have indicated that the amount of absorbed vibration energy better correlates with the risk of vibration injuries or reduction in comfort, for frequencies beneath 1250 Hz (2,5).

A great number of reports can be found where the transmission of vibration to the hand and arm has been studied (for a review see 7). These studies do not give any description of the distribution of the vibration energy to different parts of the hand and arm, since only the amplitude of skin movements are measured. Determination of the energy transmission requires simultaneous vibration measurements for determination of the phase shift between the excitation point and the test point of the hand-arm system. Moreover, it has also been discussed in the literature if the vibration response of the human hand depends on whether the signal is a discrete frequency signal or a signal consisting of several frequencies (1,3). However, the investigations have produced conflicting results.

The aim of the present study was therefore to see how the energy transmission changes along the hand and arm and to compare the energy transmission for two different kinds of vibration exposures, i.e. random and sinusoidal.

Methods

The transmission of absorbed energy to different parts of the hand-arm system was determined by simultaneous measurements in the contact surface of the hand and at the actual part of the hand-arm system. At the contact surface, measurements were made of the force, the velocity, and the phase between these parameters. At the surface of the hand-arm system, measurements were made of the transmitted velocity as well as the phase between the transmitted velocity and the velocity in the contact surface of the hand.

These measurements were obtained by using a specially designed handle, developed in an earlier study (6). The velocity signal could be registered on the test points at the hand and arm with a laser velocity-transducer.

Ten healthy subjects with no previous work exposure to vibration, participated. The transmission of energy was measured at three test points which were located at the knuckle, wrist and elbow. The grip and feed forces were held constant at 40 N. On three experiment occasions the subjects were exposed to vibration with different frequency contents (three different frequencies for each occasion and location). The exposures

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were random (20 to 5000 Hz) and sinusoidal vibration (eight different frequencies). The vibrations have a frequency weighted acceleration of 3 m/s^2.

Results

The results show that the energy transmission decreases with the distance from the source. The result also show that the energy transmission is dependent on the frequency for the random vibration exposures. No clear frequency dependence of the energy transmission could be found for the sinusoidal vibrations. It may also be concluded that there are differences in the energy transmission due to types of exposures, sinusoidal vibration shows higher transmission of energy to the hand-arm system than random vibration, especially at higher frequencies.

Discussion

From the results it could be concluded that there are differences in the energy transmission due to different types of exposure. One explanation could be differences in the energy content of the vibration signals. A comparison between the results of this study and some comparable studies shows very good agreement for the test point at the knuckle and major differences for the other two test points.

Conclusions

The observed differences between the transmission data from the random and sinusoidal excitation imply that more studies in this area are necessary. Furthermore, the absorption of vibration energy at higher frequencies also indicates that more studies are of importance. This will not only give an opportunity of obtaining more knowledge about the human hand-arm system, but could also be very useful in the setting of future standards.

Acknowledgement

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Reproducibility and value of hand-arm vibration measurements using the ISO 5349 method and compared to a recently developed method

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Introduction

Measurements which are both reproducible and adequate are the main features in assessing the risk to a certain pathology due to exposure to hand-arm vibrations (1). Dose-response relationship as well as other suggested limit values are based on measurements dictated by the ISO 5349 standard method (2,3). Yet a lot of critical remarks about this sort of measurement technique have been found in literature, especially concerning reproducibility (2,4,5).

The “Directoraat - Generaal van de Arbeid” (Labour Directorate-General) of the Netherlands conceived an alternative method (publication S58-8) in order to get a representative picture of workers’ daily exposure to vibration (5). This method is based on the ISO 5349 standard but is more extended. It has not been evaluated in practice yet though.

The aim of the study was to assess and to compare reproducibility.

Method

A Brüel & Kjær Human-vibration Unit Type 2522 in connection with a Hand-Arm Vibration Set type 4392 was used to measure hand-arm vibrations during working conditions on the field on 4 forestry tools (2 chain saws, 1 hand operated two stroke engine leafblower and 1 two stroke engine hand mower) for several times and on different occasions according both to the ISO 5349 standard method and to the alternative method, conceived by the ‘Directoraat-Generaal van de Arbeid’ of the Netherlands (publication S58-8). Reproducibility of these methods was compared to one another and evaluated by calculating the variation coefficient.

Results

Table: variation coefficients (in %) as calculated for the ISO 5349 method and the publication S58-8 method.

Tool	ISO 5349	publication S58-8
1	59,0	8,1
2	30,0	13,3
3	30,4	7,8
4	13,4	4,2

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The lower the variation coefficient, the more consistent and the more reproducible the measurement procedure tends to be. The method following S58-5 was much more reproducible than the one using ISO 5349.

Discussion and conclusions

The ISO 5349 method's reproducibility in measurement of hand-arm vibration was low compared to the method drawn up by order of the 'Directoraat-Generaal van de Arbeid' of the Netherlands (S58-8).

Therefore and especially when measurements are used for scientific research and to allow as well comparison of vibration levels of machines as exposure of workers to this vibration, the ISO standard should be adapted to this use.

There should also be a reasonable doubt about the ISO 5349's capability of assessing dose-response relationship, as the specific doses are based on almost non-reproducible measurements.

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Automatic test stand for the measurement of the vibration emission of hand held machines

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Introduction

It was the essential goal of a research project of the Federal Institute for Occupational Safety and Health, to create an automated test stand for vibrations and also for other investigations at vibrating hand machines. For this, requirements for the test stand were to be derived on the basis of current knowledge and practical demands at prototype testing. A test stand for selected groups of machines was to build up as an example. A particular emphasis laid on the development and realisation of a suitable hand-arm model, which has to serve in the test stand as a link between the test stand and the machine under test and which must simulate the vibrational characteristics of the human hand-arm system as exactly as possible.

Selection of test machines for the development of the test stand

Selection criteria are for instance the kind of powering, dimensions and masses as well as possibilities for easy application in the test stand. For reasons of the relatively high vibration exposure and for reasons to include several different types of machines in the investigations a pre-selection was made for percussive machines and herewith for electric hammer drills, impact hammers and percussion drills. The working principles of grinders, nailing guns, sand rammers and saws are so specific, that at reasonable expense extra test stands must be developed. Needle scalers and riveting hammers are very similar to the selected types of machines so that the transferability of the knowledge in the investigations for these machines can be assumed.

Evaluation of the test stand

Preconditions for reliable and exact vibration measurements are a hand-arm model tuned at the working conditions of the machines used and a rigidly and non-reactively designed test stand. With this test stand and the applicated hand-arm model it was realised for a relative large field of applications for electrically and pneumatically driven (may be also for combustion-powered) percussive or non-percussive hand machines with a mass until 20 kg. It is necessary that the machines work along the machine axis.

The test stand may be turned very quickly from the vertical to the horizontal direction. By the applicated construction for connecting the machines with the test stand machines of different sizes may be used, just as different grip sizes and forms. It is possible that extreme grip sizes and forms need a new adaptation. The aspects of the work safety and accident protection were taken in account.

Comparing measurements test stand - operating persons

For this comparison vibration measurements were carried out at all selected machines, both in vertical as well as in horizontal working direction. The pushing force was held constantly at 100 N. For the electric percussion drill and the hammer drill the diameter of the drills was varied in two levels. Concrete blocks of type B 35 and dimensions of

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800 x 500 x 200 mm were used. The impact hammer was measured only in vertical working direction acting on an absorber.

The measurements were carried out with 5 operating persons per machine and with 5 single measurements per person. The number of measurements was equal at the test stand. Before the measurements the machines operated several minutes to warm up. Each drill-hole was pre-drilled before the measurement with a depth of about 15 mm. The minimum measuring duration was 30 s, the longest 120 s. The measuring duration of the impact hammer was 60 s. According practical measurements the conclusion can be drawn, that a difference of the frequency weighted r.m.s. accelerations in the primary direction for several users of the machines of 3 dB must be judged as a sufficient good agreement of the results. For the evaluation of the quality of the adjustment of the hand-arm models to the human hand-arm system a criterion of 3 dB for the r.m.s. acceleration $\tilde{a}_{h,w}$ in z-direction and the vector sum VB as well as a criterion of 6 dB for the r.m.s. acceleration $\tilde{a}_{h,w}$ in x- and y-direction were used. All measuring results were within these tolerance ranges.

As measuring parameters one-third octave spectra in all three orthogonal directions were used. The r.m.s. accelerations $\tilde{a}_{h,w}$ and the vector sum VB were calculated from these spectra. Figure 1 shows a measurement result as an example.

The values measured at the test stand are very good reproducible after a longer time and also after repeated changing of the test stand.

The deviation of the measured values is lower by using the test stand as by using test persons.

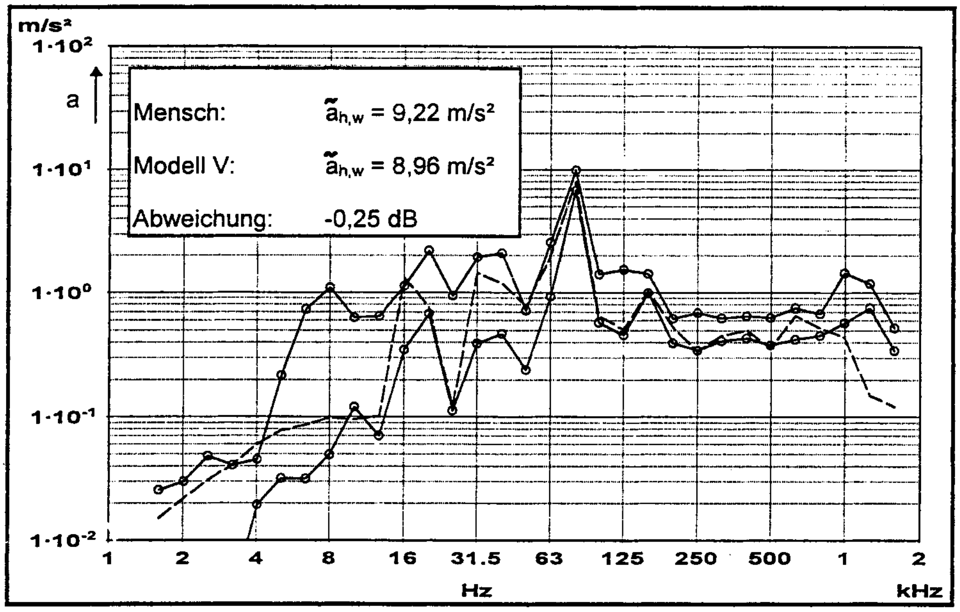

Fig.1: Comparison of $\tilde{a}_{h,w}$-values and one-third octave spectra for the test stand and for test persons.

Maschine: Bosch PBH 160 R — Modell V, z-Richtung — F_A = 100 N
Arbeitsrichtung: horizontal — (Modell V - Hand-Arm-Modell)
Bohrer: 16 mm — (F_A - Handandruckkraft)
———O——— Referenzkurven (Spannweite Mensch - Messung)
— · — · — · — Terzspektrum Prüfstand

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1. ORAL PRESENTATIONS

Session 1.2
MEDICAL ASPECTS

Part 1.2.1
Vascular effects

Vibration-induced white fingers – knowledge deficits

Gemne G

Vibration-induced white fingers (VWF) is a disorder characterised by cold-triggered finger skin blanching in patches (Raynaud's phenomenon), with distribution corresponding to the strongest vibration exposure. These symptoms are elicited when blood vessels contract so much that blood flow is obstructed. The great physiological complexity of peripheral circulation has rendered VWF research very difficult. Today, 80 years after the first reports on this disorder, there are still substantial gaps in our knowledge.

We are not quite sure of what the primary lesion consists, although we have a good notion of its location. In persons with VWF, something appears to have happened to the vessel wall that reduces the effect of normally active vasodilatory substances. Unfortunately, however, this (or any other mechanistic indication hitherto received) does not lead us far towards either prevention or therapy, for in the vasomotor mechanisms a number of factors are involved in an interaction that is insufficiently understood. Anyhow, the notion of a functional lesion based on a "local fault" is a complement to sympathetic unbalance hitherto advocated as the chief explanation for VWF.

Before we reach a real understanding of what constitutes effective prevention, a number of questions must be answered, for instance:

What are the reasons for the wide range of VWF prevalence and latency in homogeneously exposed occupational groups, and between groups with chiefly the same exposure? Obviously, some factors related to the individual lie behind this variation, which is further compounded by large or small differences in external factors.

We know that many people, who have never been in contact with a vibrating tool, sometimes experience chilly fingers, often also toes. This constitutional feature is a general pallor of the finger and toe skin rather than the conspicuously white patchiness of Raynaud's phenomenon. Does it facilitate the development of VWF? And how can we make a reliable etiologic diagnosis, when we have to always take into account the existence of those people in any occupational group? It is justified, in this context, to ask whether or not cold exposure or the contribute to the development of the disorder or only to the triggering of Raynaud's phenomenon? This is an old question on which there has been a lot of speculation, but epidemiological data are still to produce a definite answer. The same applies to the possible pathogenic influence of the use of tobacco and snuff.

In addition to the anamnestic interview hitherto relied on, we need a laboratory test of an objective kind that allows us to ascribe the white fingers to vibration exposure, excluding all other factors. But is there such a test? Not yet.

In the meantime, we will have to make do with symptomatic testing. The available tests, however, have rather low sensitivity, specificity and predictive value. The presence of vasospasm can be reasonably assessed by a test based on finger systolic blood pressure. Interindividual variation and insufficiently known intraindividual factors, however, justify some doubt on the validity of the normality figures currently used. The standardisation of test methods and selection of reference groups must be done with the help of epidemiological studies.

There are strong physiological reasons to assume that exposure intermittency is beneficial in that it allows reconditioning, in the exposure-free intervals, of various circula-

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tory functions. Thus, inserting breaks in the work with vibrating tools should do good, but to what extent should it be done, and what are the time constants of this beneficiary effect?

There are indications of a relationship between VWF and excess hearing loss, but what would be the possible pathogenic mechanism? Does the inflow of nerve signals set up by vibration exposure result in vasoconstriction, reducing the nutritional blood flow to the nervous structures in the inner ear? Related to this is another question: can vibration exposure cause a systemic disorder (on the basis of a lesion to the autonomic nervous system), the manifestations of which are white fingers, excess hearing loss, and other symptoms? Or is such a syndrome the result of physical and psychological stress factors – so abundant in some occupational groups working with vibrating tools?

What is the quantitative relationship between the risk of developing white fingers and the exposure to vibration of various kinds and various duration? Impulse vibration, for instance, may be particularly hazardous, but the extent to which that is true still escapes us, and therefore the quantification of preventive measures in this context has not been possible.

There is, and there will never be, one single reliable risk prediction model for VWF. What we can hope for is epidemiological data from prospective studies that will enable us to formulate risk prediction models for separate tools and work processes. The model published in an appendix to the ISO 5349 standard (a relationship between white finger latency and vibration amplitude of the tools involved) is based on studies involving one particular tool or one industrial process. Although it can be said to have served as an incitament for a general reduction of vibration exposure, the validity of the model can be questioned: it does not take into account the duration of effective exposure, and there is uncertainty regarding, for instance, diagnostic, latency figures, and past exposure values. Above all, it cannot be expected to apply to working environments that do not strictly conform to the selected criteria. Nevertheless, it has been used to assess the risk for occupational groups of the most varying kind and even individual risks. This is liable sometimes to have led to the institution of unnecessary, often expensive preventive measures as well as incorrect evaluation of individual hazards.

The knowledge deficits in such essential issues are chiefly due to lacking epidemiological data. Since several, more or less well-known factors contribute to produce the hazardous effects of vibration, the design of epidemiological studies is particularly difficult. For most issues, there is only one really effective way of performing epidemiological research: prospective studies. They require large study groups, the members of which should be followed, ideally, from the point in time when they start their occupational career and then for a couple of years (the length of the period being decided by the likelihood of developing the disorder). During all of that time, they should be monitored with respect to their medical status and their exposure to vibration and other environmental factors. Although prospective studies consume a lot of resources and time, they are indispensable to expand our knowledge about VWF.

Finger systolic blood pressure during cooling in VWF; value of different diagnostic categories for a routine test method

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Introduction

Vibration-induced white finger (VWF) is a secondary type of Raynaud's phenomenon (RP) caused by exposure to hand-arm vibration. A medical interview is widely accepted as the best available method of diagnosing RP and VWF. However, an objective test is desirable to confirm or support the anamnestic diagnosis of RP. Measurement of finger systolic blood pressure (FSP) during finger cooling has been reported to be a valuable test (4-6). However these results were obtained in scientific investigations of small groups. The aim of the present study was to evaluate further the value of different diagnostic categories for the FSP-test used as a routine method during several years in a large number of men with VWF.

Methods

The present study included all subjects with suspected VWF who were referred for a cold provocation test at the department of clinical physiology and nuclear medicine, Aarhus University Hospital, during an 8-years period from 1991 to 1997. Six of in total 103 men were treated with vasodilating medicine and were investigated separately. The remaining 97 men were grouped by a medical interview into 81 men with anamnestic VWF and 16 vibration exposed men without RP. The severity of the disease was classified by the Stockholm Workshop scale (1). Most subjects were in stage 2 for at least one hand and only few hands were in stage 3. No hands were in stage 1 or in stage 4. A group of 20 men without finger symptoms and never worked with vibrating hand tools served as a control group (5).

Diagnosis of RP was performed by our introduced cold provocation test measuring FSP by cuff and strain gauge technique during combined body and finger cooling (4). FSP was measured after thermostating of the middle phalanx during 5 min ischemia. FSP% was FSP measured at 15, 10 and 6ºC in percentage of FSP at 30ºC. An attack of RP with digital arterial closure as defined by Lewis (2) was verified by the presence of a zero pressure, FSP(0), in the cooled finger (3). FSP(A) was an abnormal cold response, its FSP% being below 58% for the most exaggerated cold response (5). The lower normal range of FSP% was 60%. The systolic blood pressure gradient from upper arm to finger, SPG, was measured at thermoneutral conditions to detect organic obliteration. The upper normal range of SPG was 40 mm Hg (5).

Statistical evaluation was made by non-parametric statistics with a significance limit of 0.05. Values are given as numbers or median (range).

Results

SPG was normal in all subjects. In the VWF group of 81 men FSP(0) was found in 70 men and FSP(A) in 80. FSP% was in median 0 (0-71). FSP% of the ten men with FSP(A) above 0 was 23% (14-48). In the exposed group of 16 men without symptoms

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none showed a zero pressure; one had an abnormal response of 42%; 15 showed a normal response of in median 74% (63-97). The nosographic sensitivity in diagnosing RP was 86% in the FSP(0)test and 99% in the FSP(A)test ($p < 0.05$). The specificity in vibration-exposed men without RP was 100% in the FSP(0)test and 94% in the FSP(A)test. In the separate group treated with vasodilating medicine all six had RP and a normal SPG. Their cold response was 52% (33-62) with one normal and 5 abnormal tests.

Discussion

All subjects had a normal SPG before finger cooling. This indicates that all men with VWF had a vasospastic type of RP without detectable organic obstructions in the arteries leading to and through the fingers.

The FSP(0)test had an acceptable sensitivity of 86% and a specificity of 100% in diagnosing an attack of RP as a zero pressure in the cooled finger. The objective detection of an attack of RP is of diagnostic importance especially in individual cases. A positive FSP(A)test supported the anamnestic diagnosis of RP but did not verify an attack of RP if FSP% was above zero. Because of its high sensitivity of 99% and an acceptable specificity of 94%, the FSP(A)test may be of guidance in studies of group data. However, the diagnostic support of the FSP(A)test was strongly reduced in other studies because of a low FSP(A) specificity of about 60% in combination with VWF prevalence below 35% (5-6). Negative tests did not exclude the presence of RP.

The results of the separate group indicates that the FSP-test can support the anamnestic diagnosis of RP even during vasodilating treatment but that detection of an attack is less expectable.

Conclusions

The routine test method had acceptable diagnostic values of the following two different diagnostic categories: FSP(0) that detects an attack of RP, and FSP(A) that supports the anamnestic diagnosis of RP obtained by a medical interview.

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Assessment of peripheral circulation under impulsive vibration or variation of temperature using the thermal diffusion method

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Introduction

When used for human measurement, it is necessary to monitor peripheral circulatory movement during exposure to stimulation such as local vibration of the exposed hand, especially to impulsive vibration. In such tests, it is important to know whether signals from the sensor may change due to such as vibrations. The plethysmography and clearance methods show problems in continuity, while the laser Doppler method is limited, not only in that determination of an absolute value is difficult but also in that it cannot be used on the side exposed to stimuli (1). We assessed the effects of impulsive vibration on peripheral circulation using the thermal diffusion method with a Peltier stack.

It is important to carry out early diagnosis of peripheral circulatory disorders such as vibration-induced white finger (VWF) using cold water-immersion test. Although peripheral circulation is actually being examined using skin temperature at the fingertip because of its non-invasive and continuous measurement for finger skin circulation, the value obtained by such indirect measurement as skin temperature seems unlikely to reflect peripheral circulation with accuracy. Therefore, we used the thermal diffusion method with a thermal clearance curve to monitor circulatory changes at variation of temperatures as a measure for direct observation of peripheral circulation.

Methods

The types of indices of peripheral circulation being used until now and their characteristics, using the blood flow and its related indices, are summarized in Table. Various methods have gained popularly for measuring blood flow, and the thermal diffusion method, clearance methods using hydrogen gas or Xe, the plethysmography method, the laser Doppler method, and so on have been widely used in various clinical fields. However, the method must be selected according to the application as each method has its own merits and demerits (1, 2).

Results and Discussion

Changes of finger skin blood flow (FBF) in 6 male subjects produced by two vibrations with a constant acceleration (a_{xhw} = 6.3 m/s^2) (3) were compared using the thermal diffusion method with a Peltier stack. The gripping force was 50 N. Neither exposure to chain-saw (Crest factor, 2.2) nor pneumatic nailer (Crest factor, 9.5) with a duration of 5 min changed skin temperature. Although exposure to chain-saw did not change FBF, that to pneumatic nailer decreased it at 4 and 5 min after exposure. Accordingly, we can

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assess the effects of impulsive vibration on peripheral circulation using the thermal diffusion method with a Peltier stack efficiently and specifically.

We examined effects of cold water-immersion (10 °C, 10 min) in chain-saw workers with VWF using thermal diffusion method with a thermal clearance curve which is calibrated by the hydrogen clearance method in advance. FBF of 1 min after immersion in VWF groups (11 workers) was significantly higher than that in control groups (11 workers). FBF at 5 min after immersion in the VWF group was significantly lower than that in the control group. The cold water-immersion test was recognized to be very useful in estimating peripheral circulatory function in workers using vibratory tools in a similar manner as the handgrip and the vibration exposure tests (2).

Table. Characteristics of peripheral circulatory measurement

Measurement	Invasion	Continuity	Assessment of absolute value	Observation of blood flow	Object or site	Use under temperature condition	Use in exposed side under handgrip	Use under impulsive-ness
Skin temperature	no	good	possible	impossible	human, animal surface of organ	possible	possible	possible
Volume pulse wave	no	good	possible	impossible	human, animal finger, etc	possible	impossible	possible
Plethysmograph	pressure	poor	possible	possible	human, animal finger, etc	possible	impossible	possible
Clearance method (^{133}Xe, H_2)	severe	poor	possible	possible	animal, human many organs	possible	impossible	impossible
Thermal diffusion using classical thermocouple	no	good	impossible	possible	human, animal surface of organ	impossible	possible	possible
Thermal diffusion using a Peltier stack	no	good	possible	possible	human, animal surface of organ	impossible	possible	possible
Thermal diffusion using a thermal clearance curve	no	poor	possible	possible	human, animal surface of organ	impossible	possible	possible
Laser Doppler flowmetry	no	good	impossible	possible	human, animal surface of organ	possible	impossible	impossible

Conclusions

The thermal diffusion method is very efficient in measuring peripheral circulation in finger exposed to unstable conditions, e. g. impulsiveness and cold.

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Eight cases of HAV syndrome with arterial lesions of lower extremities

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Introduction

HAV syndrome are composed of the following peripheral components: 1) circulatory disturbances, 2) sensory and motor disturbances, and 3) musculo-skeletal disturbances. In order to confirm the peripheral circulatory disturbances, we have been actively trying to perform arteriography of the upper extremities and the total number has cumulated to 442 cases in our department. With the advance of ageing of vibration-exposed workers, it is not rare to find cases with stenotic or obstructive changes of the arteries in the lower extremities.

The purposes of this presentation are as follows: (1) incidence of abnormal findings of the superficial arteries of lower extremities by palpation, (2) arteriographic findings of upper and lower extremities in 3 cases with TAO (Thromboangitis obliterans, Buerger's diseases), and (3) arteriographic findings of upper and lower extremities in 5 cases with ASO (arteriosclerosis obliterans).

Subjects and Methods

All cases exposed to vibration in mining, forestry and several other industries in Hokkaido were studied at the Iwamizawa Rosai Hospital (Workmen's Accident compensation Hospital of Iwamizawa). Hokkaido is the northern most island in the Japanese archipelago located at the north latitude from 41.5 to 45.5^{o}, where there is a heavy snow fall in winter.

(1) A hundred cases for the close examination for VD (vibration disorder, HAV syndrome) were investigated for work history, vibration exposure, smoking habit and the findings of the palpation of superficial arteries of lower extremities (mainly arteria dorsalis pedis and a. tibialis posterior) in these 3 years.

(2) Direct arteriography was carried out under general anaesthesia. After intra-arterial administration of Tolazoline as a vasodilator, serial automated arteriograms were taken at three exposures per second following intra-arterial administration of 60% Urographin.

Results

1. Among 100 cases for the close examination for VD, 19 cases (19%) showed defect or weakness of pulsation of a. dorsalis pedis and/or a. tibialis posterior. Mean age was 55.8 years and mean exposure to vibration was 19.4 years. Number of smokers was 66 and mean smoking period was 16.5 years. Mean blood pressure was 134-81 mm Hg.

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Eighty-one subjects complained of Raynaud's phenomenon and 56 subjects were examined by arteriography of the upper extremities. In some cases, arteriography of the lower extremities was performed.
2. Three VD cases with TAO were all male and mean age was 54.3 years. Two of them were smoker. Arteriography of the upper extremities revealed; (1) complete or 90% stenosis of ulnar artery at hand joint in 2 cases, and (2) obstructions of the common finger arteries and the proprietary finger arteries in all 3 cases. Arteriography of the lower extremities revealed; (1) tapering-off or obstruction of a. tibialis anterior or a. tibialis posterior at the lower leg, and (2) bellows-like changes of superficial femoral artery in all 3 cases.
3. Five VD cases with ASO were all male and mean age was 57.4 years. Four of them were smoker. Arteriography of the upper extremities revealed stenosis and/or tapering-off of the proprietary finger arteries in all 5 cases. However, both ulnar and radial arteries were without any findings arteriographically. Arteriography of the lower extremities revealed; (1) 90% stenosis of the common iliac artery in 1 case, (2) obstruction or stenosis of superficial femoral artery in 2 cases, and (3) obstruction or stenosis of anterior or posterior tibial arteries in 2 cases.

Conclusion
With the advance of worker's ageing, VD subjects are frequently accompanied with hypertension, diabetes mellitus, hyperlipidemia, and so on. Among such cases, some of VD subjects will be accompanied with the obstructive changes of arteries of the lower extremities. Although the technique is quite simple, palpation of superficial arteries of lower extremities and upper extremities (especially Allen’s test) is always indispensable. In order to clarify the pathological status of arteries of upper and lower extremities, arteriographical examinations such as MR-AG should be actively performed in the diagnosis or differential diagnosis of VD.

Response of neuroendocrine system in men with different constitutional types to the experimental and occupational hand-arm-vibration exposure

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Introduction

The high sensitivity of neuroendocrine system to the vibration exposure (VE) was shown in many studies. Depression of functions of the hypothalamo-pituitary-adronocortical (HPA) and hypothalamo-pituitary-gonadal (HPG) systems as well as discoordination in regulation of hormonal secretion by pituitary gland were revealed in patients with vibration disease (VD) (1,2). Epidemiological, morphological and functional investigations carried out among riveters with long-term vibration exposure had shown that symptoms of the VD developed earlier and in a greater number of cases in persons of pectoral somatotype (PS) than in persons of abdominal somatotype (AS) (3, 4). The authors found activation of HPA system in persons of PS and activation of HPG system in persons of AS after experimental hand-arm vibration exposure (VE) (5).

The aim of the present work is to compare functional state of HPA and HPG systems in persons of AS and PS after experimental and occupational hand-arm VE.

Materials and methods

Two groups of men were studied. Group 1 consisted of 37 riveters in the age of 23 to 45 years (mean 34,2 ±1,2; M ± SD) with total time of VE 2.800 to 10.500 hours (6650 ± 300,5; M ± SD). The workers were chosen after investigation of occupational histories and medical examination. No one had vibration syndrome.

Group 2 consisted of 24 healthy men in the age of 20 to 30 years (25,8 ± 1,4; M ± SD) whose work was not connected with VE, physical strain or other harmful occupational factors. These persons were exposed to 5-minute hand-arm-vibration at 30 Hz with vibration velocity of 121 dB (re. 5,6 10^{-2} m/s $_{r.m.s.}$). The gripping force was 50N. We classified this VE as medium stress factor.

For determination of the constitutional types the anthropometric and morpho-functional signs were measured. Groups of AS and PS were furthermore determined (according to the classification of Bunak V, 1941).

The states of HPG and HPA systems were estimated according to the concentrations of hormones cortisol (Cort.) and testosterone (T) in saliva. Samples of saliva were collected in group 1 at 7.00, 11.00, 15.00, 19.00 and 23.00. Samples of saliva were collected in group 2 at 7.00 and 9.00-before, immediately and 30 minutes after VE, and at 11.00. The concentration of hormones we determined by radio-immunoassay.

Results

Some of the results of investigations are presented in table 1 and table 2.

Table 1. Concentration of Cortisol (ng/100 ml) in saliva in persons of AS and PS in groups 1 and 2.

Group	Somatotype	Time				
		7.00	11.00	15.00	19.00	23.00
1	Abdominal, n=22	335 ± 26,1 *∆	158 ± 17,0 *	129 ± 17,5	100 ± 16,2	86 ± 16 ∆
	Pectoral, n=15	262 ± 13,7 **	172 ± 20,2 **	113 ± 15,2	81 ± 7,0	42 ± 6,5
2	Abdominal, n=12	196 ± 10,2 ∆	44 ± 5,0	-	-	-
	Pectoral, n=12	148 ±14,0	53 ± 3,3	-	-	-

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Mean ± SD * p< 0,01 comparison between AS of group 1 and group 2. ** p< 0,001 comparison between PS of group 1 and group 2. ℓ p< 0,05 comparison between AS and PS within each group.

Table 2. Concentration of Testosterone (pg/ml) in saliva in persons of AS and PS in groups 1 and 2.

Group	Somatotype	Time				
		7.00	11.00	15.00	19.00	23.00
1	Abdominal, n=22	112 ± 8,8	77 ± 5,6	82 ± 5,0	77 ± 8,4	70,3 ± 5,0
	Pectoral, n=15	125,2 ± 14,7	97,3 ± 7,5 *ℓ	86,3 ± 7,7	70,0 ± 7,3	68,6 ± 8,2
2	Abdominal, n=12	113 ± 4,0	95,5 ± 8,0 **	-	-	-
	Pectoral, n=12	126 ± 7,0	72,8 ± 4,5	-	-	-

Mean ± SD * p< 0,05 comparison between AS and PS in group 1.
** p< 0,05 comparison between AS and PS in group 2.
ℓ p< 0,05 comparison between PS of group 1 and group 2.

Discussion and conclusions

Table 1 shows significantly higher Cort. concentration in riveters of both somatotypes in comparison with persons whose work was not connected with VE. Persons of AS had higher levels of Cort. concentrations in almost all investigated periods. At the same time we have found significant activation of HPA system in persons of PS in group 2, immediately after 5 minutes VE (5). Taking in account the previously reported results (6) we can conclude that, long-term VE promotes activation of HPA system in persons of both somatotypes with preservation of diurnal rhythm.

From table 2 we can not reveal evident signs of activation or depression of HPG system under long-term VE. However there is significant differences of T concentration at 11.00 o'clock between persons of AS and PS as within each group, as well as between groups. We observed in group 2 significant increase of T concentration in persons of AS and decrease in persons of PS after 5 minute VE. This fact allowed us to make the conclusion that the HPG system has a high sensitivity to VE (5). In riveters we found changes of diurnal rhythm HPG system with enhanced T concentration at 11.00 to 19.00 in 78% of the cases with prevalence in this group of persons of PS. These findings indicate that HPA system reacts to VE mainly by changes of diurnal rhythm and this effect is more expressed in persons of PS.

The results of this study indicates that physiological response of neuroendocrine system to hand-arm vibration exposure have constitutional differences.

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Cardiac autonomic nervous activity in response to cold in VWF patients

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Introduction

The pathophysiology of circulatory disturbances in patients with vibration-induced white finger (VWF) is characterised by an enhanced vasospastic response to cold, which can be due to an increased sympathetic nervous activity in response to cold in the patients (1). In recent years the power spectral analysis of heart rate variability has been developed to assess the sympathetic and parasympathetic nervous function separately, by dividing the power spectrum into high- and low-frequency components (2-4). The aim of the present study was to examine the cardiac autonomic nervous activity in response to cold in VWF patients, using the power spectrum analysis of R-R intervals.

Methods

The present subjects examined were 22 patients with VWF aged 59.3±3.6 years and 19 healthy controls aged 59.3±3.6 years. They all were selected from those without diabetes mellitus or heart diseases.

Subjects lay supine during the study. They rested quietly for about 30 min, then immersed the right hand into cold water at 10 °C for 10 min, and thereafter put the hand out of the water for 10 min. In the meantime, ECG and skin temperature of the index finger were automatically recorded with an ambulatory ECG recorder (Fukuda Denshi, SM-50) and an electrode thermometer (Takara Thermister, HR116). The room temperature was 27±1°C.

After the examinations, ECG signals were converted to R-R interval signals. The power spectrum was then calculated for 128 seconds with a software program using the algorithm of maximum entropy method (Fukuda Denshi), and was divided into the low-frequency component (0.02-0.15 Hz: LF) and the high-frequency component (0.15-0.40 Hz: HF). The LF/HF ratio is considered to show a measure of sympatho-vagal balance, an index of sympathetic nervous activity (2-4).

In the pre-cold exposure, ECG signals were analysed for 128 seconds which ended one minute before the beginning of the immersion. During the cold exposure, four consecutive series of 128 seconds were analysed with the first one that started 30 seconds after its commencement. In the post-exposure, four consecutive series were analysed, in which the first one began one minute after the end of the immersion.

Results

As shown in Fig. 1, the LF/HF ratio in the VWF patients tended to be larger than that in the controls in the pre-exposure, though it did not differ significantly. During the cold exposure, the LF/HF ratio in the patients increased greatly in the first 1-2 minutes following the immersion, while the ratio in the controls increased little, so that the ratio in the VWF patients was significantly greater than that in the controls. In the post-exposure, it tended to be still greater in the VWF patients.

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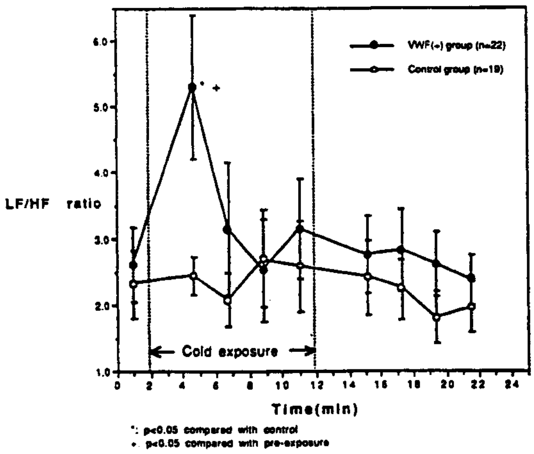

Fig.1 LF/HF ratio (mean±S.E.) of VWF group and controls

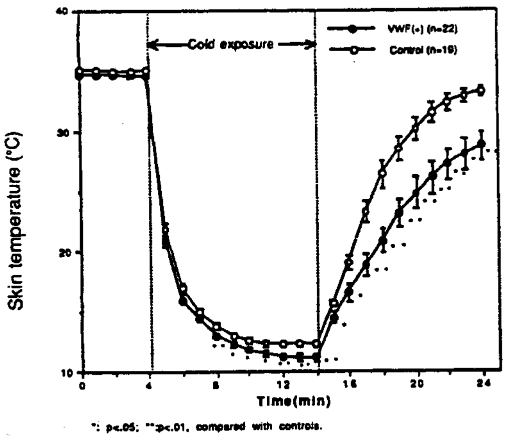

Fig.2 Skin temperature of right index finger (mean+S.E.)

Fig. 2 shows that finger skin temperature tended to be lower in the VWF patients in the pre-exposure period, though the difference was not significant. In the cold exposure, skin temperature dropped rapidly in the first three minutes of the exposure. Then it was significantly lower in the patients than in the controls at the 4th to 10th minutes of the cold exposure and also in the post-exposure period when its rewarming was delayed in the VWF patients.

Discussion

The present spectral analysis of R-R intervals showed that the cardiac autonomic nervous activity of VWF patients is more likely to shift to the sympathetic dominant in response to cold than that of healthy controls. As a result, VWF patients have an increased cardiac sympathetic activity in response to cold.

The sympathetic activity in VWF patients increased to its peak in the first 1-2 minutes of the cold exposure. Meanwhile, skin temperature dropped rapidly in the first 3 minutes and then became lower than that of the controls. These findings indicate that an increased sympathetic activity in response to cold contributes to an enhanced vasospastic response in VWF patients. It is considered that the increased sympathetic response to cold play a role in circulatory disturbances of the feet as well as the hands in VWF patients (5).

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Effects of room temperature, seasonal condition and food intake on cold immersion test for diagnosing hand-arm vibration syndrome

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Introduction

For diagnosis of the hand-arm vibration syndrome, cold exposure test immersing one hand in cold water at 10°C for ten minutes has been performed widely in Japan (1). The test results are thought to be influenced by the measurement circumstances such as environmental temperature, clothing condition, cigarette smoking, food intake, etc. We investigated the effects of room temperature, seasonal condition and food intake on the test results, especially finger skin temperature.

Methods

In experiment 1, six healthy male subjects aged 23 to 29 were examined repeatedly under six different room temperatures at 10°C, 15°C, 20°C, 22.5°C, 25°C and 30°C. The seasons were autumn and winter.

In experiment 2, eight healthy male subjects aged 28 to 39 were examined under room temperatures at 10°C, 20°C and 30°C, repeatedly in four seasons. The average outdoor temperatures were 4.5°C in winter, 12.4°C in autumn, 17.7°C in spring and 24.5°C and 27.3°C in summer.

In experiment 3, five healthy male subjects aged 21 to 27 were examined repeatedly 1 hour after, 3 hours after meal and after fasting for 13 hours. The room temperature was at 22.5°C. The seasons were summer and winter. The energy of meal taken before the experiment was controlled as 754 kcal.

Left hand of each subject was immersed in stirred water at 10°C for ten minutes. Number of clothes was controlled. Analysis of variance was used.

Results

The finger skin temperature was strongly affected by room temperature. Between the room temperatures at 15°C and 25°C, average values of finger skin temperatures before exposure and at 10-minute point after immersion changed with the range of more than 10°C. The effects of room temperature were statistically significant ($p < 0.05$, $p < 0.01$).

The effect of seasonal conditions on the finger skin temperature was statistically significant ($p < 0.01$). Especially, the finger skin temperatures in summer were higher than those in other seasons. Those under the room temperature at 30°C in autumn were lower.

The average values of the finger skin temperature indicated no remarkable differences among three different conditions of food intake in summer. Those in winter tended to be higher at 1 hour after meal and lower after fasting for 13 hours. However, the differences were small.

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Discussion

The core temperature of human body is maintained by mechanisms of adjusting heat-production and heat loss. The heat is produced by basic metabolic processes, food intake and muscular activity (2). The basal metabolic rate in Japanese general people is reported to be affected by seasonal condition. That in summer is lowest and in autumn tends to increase faster beyond the decrease of environmental temperature (3).

The effects of seasonal condition on the finger skin temperature were to be the reverse of changes of the basal metabolic rate. However, cutaneous vasoconstriction is induced in cold environment for maintaining the core temperature. Seasonal effects on the basal metabolic rate and finger skin temperature can be understood as co-ordinated mechanisms for the purpose.

Food intake increases the metabolic rate because of its specific dynamic action (SDA). The SDA may last up to 6 hours after the food intake (2). The effect of food intake was not so remarkable, especially in summer. The reason may be that sympathetic discharge is increased after food intake (4).

Conclusions

For estimating circulatory function of the upper extremities using the finger skin temperature, the room temperature should be strictly controlled and the effect of seasonal condition must be taken into consideration.

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Palmar sweating reaction to vibration stress

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Introduction

Both signs of palmar hyperhidrosis and Raynaud's phenomenon in the fingers are often seen in the patients with vibration syndrome. These signs are considered to be related to the exceeding excitation of the sympathetic nervous system, of which mechanism is still obscure in detail. The aim of this study is to clarify the relation between autonomic nerve tone and local sweating response to vibration. We used palmar sweating and digital blood flow as an indicator of the responses.

Methods

The subjects were 20 healthy men aged 21 to 25 (mean 22.4) years. At first, the level of activity of autonomic nerve was examined by photoplethysmographic responses to auditory stimuli (1). The noise of 90 dB(A) used as auditory stimuli was given to the subject through a headphone for 10 sec. The responses were divided into four types: normal (N), intermediate (I), delayed (D), and poor response (P). The left hand was exposed for 3 minutes to sinusoidal vibration with a frequency of 125 Hz and an acceleration of 30 m/s^2 (r.m.s.). The subjects were asked to grasp the handle with the force of 5 kgW during vibration exposure. The control condition was just to grasp the handle without vibration by the same force. Palmar sweating was measured on the right palm continuously by the ventilated capsule method (2). Digital blood flow was examined on the tip of index finger of the non-exposed hand using digital photoplethysmography. We analyzed the changes of sweating and the plethysmographic amplitudes during and after vibration.

Results

Fig.1 shows the typical responses of N and I type. In N type, plethysmographic amplitude reduced and the sweating increased when grasp started. But the both responses had been recovered to the former level during the grasp. It had the same tendency under the condition of vibration stress. In I type, on the other hand, the responses between grasp and vibration was different. In vibration stress, sweating was much greater and the recovery of plethysmographic amplitude was worse than that in control. When sweating in I type compared to that in N type in vibration stress, the former tended to be greater as shown in Fig.1. The facts may mean that the sympathetic nervous system got excited by the vibration and that the effect continued through it in I type. The sweating showed some peaked waves, in which we named α, β and γ. The phenomena were augmented by vibration stress.

Discussion

Sakakibara et al. (3) have reported combined effects of vibration and noise on palmar sweating in healthy subjects. In the study, they referred to a marked increase in palmar

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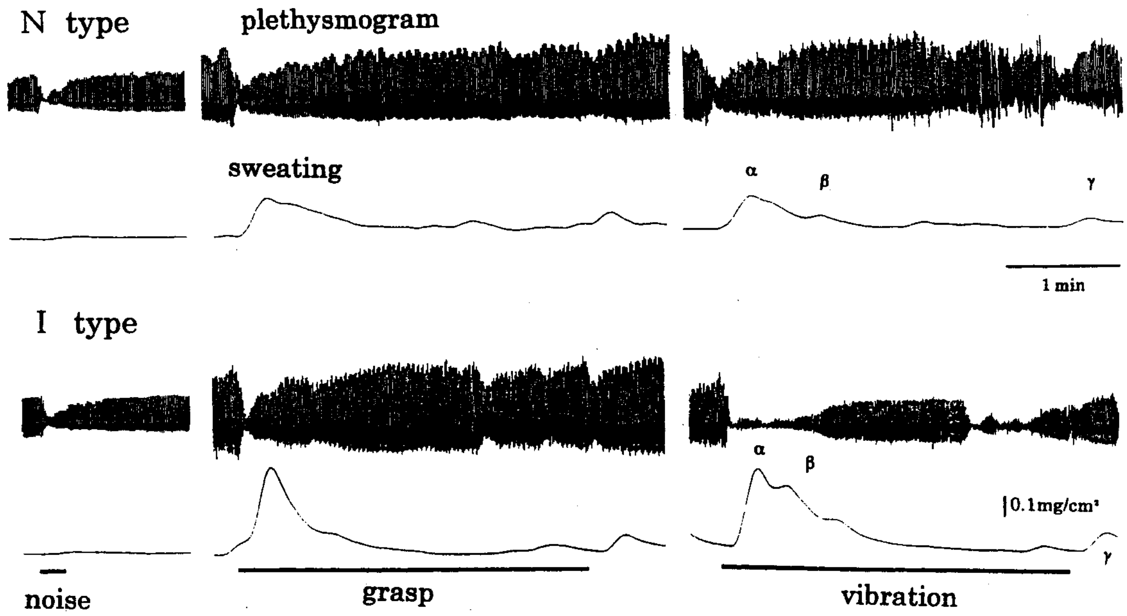

Fig.1. The typical responses of palmar sweating and plethysmogram in N and I type.

sweating of non-exposed hand. We have got the same results even in the weaker vibration stress. According to our results, the subjects of I type could be easier to respond to vibration than those of N type. This suggests that the level of activity of sympathetic nerve reflects sweating responded to vibration. Also, we have found clearly some sweat waves, namely α, β and γ, especially in vibration stress. Among these waves, α and γ wave appear when plethysmogram shows low amplitude, namely, at the times of excitation of sympathetic nerve. β wave, on the other hand, appears being unrelated to the change of the plethysmographic response. We are carrying out further studies in order to answer that question.

Conclusions

Vibration increased palmar sweating, showing some waves.

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Transient vibrations from impact wrenches cause damages on blood cells and the effects are not taken into account in by ISO 5349

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Introduction

This paper shows how the cell membrane of blood cells is destroyed by transient vibrations from impact wrenches and how ISO 5349 (1) filters away these transients and thereby do not take them into account. It is also shown how these transients to a large extent can be dampened.

Vibrations from hand held tools with transient type vibrations such as impact wrenches in car repair shops are a common cause of vibration related injuries (2). This is in spite of the fact that these machines only have a typical vibration level around 3 m/s^2 measured in accordance with ISO 5349 and are only used 10 minutes per day. This can be compared to grinders where the vibration level often is 6 m/s^2 and the typical time it is used is several hours per day. The exposed vibration dose is several times higher on the grinder and one would suspect that vibration related injuries would be very scarce among people working with impact wrenches but this is not the case.

What we suspect is that it is the transient vibration peaks from the impact wrenches that causes these injuries in the human hand and that this risk is not covered by ISO 5349.

Methods

In order to investigate if the transient vibrations have an impact on biological tissue an experiment was set-up where cow blood were filled into polyurethane rubber containers mounted on the following:

1. The handle of a 1/2 inch pneumatic impact wrench with aluminium housing.
2. The socket of the impact wrench.
3. The handle of a 180 mm pneumatic vertical grinding machine with standardised unbalance.
4. The handle of a 180 mm pneumatic vertical grinding machine with grinding wheel.
5. The handle of a 1/2 inch pneumatic impact wrench with aluminium housing and internally vibration dampened.

The impact wrenches were run for 15 minutes on a fixed nut and the grinders were run for 15 min in the air for test 3 and during grinding in test 4.

The idea is that if it can be shown that the blood cell membrane is destroyed by impact vibrations also larger and more sensitive biological structures such as nerve cells may be harmed by this kind of vibrations.

The proportion of damaged blood cells is estimated through the amount of the red coloured haemoglobin being released to the blood plasma as measured spectrographically.

In parallel the vibrations from the machines were measured both unfiltered and filtered in accordance with ISO 5349 in order to investigate the filters effect on transient vibrations.

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Results

The results from the blood cell experiment shows that the rate of destruction is closer to be correlated to the peak vibration amplitude than to the ISO 5349 vibrations:

Test condition	Amount of destroyed blood cells	Peak vibration amplitude, m/s^2	Measured ISO 5349 vibration, (m/s^2)
1 Handle of impact wrench	0.4%	11.000	3
2 Impact wrench socket	100%	>>30.000	-
3 Vertical grinder with unbalance wheel	0.1%	800	5
4 Vertical grinder with grinding wheel and grinding	0.1%	900	4
5 Handle of impact wrench with dampened mechanism	0.07%	4.000	3

Discussion

The results show a relation between the damages to the cell membranes of blood cells and the exposed transient vibration and also that the values according to ISO 5349 do not reflect this.

Conclusion

- Impact wrenches generate very high transient acceleration peaks causing high stresses in the tissue when transferred to the hand.
- The transients cause destruction of the cell membrane of blood cells subjected to these peaks.
- The filtering in ISO 5349 almost completely eliminates these peaks and thereby does not take into account the associated risks.
- Transient peaks can easily be significantly reduced to a low cost by redesigning the tool.

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Vascular and neurological impairment in forest workers of Sardinia

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Introduction

Vibration pathology due to the use of chain saws has been investigated in several studies.

Similar to what has been observed in angioneurosis from vibrating tools typical of the mining and mechanical industries, the physical characteristics of vibrations and vascular and osteoarticular pathology have been investigated with special interest.

All studies in the literature stress the high incidence of vascular, osteoarticular and neurological alterations in forest workers using chain saws and this explains the great attention paid to this kind of pathology in all countries.

Materials and methods

Our study includes 25 subjects who work or worked as woodcutters. Their occupational activities were in all cases performed in the woods of Sardinia and consisted of cutting down trees and lopping off branches with chain saws. They worked an eight-hour day for five days a week in all seasons of the year. We excluded from our study all subjects with a previous vibration risk of different origin (jobs in quarries or mines, machine shops, etc.). We considered only subjects who had a job seniority of at least three years. The longest exposure to risk was found in a woodcutter with 29 years of working activity; mean exposure of all subjects was 14.5 years.

The age of subjects examined varied from 26 to 73 years (mean age 51.6); 18 of these were still working, while eight subjects had left the risky activity, for periods varying from one to seven years.

As concerns the type of the chain saws used, they were the most widely diffused brands on the market and had similar technical characteristics. All chain saws were powered by internal combustion, two-stroke, single-cylinder engines; fuel was a mixture of regular fuel and mineral oil at a ratio of 25 (sometimes as much as 40) to 1, and were air-cooled. Volume varied from 50 to 120 cc., with a speed from 7000 to 8500 rpm and a weight ranging from 5 to 14 Kg. (subjects examined normally used chain saws of middle to heavy weight) and an overall length, including blade, between 30 and 150 cm. Many of these chain saws are equipped with silencers, anti-vibration handles (with rubber bonded metal shock absorbers) and safety systems (chain brake systems, shields, oil sumps, etc.). Our cases include 12 smokers, 8 former smokers and 5 who have never smoked.

As concerns referred symptoms: all subjects reported symptoms clearly similar to Raynaud's symptomatology, with the appearance of a pale crisis in one or more fingers, followed by the cyanosed phase, five woodcutters complained of one of the two phases of Raynaud's phenomenon and only three subjects had no clear vascular involvement, their symptomatology being entirely neurological and represented by prickles and paresthesia.

In all cases we examined vascular functionality by Doppler C.W., photoplethysmography Laser Doppler flowmetry, in basal conditions and after a "cold-test", veni-vasomotor reflex, capillaroscopy and cutaneous thermometry. X-rays of the osteo-articular districts most exposed to vibration trauma were performed on all subjects.

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We conducted a study on neurological abnormalities in 19 subjects (age 38-64 yrs (x 53.2) by performing an electromyography with a coaxial electrode needle on the adductor muscle of the thumb, thus determining the speed of motor neurone conduction of the ulnar nerve; in eight cases we also performed the test for ischemia under electromyographic control for 10 minutes.

Results

In all cases routine examinations did not reveal pathological elements worthy of note, nor were alterations of the great vessels, as documented by the Doppler C.W., observed; in one case, photoplethysmography, showed an abolition of the pulsatory waves in some fingers in basal conditions.

Finally, in 20 subjects, still in basal conditions, it was possible to highlight alterations due to peripheral vascular hypertonia. Laser Doppler flowmetry performed on ten subjects showed rest values below our normal laboratory reference values and the venivasomotor reflex was clearly altered; likewise, perfusion units during cold testing in eight cases were quite close to biological zero.

Through photoplethysmography after “cold testing” we were able to diagnose our cases as hand-arm vibration syndrome in 16 subjects (52,38%), vascular hypertonia in 7 subjects (26,20%) and 2 functionally normal subjects (21,42%). Video-capillaroscopy showed a reduced number of capillaries with avascular areas, giant capillaries, interstitial oedema and reduced flow in most of the subjects.

Electromyographic examination revealed normal voluntary activity and nerve conduction. Neuromuscular hyperexcitability with the typical picture of tetanic spasm was noted in two out of eight subjects tested with provoked ischemia of the forearm for 10 minutes.

Conclusions

We underline the high incidence of vascular functional alterations documented by photoplethysmography, Laser Doppler flowmetry and capillaroscopy, despite nearly normal electromyography and other neuromuscular tests. Moreover, we can assume that a relatively new test like Laser Doppler flowmetry can be considered quite useful in determining the vascular functional balance of workers exposed to hand-arm vibration syndrome risk.

Mean values and standard deviation of Laser Doppler flowmetry in ten cases.

AGE	JOB SENIORITY	Rest Flow 3rd finger	S. F. 3rd finger	VAR%	Cold Test 3rd finger
Yrs	Yrs	P.U.	P.U.	%	P.U.
44.7 6.2	14.9 6.3	60.3 16.2	31.1 18.3	48.1 19.7	10.8 8.5

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1. ORAL PRESENTATIONS

Session 1.2
MEDICAL ASPECTS

Part 1.2.2
Quantative sensory testing
(QST)

Possibilities and potential pitfalls of combined bedside and quantitative analysis of somatosensory functions

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The presentation will focus on the facilitatory effect of combined bedside and quantitative sensory testing with special emphasis on diagnostic work up in pain patients. Illustrative cases will be presented where a combination of different techniques has provided a precise description of the sensory dysfunction profile and enabled a correct diagnosis. The use of detailed techniques for somatosensory examination, especially those monitoring the small fibre channels, is mandatory to complement the use of standard clinical neurophysiological methods which fall short in demonstrating small fibre system pathology.

In patients with nerve damage, with or without spontaneous pain, typical findings include hypoesthesia/hypoalgesia in various combinations with uni- or polymodal hyperesthesia as well as hyperalgesia and allodynia. Hypoesthesia is most frequently characterised by an increased perception threshold and a rightward shift of the stimulus-response function. In a fraction of patients the perception threshold is unaltered and the hypoesthesia can be detected during bedside examination procedures only. Occasionally the reverse may occur with sensory alterations confined to the perception threshold. In such cases sensory quantification with threshold tracking techniques will be mandatory to detect nerve damage. Temporal (e.g., aftersensation, abnormal latency) and spatial (e.g., faulty localization, extraterritorial spread) sensory aberrations are also frequently found.

A source of potential pitfalls when interpreting signs of altered sensation in different painful conditions is the recent observations of sensory dysfunctions in experimental and clinical nociceptive pain states. It is widely appreciated among clinicians that patients with clear cut nociceptive pain, especially musculoskeletal and visceral pain, not infrequently report focal and/or referred symptoms such as numbness and paresthesia, reminiscent of neurological involvement. It has previously not been systematically studied whether these patients, or even patients with nociceptive pain without such symptoms, have sensory alterations in the focal pain area or in the region of referred symptoms. Evidence and characteristics of such alterations in nociceptive pain states will be presented, indicating an interaction between the nociceptive system and other somatosensory modalities.

Sensory examination is a crucial part of the diagnostic work up in patients with chronic pain. Further characterisation of sensibility in patients with pain of different pathophysiologies is warranted to improve diagnostic accuracy.

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Rationale for measuring vibrotactile perception at the fingertips as proposed for standardization in ISO CD 13091-1

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Introduction

The second committee draft of ISO 13091-1 strives to obtain comparable results from two methods for measuring vibrotactile perception thresholds at the fingertip: *method A*, in which the stimulating probe is simply a flat-ended cylinder; and *method B*, in which the probe has a "surround", or rigid, planer annulus on which a fingertip rests and through which the probe contacts the skin surface (1).

The purpose of this paper is to summarize the rationale for the measurement methods proposed, recognizing that the future standard is to: 1) produce reproducible and comparable results; 2) provide thresholds mediated by a single mechanoreceptor population, to facilitate interpretation, and; 3) enable thresholds from different receptor populations to be obtained from one apparatus by changing the stimulation frequency.

Requirements for measurement methods

The committee draft specifies the waveform and frequency of the stimulus; the provision of support for the subject; the skin surface conditions at the point of stimulation; the probe tip geometry; the skin-stimulator contact conditions - skin indentation or contact force, the probe-surround gap and surround contact force; the psychophysical algorithm, and; attributes of the subject’s response.

The requirements are summarized in Table 1, (1) and are driven by inter-related physiological and psychophysical mechanisms. The preference for intermittent (‘P’ - preferred), as opposed to continuous (‘O’ - optional), stimulation is to avoid elevated thres-holds caused by forward masking,(2) or temporary threshold shift(3) This limits both the duration and the rate of change of stimuli. The frequency ranges, and skin-stimulator contact, are selected to optimize responses from different mechanoreceptor populations(4) Psychophysical studies confirm various aspects of this selection. The subject support and skin-stimulator contact are also designed to control threshold errors introduced by physiological “noise”(5). Monitoring the inconsistency of a subject’s response to the stimulus provides a means for controlling errors introduced by the psychophysical algorithm, and provides an immediate test of the reliability of the results.

The committee draft also details requirements for background vibration, the calculation of vibrotactile perception thresholds, and the preparation and instruction of subjects. The background vibration is specified in terms of masking the minimum descending threshold at the stimulation frequency.

Conclusions

The second committee draft of ISO 13091-1 provides a consistent set of requirements based on the physiological and psychological mechanisms currently known to influence the measurement of vibrotactile perception thresholds.

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Table 1: Summary of requirements in ISO/CD 13091-1 (from Ref. 1)

Stimulus	**SAI**	**FAI**	**FAII**
Frequency (Hz)			
- 3 recommended	4,0	25	125
- other	3,2; 5,0	20;32	100;160
Intermittent	‘P’	‘P’	‘P’
- burst duration	<10s	<10 s	0,6 - 10 s
- quiescent duration	≥0,6 s	≥0,6 s	≥0,6 s
Continuous	‘O’	‘O’	‘O’
- maximum duration	50 s	50 s	50 s
Subject positioning			
- support	full length of forearm, hand and finger; seat with back		
Skin surface conditions			
- skin temperature		27 - 36 °C	
- test room temperature		20 - 30 °C	
Probe tip			
- geometry		flat ended cylinder	
- diameter		4,0 ± 2,0 mm	
Skin-stimulator contact	**A - No Surround**		**B - Surround**
- skin indentation	1,0 ± 0,5 mm		1,0 ± 0,5 mm
- contact force	0,1 ± 0,05 N		0,35 ± 0,18 N
- probe-surround gap	-		1,5 ± 0,5 mm
- surround force	-		0,5 - 1,0 N
Psychophysical algorithm			
- up-down/von Békésy		‘O’	
Subject’s response			
- detection		automatic and unambiguous	
- inconsistency		automatic detection of inconsistent responses	

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A standardised test battery to detect neurological and vascular components of the hand-arm vibration syndrome

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Introduction

Various vascular and neurological measures are used to identify components of the hand-arm vibration syndrome. A test battery, including the measurement of thermal thresholds, vibrotactile thresholds, rewarming times and finger systolic blood pressures, has been proposed for standardisation in the United Kingdom. This study investigated methods for performing the tests such that within the constraints of current knowledge and practicality they would give maximally sensitive, specific and repeatable results.

Methods

From a review of the literature, possible test methods were identified. The methods were selected so that they could be conducted within approximately 1 hour during pre-employment screening or routine examination of workers exposed to hand-transmitted vibration. Consideration was given to factors influencing intra-subject variability and inter-subject variability.

Results

It was concluded that the four tests should be performed in a room at a mean temperature of 22°C (± 2°C) with air flow not noticeable and an ambient noise level below about 50 dB(A). Control over vasoactive and neuro-active physical and chemical agents prior to measurements is recommended. Subjects should wear light indoor clothing; they should be habituated to the test environment for 15 minutes before measurements begin, or until finger skin temperature is stabilised at a temperature above 22°C, whichever is greater.

It is recommended that the two neurological tests (for thermal and vibrotactile thresholds) should be performed before the vascular tests. Subjects should be seated for neurological tests and either seated or supine for the vascular tests. For both the neurological and the vascular tests, the wrist should be straight with the forearm and hand supported. Neurological tests should be performed on both hands using one digit innervated by the median nerve and one digit innervated by the ulnar nerve.

Thermal thresholds may be measured using the method of limits, or the Marstock method, with a rate of change of temperature of 1°C/s and a reference temperature of 32°C (± 2°C). The stimulus should be applied to the palmar surface of the most distal phalanx of the test digit by means of a smooth flat surface contacting the digit with a force of 2 N (± 0.5 N). When using the method of limits to determine the mean hot threshold and the mean cold threshold independently, a minimum of 6 judgements is suggested, with a delay of at least 3 seconds at the reference temperature between judgements. A minimum of 6 cycles should be made when using the Marstock method. For both psychophysical methods, the first two hot judgements and the first two cold judgements should be ignored when calculating mean threshold values. The mean hot threshold, the mean cold threshold and the neutral zone (the difference between the mean hot threshold and the mean cold threshold) should be reported. All measures should be reported in degrees Celsius (°C).

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Vibrotactile thresholds may be obtained using the up-and-down method of limits (von Békésy method) with sinusoidal vibration at frequencies of 31.5 Hz and 125 Hz, with a rate of change of vibration magnitude between 2 dB/s and 5 dB/s and a measurement duration between 30 seconds and 45 seconds. The vibration stimulus should be applied at the centre of the whorl on the most distal phalanx of the test digit by means of a circular contactor, 2 mm to 8 mm diameter, concentric to an annular surround, allowing a gap of 2 mm between contactor and surround. For threshold magnitudes to be comparable between equipment, contactor diameter should be more tightly controlled. A diameter of 6 mm (± 0.5 mm) is suggested. The test digit should push on the surround with a force of 2 N (± 0.5 N) and the contactor should either apply a force to the digit of 1 N (± 0.5 N) or indent the skin by 2 mm (± 0.5 mm). Vibrotactile thresholds should be reported in ms^{-2} r.m.s. (or in dB with reference to 1.0×10^{-6} ms^{-2} r.m.s.).

Rewarming times (following cold provocation of the hand) should be measured either on the hand most affected by symptoms of blanching or on both hands simultaneously. Transducers for measuring finger temperature should be in good thermal contact with the skin at defined locations. The temperature of the test hand(s) should stabilise in air for a minimum period of five minutes prior to testing. The hands(s) should then be placed within a thin waterproof covering before being immersed up to the wrists in stirred water controlled at 15°C (± 1°C). The hand(s) should remain immersed for five minutes with no ischaemia. On removal from the water, the waterproof covering should be removed and the hand(s) supported at heart level during a 15-minute recovery period. Results should be reported in degrees Celsius (°C) in the form of a rewarming curve, from the beginning of the settling period to the end of the recovery period.

Finger systolic blood pressure measurements should be obtained on all fingers of both hands, or on the fingers most affected by symptoms of blanching. Finger systolic blood pressures should be measured simultaneously with reference pressures on the thumb, the latter being obtained with an air-inflated pressure cuff placed around the proximal phalanx. Water-perfused pressure cuffs should be used to measure on test fingers; they should be placed around the medial phalanges of the index, middle and ring fingers and on the proximal phalanx of the little finger. All pressure cuffs should be 24 mm wide. Transducers sensitive to the return of blood flow to the digits should be placed on the distal phalanges of the reference and test digits. The tips of the fingers should be squeezed and a supra-systolic pressure applied to all cuffs (e.g. 250 mm Hg). Water, controlled at either 30°C, 15°C, or 10°C (±0.5°C), should perfuse the double-inlet cuffs for 5 minutes before all cuffs are deflated at a maximum rate of 3 mm Hg/s. The finger systolic blood pressure of a digit is the pressure at which the transducer detects the return of blood flow in that digit. Measurements should be made at 30°C and then at 15°C; a further measurement may be performed at 10°C if required. Finger systolic blood pressures should be reported in millimetres of mercury (mm Hg), percentage finger systolic blood pressures should also be calculated and reported.

Conclusions

Studies have shown that the suggested methods for determining thermal thresholds, vibrotactile thresholds, finger rewarming times and finger systolic blood pressures give repeatable results. The tests have also been shown to be sensitive to some of the dysfunctions resulting from exposure to hand-transmitted vibration.

Acknowledgement

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Effect of push forces on vibrotactile thresholds measurement

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Introduction

Peripheral neuropathies in the upper extremities, may occur as a result of occupational exposure to hand-transmitted vibration. These diseases may cause a variety of disorders of the fingers, hands and arms. Neurological disturbances and vascular disorders (known as Raynaud's phenomenon or vibration-induced white finger) are important symptoms of the vibration syndrome (1). Fingertip vibrotactile thresholds have been used to quantify the neuropathy produced by hand-transmitted vibrations. Vibrotactile thresholds have also been used to estimate the acute physiological effects of hand-transmitted vibration exposure on the sensory system, and to investigate the permissible limits of occupational exposure to vibrations. Vibration sense thresholds at the finger-tips are sometimes used to evaluate the neuropathy, and the vibrotactile thresholds on the fingers are known to depend on these specifies, measuring equipment, procedure, and method or algorithm. Researchers around the world have used many different types of vibrotactile measurement equipment.

Since 1991 The Working Group 8 (Vibrotactile Perception) of ISO/TC108/SC4 has been involved in optimising testing procedures and interpreting vibrotactile perception thresholds. Although the Committee Draft International Standard ISO/CD 13091 (2) has been proposed by ISO/TC108/SC4/WG8, the measuring equipment, algorithms, and conditions, specially the conditions of contact have not yet been agreed upon internationally.

Therefore, few researchers have been considered the measuring equipment and measuring algorithms by using commercially available vibrometers (4). One researcher has been considered the relationship between contact conditions at the stimulus interface and their effects on vibrotactile thresholds for the Meissner's and Pacinian corpuscles (3). But, it is not clear whether the results of the contact conditions can apply to Japanese people.

The purpose of this study was to investigate the effects on vibrotactile thresholds for Pacinian corpuscles under different contact conditions using Japanese subjects.

Methods

Eight male subjects participated in the experiment. They were healthy and 22 years old students of the Kinki University with no history of neuromuscular or vascular disorders. The experiment was performed on three different days, and each subject was measured once a day. The experimental conditions of vibrotactile measurement equipment were almost the same for ISO/CD 13091 conditions. The probe contact force of the contact conditions was 1 N from the results (3). Seven different fingers push forces on a stationary surround to the vibrating probe (0.25N, 0.5N, 1N, 1.5N, 2N, 2.5N, and 3N) were used in the experiment. Vibrotactile thresholds were measured for each push force

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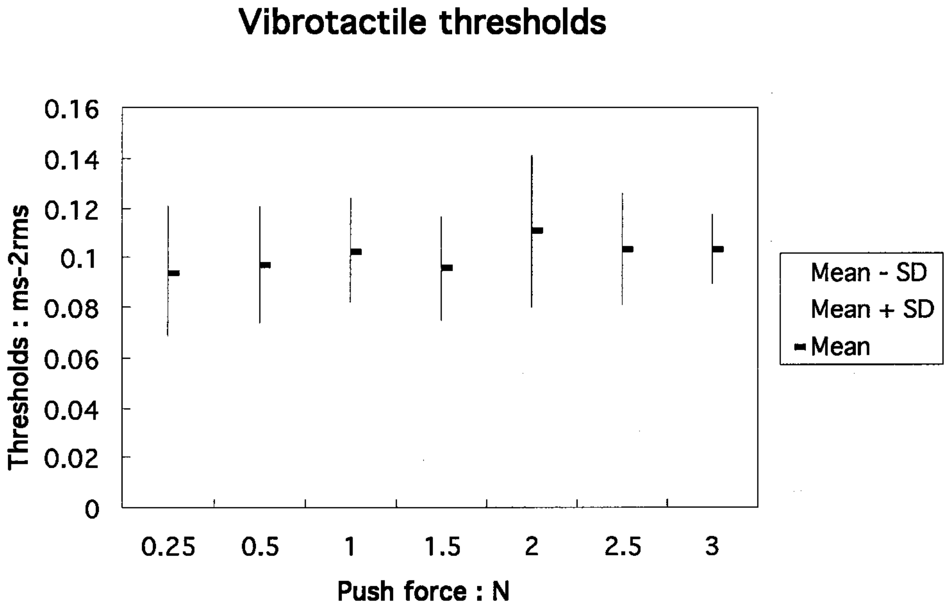

Fig. 1 Relation between push forces and vibrotactile thresholds.

at 125 Hz using an *HVLab* Tactile Vibrometer. The UD method was used in the experiment. The UD method is a simple generalisation of the most orthodox algorithm for estimating a 50-percent threshold. The level of the test stimulus is varied in steps of a constant size, 2.5 dB was adopted.

Results and Discussion

Figure 1 shows the mean vibrotactile threshold results and the standard deviations obtained from eight subjects as a function of push force. Differences between push forces were analysed by using a multifactor variance analysis. It's seems that increasing the push force on a surround had the effect of decreasing the sensitivity of the Pacinian corpuscles. There were no significant differences between the results of Figure 1. From the questionnaire to subjects, the most comfortable push force during the experiment was 1 N.

Conclusions

From these results, it was cleared that the vibrating probe force 1N and the push force on a stationary surround to the vibrating probe 1N were good conditions to measure the vibrotactile thresholds for Japanese people.

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Equivalent skin-stimulator contact forces for vibrotactile measurements with, and without, a surround

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Introduction

An international standard currently under development in ISO/TC108/SC4 specifies two basic methods for measuring vibrotactile perception thresholds at the fingertip: *method A*, in which the stimulating probe is simply a flat-ended cylinder; and *method B*, in which the probe has a "surround", or rigid, planer surface on which a fingertip rests, containing a hole through which the probe contacts the skin surface (1).

The purpose of this study was to measure the dependence of skin indentation on the static force applied by a stimulating probe both with, and without, a surround for the preferred measurement parameters specified in reference 1: namely, a 4,0 mm diameter stimulating probe with, if present, a 7,0 mm diameter surround.

Apparatus and Procedure

Method A. A version of the instrument described in reference 2 was used. The subject was seated comfortably with a back rest. Support was provided for the full length of the forearm, hand, and the finger to be tested. The forearm was horizontal, the palm upwards, and the finger was in a relaxed, natural position curving upwards (close to the neutral position). A 4,0 mm diameter probe, rigidly suspended from one arm of a beam balance, the fulcrum of which was mounted on a vertical track, was then lowered onto a fingertip, approximately midway between the centre of the whorl and the fingernail. The static force exerted by the probe on the flesh of the fingertip was increased gradually in a sequence of steps, and the indentation of the flesh measured for each step. Throughout the sequence of measurements, taking about 15 minutes, the subject was required not to move. The contact force was measured with an accuracy of ±0.001 N, and skin indentation with an accuracy of ±0.02 mm. The skin temperature was recorded and the precise skin site marked for future reference. Measurements were repeated on each subject over a period of several days to establish the repeatability of the procedure.

Method B. An annular disk, with an outer diameter of approximately 58 mm and a hole 7,0 mm in diameter centred on its axis of symmetry, was first machined to weigh 100 g. The procedure described above for the method A measurement (without surround) was repeated with one additional step: immediately before the probe was lowered onto the skin of the subject, the 100 g disk was balanced in a horizontal position on the fingertip. The probe was then lowered onto the fingertip through the centre of the 7,0 mm hole in the disk. In this way skin indentation could be measured for the probe diameter (4,0 mm), gap between the probe and surround (1,5 ± 0,5 mm), and surround-fingertip contact force (1,0 N) specified as preferred skin-stimulator contact values in reference 1.

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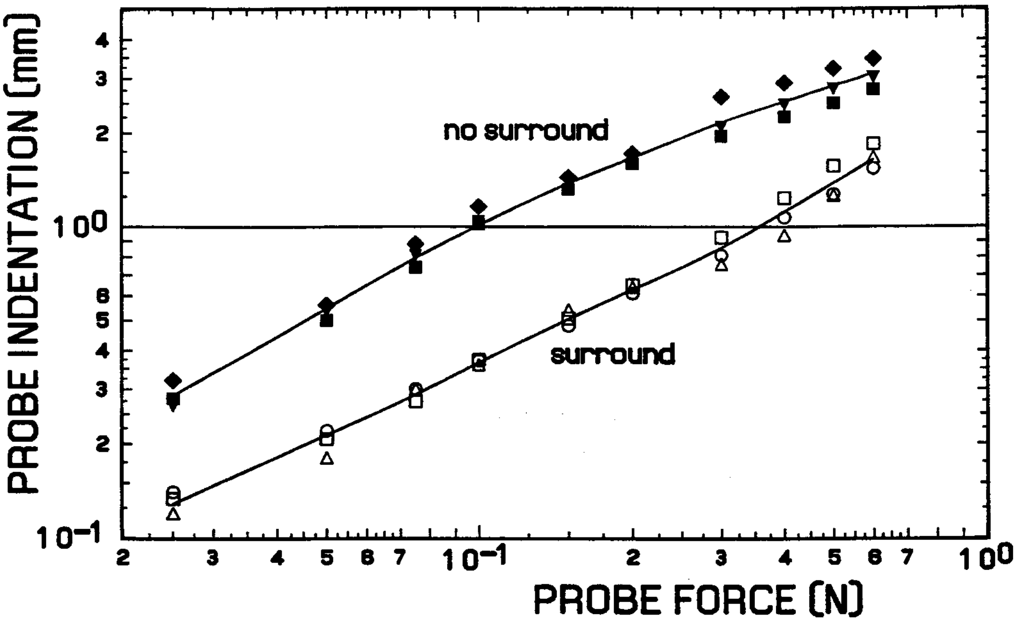

Figure 1. Indentation of the skin at the fingertip for values of the static force with which a 4,0 mm diameter stimulating probe is applied to the skin. When present, the gap beetween the probe and surround, is 1,5 mm, and the surround-fingertip contact force is 1,0 N.

Results

The static indentation of the skin at the fingertip is shown in Figure 1 for three male subjects (aged from 43 to 72 years), for values of static force ranging from 0,025 to 0,6 N, together with a curve showing the mean indentation for these subjects. The results with, and without, a surround were obtained from the same subjects and fingertips.

Discussion

The results of this study indicate that the presence of a surround effectively stiffens the flesh at the fingertip, thereby resisting static indentation by the stimulating probe for all values of the applied force. For the specific case of a 4,0 mm diameter probe applied to produce a skin indentation of 1,0 mm, as proposed in reference 1, an applied force of 0,10 N is required for method A (without surround), whereas a force of 0,35 N is required for method B (with surround) when the surround-fingertip contact force is 1,0 N.

Conclusions

The measurements shown in Figure 1 provide an empirical basis for specifying skin-stimulator contact forces for measuring vibrotactile perception thresholds at the fingertips with, and without, a surround.

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1. ORAL PRESENTATIONS

Session 1.2
MEDICAL ASPECTS

Part 1.2.3
Neurological effects

Vibration-induced neuropathy of the hand

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The problem

Vibration-induced impairment of hand function is a well recognized, yet puzzling and intriguing phenomenon. Although the occurrence of white fingers is known since long, the main cause of impaired hand function in vibration-exposed workers is the *neuropathy* of the hand which may occur alone or in combination with white fingers (4). The human hand is a *sense organ,* normally exhibiting delicate sensory functions which allow fine discrimination between forms, shapes and textures (stereognosis). Normal sensibility is an absolute prerequisite for normal hand function, since the sensory feedback is a base for balanced and well co-ordinated movements of the hand.

The nature and character of vibration-induced neuropathy is not sufficiently recognized among physicians, and these patients are often misunderstood and sometimes classified as malingerers. The situation may have tragic consequences from the socio-economic point of view since these patients may not be able to manage the work situation.

Diagnostic problems

Vibration-induced neuropathy of the hand may constitute diagnostic problems. Clinical routine tests for sensibility are often normal. The two-point discrimination (2PD) test is usually normal, even at a moderate or severe stage of the disease. Tests for constant touch (Semmes-Weinstein monofilament) and stereognosis may, however, be pathological already at an early stage of the disease. In the diagnostic test battery of hand therapists there is a large number of sophisticated tests for stereognosis, precision and dexterity (e.g. Crawford small part dexterity test, Pergue Pegboard test, Minnesota manual dexterity test etc) (3). Such tests may also serve as a useful base for creating improved classification systems for objective staging of sensorineural problems.

The vibrotactile sense of the hand is impaired at an early stage. The tactilometry technique therefore represents a useful principle for screening and longitudinal follow up of individuals. Neurophysiological measurement of nerve conduction requires a competent and interested neurophysiologist, and should always be combined with assessment of the vibrotactile sense. Carpal tunnel syndrome may sometimes be a component of the vibration-induced neuropathy, but in a large number of cases the nerve lesion is located *distal* to the carpal tunnel. In such cases nerve conduction across the carpal tunnel may be normal and carpal tunnel release would have no effect on sensory dysfunction.

Treatment and prophylaxis

Vibration-induced neuropathy is a problem progressing with continuing vibration exposure. There is no clinically documented effective medical treatment for it. Although Ca^{2+} channel blockers may prevent reaction induced to neurones by vibration (5) such treatment has no documented effect in clinical praxis. Prophylactic measures are therefore of great importance to prevent development of vibration-induced neuropathy, and

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methods for early diagnosis are of fundamental importance for initiation or strengthening of such measures before the neuropathy is fully developed.

Pathophysiology

It has been demonstrated in animal studies that vibration may induce various types of structural and functional changes in peripheral nerves, e.g. intraneural edema, transient nerve fibre damage as well as cell activation and proliferation with increased synthesis of growth factors. Vibration induces an ”alarm reaction” in the peripheral nerve, reflected in several types of functional changes in the neurones and the Schwann cells.
With high frequency vibration the nerve lesions are limited to the most terminal parts of the hand or to those parts of the hand that are in immediate contact with the vibrating tool. Vibration of lower frequencies may be transmitted more proximally in the hand-arm system. Hypothetically, there may also be a central nervous component, forming a base for the frequently seen impaired precision, dexterity, and motor functions of the hand. It is known from brain-mapping studies on primates that monotonous, iterated movements of the hand may induce deterioration of the sharp borders, normally separating the projections of separate fingers in the somatotopic brain cortex (2) tissues of the hand a similar functional cortical reorganization may well take place as a result of vibration, and could hypothetically contrib (1). Since vibration to a large extent represents iterated and monotonous micromovements of the tissues of the hand a similar functional cortical reorganization may well take place as a result of vibration, and could hypothetically contribute to the motor dysfunction of hands in individuals subjected to long-term vibration.

Conclusions

Vibration-induced neuropathy of the hand is an important entity that is not sufficiently recognized, yet it is a main component of the hand-arm vibration syndrome. Sensory dysfunction of the hand is the main cause for impaired hand function in these cases, and is only in a limited number of cases attributable to a carpal tunnel syndrome. Improved techniques for early detection of disturbances in hand function, with special reference to sensibility, is of fundamental importance for understanding the problem, for initiating prophylactic programs and for creating new classification systems based on objective findings.

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Vibration-induced nerve injuries – experimental and clinical aspects

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Introduction

Long term exposure to hand-held vibrating tools may lead to sensorineural symptoms in the hands. The pathophysiology of vibration-induced nerve lesions is not known well enough. The purpose of this project was to study and relate clinical, pathophysiological, morphological and therapeutic aspects of vibration-induced nerve injury.

Methods

Clinical part

One hundred symptomatic vibration-exposed men were interviewed and clinically examined (3). Tactilometry of both hands (digits II and V) was done in 96 patients (2) and nerve conduction studies were carried out in 73 (2).

Morphological examination of the human dorsal interosseous nerve proximal to the wrist was performed in 10 vibration-exposed men and in 12 autopsy controls (5).

Experimental part

One hind limb of anesthetized rats was exposed, in an especially designed set up, to sinusoidal vibration for 5 hours daily for 2-5 consecutive days (40-80 Hz; 16-32 m/s^2_{rms}). The regenerative capacity of the sciatic nerve was investigated following a crush or nerve transection and repair following the vibration exposure (1,4,6). In some of the experiments a calcium channel blocker (D600; metoxyverapamil) was given locally to the sciatic nerve through a miniosmotic pump. Activation and proliferation of non-neuronal cells (induction of early immediate gene product, *c-jun* and incorporation of 5-bromodeoxyuridine) and signs of degeneration (induction of Nerve Growth Factor receptor) were also investigated in nerves following vibration exposure (1).

Results

Clinical part

Three groups of symptoms were seen: sensorineural ones (48%), vasospastic ones (20%) and both combined (32%). Cold intolerance occurred in 27%. Twenty-two patients had clinical signs of carpal tunnel syndrome (CTS). Tactilometry did not differ between the symptomatic groups nor was it reflected in CTS. Vibration perception thresholds were elevated in cold intolerance and increasingly so with progressive sensorineural, but not vasospastic, symptoms (2). Nerve conduction was impaired in the median, but not the ulnar nerve. It did not differ between the symptomatic groups nor between the sensorineural stages.

In biopsies from vibration-exposed patients demyelination in various stages of development, loss of nerve fibres, and fibrosis were seen.

Experimental part

Following vibration exposure (displacement 127µm) an increased regenerative capacity was induced by the vibration exposure and the findings suggest that both distal part (non-neuronal cells) and proximal parts (the whole neurone) may be affected (4,6). With higher displacement (254 µm) even an impaired regenerative capacity could actually be observed. Local application of the calcium channel blocker D600 abolished

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the stimulatory effect of the exposure to vibration (6). Following 5 days of vibration exposure there were signs of cell activation and cell proliferation in the plantar nerves and to a less extent more proximally in the leg. Upregulation of the NGF-receptor indicating nerve fibre degeneration was also seen in some nerves.

Discussion

Sensorineural and vasospastic symptoms may occur separately or together. Common to both is an impairment of the vibrotactile sense which progresses along with the sensorineural symptoms only. This suggests that the symptoms pursue different courses of development. Together, the vibration perception thresholds and the nerve conduction studies indicate neural injuries at two levels, one at receptor level or distally in the finger tips, and another one more proximally at the level of the carpal tunnel. Cold intolerance without blanching of the fingers appears to be a sign of neural injury.

Morphological changes in the dorsal interosseous nerve proximal to the wrist have not been described previously. Neurophysiologically, demyelination and loss of nerve fibres appear as reductions in conduction velocity and nerve response amplitudes respectively. Regarding the pathophysiology it has been shown that vibration can induce signs of injury in the peripheral nerves indicated by changes in regenerative capacity depending on the displacement. The results also indicate that mechanisms affecting both the nerve cell body and the non-neuronal cells in the nerve trunk – such as cell activation and cell proliferation – probably are involved. The experimental study also indicates that local treatment with a calcium channel blocker (D600) can abolish the vibration-induced alarm reaction in the nerve (sign of nerve injury). Demyelination may be the primary lesion followed by loss of axons due to a change in the regeneration capacity and by fibrosis.

Conclusions

Experimental and clinical studies indicate that vibration exposure can induce nerve injury, such as cell activation/proliferation of non-neuronal cells, demyelination, axonal degeneration and fibrosis, which may underlay the clinical symptoms. Early signs of injury may be prevented by local administration of a calcium channel blocker. The peripheral injuries may also lead to more proximal lesions (nerve cell body level).

Acknowledgements

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Comparison of absolute thresholds for vibration at the fingertip and on the hand in two different postures

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Introduction

Contact with the vibrating surfaces of tools is usually made with the skin of the glabrous part of the hand. Miwa (3) determined thresholds and equal sensation contours over the range 3-300 Hz for the hand pressing on a flat plate; these data influenced the development of the frequency weighting now used to evaluate the hazards of hand-transmitted vibration. From later studies, Mishoe and Suggs (2) reported equal sensation curves obtained with sinusoidal and non-sinusoidal vibration in both a single direction and in three directions at frequencies from 32 to 2000 Hz; Reynolds et al. (4) presented equal sensation contours for different grip forces and three axes of vibration for both a palm grip and a finger grip; Lundström (1) compared vibrotactile thresholds at 15 different points on the glabrous part of the human hand within the frequency range of 25 to 1000 Hz.

Much research has investigated vibrotactile thresholds at the fingers, often to identify mechanisms responsible for the perception of vibration, or the detection of disorders caused by vibration. Other research has investigated the perception of vibration with hands grasping handles. Few studies have investigated the sensory differences between the fingertip and the whole hand. For both the fingertip and the hand, the various studies show different thresholds, partly because different conditions and different methods have been used.

The purpose of this study was to compare absolute thresholds for hand-transmitted vibration obtained in two different hand postures (grasping a handle, and with the palm pressing on a flat plate) with absolute thresholds for vibration at the fingertip.

Method

Twelve healthy male volunteers, aged 22-33 years (mean 24.6 years), participated in the study. All subjects were non-smokers, right handed and not occupationally exposed to hand-transmitted vibration. Subjects were asked not to consume coffee, tea or alcohol for at least two hours before the tests. Finger skin temperature was measured before and after the threshold measurements; tests proceeded if the skin temperature was higher than 29 Celsius.

Three sessions were conducted using three devices: *condition A* - a flat horizontal wooden plate (200 mm by 150 mm); *condition B* - a cylindrical wooden handle (30 mm diameter); *condition C* - *HVLab* tactile vibrometer (6 mm diameter contact area) applied to the distal phalanx of the middle finger. The hand posture was controlled in each condition. In conditions 1 and 2, subjects used the whole of the right hand to contact the wooden surface (plate or handle) and maintained a push force of 10 N (no grip force); visual feedback of the force was shown on an analogue meter. In condition C, the tip of the middle finger was placed over the vibrometer probe (diameter 6 mm, 2 mm gap, 10 mm diameter surround) with 2 N push force on the surround and an upward force of 1 N applied by the probe.

Absolute thresholds were determined with the up-and-down transformed response method (UDTR method), proposed by Wetherill and Levitt (5). Using a two-interval

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two alternative forced-choice (2IFC) tracking procedure, subjects were exposed to vertical sinusoidal vibration as a 3 second ‘test’ motion, followed by a 1 second pause, followed by a 3 second ‘null’ motion. The order of the ‘test’ and ‘null’ stimulus was randomised. A light indicated when either stimulus was being generated. The task of a subject was to judge whether the first or the second stimulus was perceptible. The ‘test’ stimuli commenced from a level the subject could not feel; a ‘test’ stimulus was increased by 2 dB following one incorrect response and decreased by 2 dB following three consecutive correct responses. A run was terminated after six reversals, and an absolute threshold was calculated from the average of the peaks and troughs. Seven different frequencies (at preferred octave centre frequencies from 8 Hz to 500 Hz) were applied in each session. The order of presenting the three conditions and seven frequencies was randomised.

Results and conclusion

Figure 1 shows that the absolute thresholds obtained for the whole hand were different from those for the fingertip. Lower thresholds were obtained with the fingertip at low frequencies, possibly due to the surround around the probe enhancing the perception of vibration via FA I units. At frequencies above 31.5 Hz, lower thresholds were obtained with the hand in contact with handle and the plate than with the fingertip in contact with the probe, possibly as a result of spatial summation in perception by FA II units with the larger contact area of the hand. For the handle and the plate, the most sensitive frequencies were within the range 100 to 150 Hz, and there were no significant differences between the thresholds in these two postures (Wilcoxon, $p>0.05$). The frequency-dependence of the thresholds with the plate and the handle were similar to those presented by both Miwa (3) and Reynolds (4), respectively.

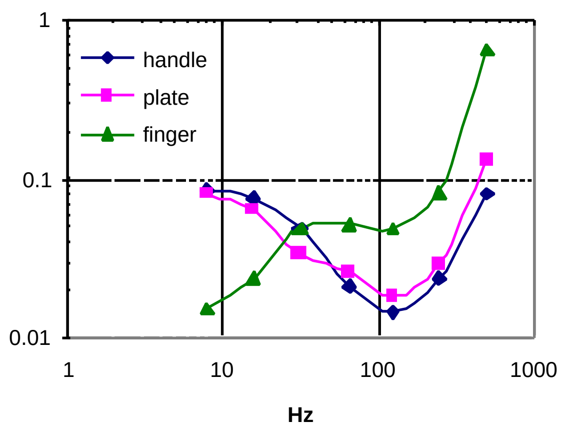

Figure 1. The median absolute thresholds obtained in the three conditions.

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Quantitative thermal perception thresholds in relation to vibration exposure

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Introduction

Work in occupations which entail awkward postures, repetitive tasks, high musculoskeletal load and physical factors such as cold, vibration and mechanical stress, have been associated with disorders exhibiting neuropathic symptoms. The symptoms may reflect both negative (loss of sensation) and positive (e.g. paraesthesia) manifestations of nerve fibre dysfunction. The present study focuses on the effect of vibration on the function of the small calibre nerve fibres transmitting the sensory correlate of cold and warmth. The study aims were: to assess the risk of disturbed thermal perception in relation to vibration exposure, to investigate a possible exposure-response relationship and to analyse the possible relationship between thermal perception and sensory symptoms.

Methods

The investigation was a cross-section of 128 vibration-exposed and 62 non-vibration-exposed male workers. Thermal perception was determined by a Somedic modification of the "Marstock” method (1) with computer assisted automatic exposure and response recording (Thermotest; Somedic, Sales AB, Sweden). Thermal perception of cold and warmth was determined from the thenar eminences and the distal phalanges of the second digits of both hands.

Quantified personal energy-equivalent vibration exposure was assessed for all subjects. The vibration was measured in accordance with ISO 5349. Based on the results, a separate quantified estimate according to job title of the vibration exposure for the left and the right hand could be arrived at. Combining exposure times and intensities gave the left hand a 0.80 exposure to vibration compared to the dominant right hand.

Results

The mean perception threshold at the thenar region for the sensation of cold was 27.2°C, and 31.0°C for warmth. The corresponding values for the second digit were 25.1°C for cold and 34.2°C for warmth. The sensibility on the right hand side was impaired compared to the left. The mean neutral zone at the thenar test site was increased 0.64°C (95% CI 0.37°C - 0.90°C) for the right hand compared to the left hand. Measurements from the distal phalanges of the second digit revealed less perceptual sensibility for both cold and warmth, (Figure 1). The trend between the vibration exposure categories was significant for the neutral zone at the thenar test site both for left (0.01) and right (0.00) hand side. The risk of contracting reduced thermal sensibility was increased for all test sites. Subjects with symptoms of nocturnal numbness have an increased risk of having wider neutral zones. The rate ratio for an increased neutral zone at the thenar eminence was 2.80 (95% CI 1.17 - 6.67) for the right hand and 2.72 (95% CI 1.12 - 6.63) for the left hand.

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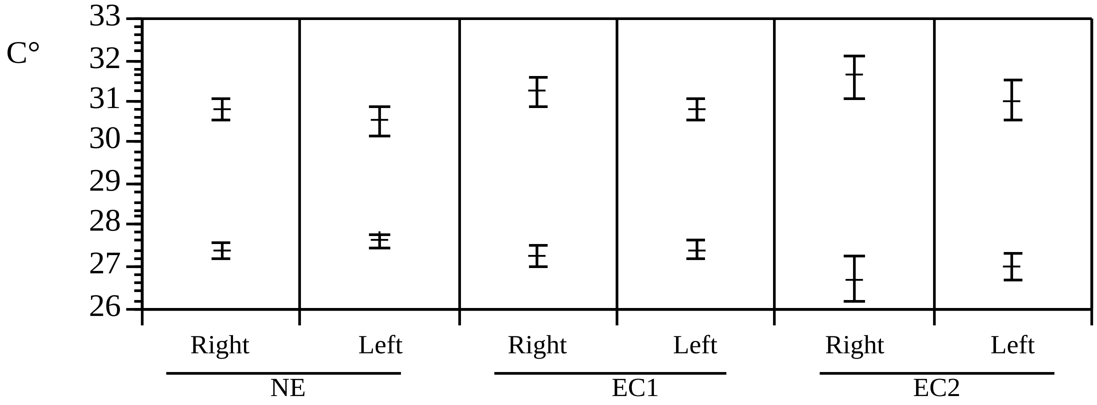

Figure 1. Thenar warm and cold perception thresholds (mean, 95 % CI) for the right and left hand in relation to cumulative vibration exposure (CVE) categories. NE; 0 mh/s^2, EC1; 0 < CVE ≤ 24000 mh/s^2), EC2; CVE >24 000 mh/s^2.

Discussion

In this cross-sectional study hand intensive work including vibration exposure was associated with an increased risk of impaired thermal perception. This outcome is consistent with the results from clinical experience, threshold shift measurements (2), clinical case series (3,4) and case-control studies (5). Virokannas et al (5) found reduced cold perception thresholds and wider neutral zones for lumberjacks than for matched controls. This neutral zone pattern was similar to that observed for the crude values by Bovenzi et al (6) but which disappeared when they adjusted for age and drinking habits.

Conclusion

The results of this study indicate sensory impairment, as assessed by increased perception thresholds for warmth and a lowered threshold for cold, associated with cumulated vibration exposure. The effect appeared at vibration levels below the currently suggested standards. Quantitative sensory testing of thermal perception offers the only possibility of assessing this specific hazard to the peripheral neurosensory system.

Acknowledgement

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Comparison of thermal perception thresholds on the fingertip for vibration exposed and controls

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Introduction

Work with vibrating power tools may cause symptoms of sensorineural disturbances in the hand, such as impaired tactile and thermal sense, numbness and paræsthesia (for an overview, see (2)). In hand-arm vibration associated neuropathy, conceivable target structures are mechano- and thermo-receptive afferents supplied by myelinated and non-myelinated nerve fibers, respectively. The present study focuses on the effect of vibration on thermal afferents in the glabrous skin of the hand, i.e. naked nerve endings with thin non-myelinated nerve fibers mediating perception of cold and warmth. Measurements of thermal perception thresholds (TPTs) for cold and warmth have therefore be carried out on two groups of young males one of which consisted of professional users of vibrating hand-held power tools.

Methods

The investigation was a cross-section of 246 vibration-exposed workers and 88 non-vibration-exposed controls, respectively. All subjects were males aged between 18 and 32 years. None had symptoms of diseases known to cause sensory neuropathies, such as diabetes, metabolic disturbances, etc. TPTs for cold and warmth were determined by a modified version of the "Marstock” (1) method (Apparatus: Thermotest®, Somedic Sales AB, Sweden). Measurements were bilaterally taken on the index finger (distal and middle phalangs), index plus middle finger tips together and on the arch of the foot.

Quantified personal energy-equivalent vibration exposure was assessed in accordance with ISO 5349 (3) for subjects in the exposed group.

Results

The results from the assessment of vibration exposure showed that 151, 69 and 26 people fell into the categories: Exp1<1.5 m/s^2, Exp2=1.5-3.0 m/s^2 and Exp3>3.0 m/s^2, respectively. The exposed group had used vibratory hand-held power tools for an average of 4.5 years. The highest exposure levels were found among welders.

Mean (±Sd) absolute TPTs for cold (TPT_C), warmth (TPT_W) and neutral zone (TPT_{NZ}), split by groups, are shown in Table 1. The neutral zone is defined as the arithmetic difference between TPT_W and TPT_C. As can be seen, the exposed category had on average, a somewhat lower TPT_C and higher TPT_W and a wider neutral zone as measured on the fingers. The differences between exposed and controls were in most cases significant. Very small and insignificant differences were found between hands for controls. For exposed there was, on average, a tendency towards larger effects on the right hand. The results for especially TPT_{NZ}, split by exposure category, indicate a tendancy towards an exposure-response relationship. No differences were found for TPTs measured on the foot both within and between groups.

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Table 1. Mean (±Sd) thermal perception thresholds for cold, warmth and neutral zone as measured bilaterally for the index finger (LIF, RIF), index plus middle finger (LIMF, RIMF) and foot (Lfoot, Rfoot). * indicate p<0.5 (unpaired means comparison).

	TPT_C		TPT_W		TPT_{NZ}	
	NEXP	EXP	NEXP	EXP	NEXP	EXP
LIF	33.2 (1.4)	31.9 (1.8) *	36.3 (1.6)	36.7 (2.1)	3.0 (0.9)	4.8 (2.1) *
RIF	32.8 (1.5)	31.8 (1.6) *	36.3 (1.9)	36.9 (1.6) *	3.5 (1.1)	5.1 (2.0) *
LIMF	33.0 (1.4)	31.5 (2.1) *	36.4 (1.4)	36.9 (2.0) *	3.4 (1.0)	5.5 (2.6) *
RIMF	32.8 (1.6)	31.8 (1.8) *	36.5 (1.6)	37.4 (1.7) *	3.7 (1.2)	5.6 (2.4) *
LFoot	29.8 (2.1)	29.5 (1.9)	34.5 (2.7)	34.3 (2.7)	4.7 (2.5)	4.8 (2.6)
RFoot	29.7 (2.2)	29.3 (3.9)	34.6 (3.0)	34.0 (2.7)	4.9 (3.1)	4.6 (2.5)

Discussion

In this cross-sectional study work with hand-held power tools was associated with an increased risk of impaired thermal perception. Interestingly, the effect appeared on a young group of males and at fairly moderate vibration levels. About 90% of persons in the exposed group had a quantified personal energy-equivalent vibration exposure lower than 3.0 m/s^2. About 30% of persons in this group had TPTs, on the index fingers on both hands, classified as abnormal, i.e outside the range of the mean plus 2 Sd obtained for the controls. An exposure duration of about 30 years is in accordance with ISO 5349 required for corresponding prevalance for vascular disorders. Thus, the results indicate that thermoreceptive afferents are far more sensitive to vibration exposure compared with the peripheral vascular system in the hand.

Quantitative sensory testing of thermal perception seem to offer a good possibility of assessing this specific hazard to the peripheral neurosensory system.

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1. ORAL PRESENTATIONS

Session 1.2
MEDICAL ASPECTS

Part 1.2.4
Miscellaneous effects

Effects of acute psychological stress on autonomic nervous system in hand-arm vibration syndrome patients

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Introduction

Autonomic nervous function in hand-arm vibration syndrome patients was previously assessed using time domain analysis of heart rate variability, and measuring levels of plasma catecholamines and cyclic nucleotides. It was observed that cold exposure activates the sympathetic nervous system to a higher degree in subjects with hand-arm vibration syndrome than in controls (1,2). In a previous study using urinary catecholamines' response, we observed that sensitivity of hand-arm vibration syndrome patients to acute psychological stress increased (3).

The purpose of the present study was to investigate noninvasively the cardiac autonomic and urinary catecholamines' responses to acute psychological stress in hand-arm vibration syndrome patients.

Methods

After an initial rest for 1 hr, 30 male subjects (10 patients with vibration-induced white finger (VWF), 6 patients without VWF and 14 healthy controls) were exposed to acute psychological stress for about 1 hr with stressors - mirror drawing (8 min), watching horror video (23 min) and arithmetic under intermittent noise of 90 dBA (15 min). During the rest period, every subject was allowed to drink 350 ml of soft drink. The average age (SD) of the patients with VWF, patients without VWF and controls was 60.1 (7.0), 58.2 (4.7) and 56.1 (5.1), respectively. The average years (SD) exposed to vibration in the patients with and without VWF was 20.1 (11.5) and 24.3 (8.7), respectively.

ECG was recorded in supine position during spontaneous and deep (6 cycles/min) breathing before and immediately after exposure and was analysed using a Fast Fourier Transformation program. Frequency domain indexes of heart rate variability, the normalised low frequency (0.04-0.15 Hz) component power (LF%, index of both the sympathetic and parasympathetic nervous activity), normalized high frequency (0.15-0.40 Hz) component power (HF%, index of the parasympathetic nervous activity) and their ratio (LF/HF, index of sympathovagal balance) were calculated from 2 min electrocardiographic data during spontaneous and deep breathing, respectively.

Urine samples were collected from every subject during the rest and exposure periods and urinary catecholamines (norepinephrine, epinephrine and dopamine) were analyzed using HPLC with the ECD method.

Results

The LF% of the patients with and without VWF and the total patients during deep breathing after exposure was significantly larger than that of the controls ($p < 0.05$, $p < 0.01$). The LF% significantly increased after exposure during spontaneous breathing in the patients without VWF and total patients ($p < 0.01$). The HF% of the total patients

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during deep breathing after exposure was significantly larger than that of the controls ($p < 0.05$). The LF/HF of the patients with VWF and total patients during both spontaneous and deep breathing after exposure was significantly larger than that of the controls ($p < 0.05$). The LF/HF of the patients with VWF and total patients significantly increased after exposure during both spontaneous and deep breathing ($p < 0.01$, $p < 0.001$).

The amounts of urinary catecholamines during exposure period were largest in the patients with VWF followed by the total patients and then the patients without VWF. The differences in the amounts of norepinephrine and epinephrine between the patients with VWF and the controls, and between the total patients and the controls were statistically significant ($p < 0.05$, $p < 0.01$). The patients with VWF indicated significant increase of urinary epinephrine ($p < 0.05$).

The LF% and LF/HF were positively and significantly correlated with the increase of urinary norepinephrine and epinephrine during spontaneous breathing after exposure ($p < 0.01$, $p < 0.001$).

Discussion

The results of the frequency domain analysis of heart rate variability in this study showed that the autonomic nervous response to acute psychological stress in hand-arm vibration syndrome patients was different from the healthy controls. The LF/HF of the patients with VWF and total patients during both spontaneous and deep breathing after exposure was significantly larger than that of the controls and also significantly increased from the corresponding before exposure value, which indicates predominance of sympathetic tone in the cardiac sympathovagal balance (4).

The amounts of urinary norepinephrine and epinephrine during exposure period were significantly larger in the patients with VWF and total patients, and urinary epinephrine of the patients with VWF significantly increased, which indicates larger sensitivity of the sympathoadrenal medullary system to psychological stress (3).

Conclusions

It could be concluded that the sympathetic tone in cardiac sympathovagal balance and sympathoadrenal medullary responses to acute psychological stress increased especially in hand-arm vibration syndrome patients with VWF and should be taken into consideration when they are under medical treatment.

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Effects of hand vibration frequency and duration on eye-hand coordination in pointing tasks

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Introduction

Visual control of hand movement is essential in occupational activities requiring precise manipulation. Coordination of eye and hand movements is required in these tasks. Hand vibration has been shown to alter continuous manual control and oculomanual coordination (2). In addition, vibration-induced alterations were found to be frequency dependent (3). The question then arises as to how alterations of manual performances and eye-hand coordination are related to vibration frequency. In particular, which vibration frequencies would have less influence on oculomanual coordination? Furthermore, as visual control may not be efficient in all situations it is of interest to assess its role in simple pointing tasks, which are frequently performed under vibration exposure in various powered hand tool manipulations.

The aims of this study were to determine a) the influence of hand vibration on the alteration of eye-hand coordination, and b) the role of visual information in the eventual compensation of the vibration-induced alterations affecting other sensory modalities.

Methods

Ten right handed healthy subjects aged 20 - 40 years participated in the experiment. The subject was seated in front of a display panel. LEDs horizontally spaced by 5 cm (5° viewing angle) served as visual targets. Eye position was monitored using an infrared optoelectronic device. Hand pointing position was measured by a two-dimensional sonic device. The pointing device consisted of a handle with a pointer running off the top at a right angle. The handle contained a cam load vibrator. Vibration (100 and 200 Hz, 0.2 mm amplitude) was applied to the dominant hand of the subject using either the self-contained vibrator of the pointing device or a vertical handle fixed to an electromagnetic vibrator. In this later case, the handle was equipped with a digital dynamometer. The task consisted of pointing 7 cm below the horizontal targets presented ten times in a random order. A mark placed under the center target indicated the starting location of all pointing movements. The subjects were instructed to simultaneously move the eye and the hand, and perform the hand motion as quickly as possible while emphasizing accuracy. Two experiments were carried out. In the “per-vibration” experiment the task was performed before and during hand vibration with the hand in sight or masked by an opaque screen. In the “post-vibration” experiment the task and visual conditions were identical to the above. The pointing performance was tested before and after vibration exposure. During the vibration period the subject grasped the handle and exerted a grip force of 5% MVC during 5 sec and relaxed for 25 sec. Horizontal eye position signal, coordinates of the hand pointing location and movement time were recorded simultaneously. Repeated measures analysis of covariance was performed on the eye and hand constant error (Ce), error variability [Ev], absolute error [Abe], s.d. of absolute error, and hand movement time.

Results

Per-vibration pointing

Hand movements. In the no vibration situation, Ce and Ev increase when the hand is masked. Changes in Ce were significant only for the ±10° and ±15° targets. The average magnitude of the shift in pointing position induced by the 100 Hz vibration is 1.2 mm when the hand is visible and 3.7 mm when the hand is masked. Abe increases from 4.9 mm to 5.9 mm during 100 Hz vibration when the hand is visible. In the no-vibration situation, the s.d. of Abe was larger for the mask (± 6.6 mm) than the no-mask condition (± 3.5 mm). The movement time decreases significantly only during 100 Hz vibration. The 200 Hz vibration had no significant influence.

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Eye movements. Changes in the gaze Ce (mean = 0.25° for both visual conditions) are only significant for large amplitude movements (±10°, ± 15°). The Abe increases significantly by 0.2° for the 100 Hz vibration in the no-mask visual condition. In this visual condition, the Ev increases significantly for the 100 Hz vibration.

Post-vibration pointing

Hand movements. An undershoot hand pointing is observed when the hand is masked. Ce, Abe and Ev are not affected by visual condition in the control situation. Changes resulting from vibration exposure are as follows. Changes in Ce are significant only for the ±10° and ±15°targets and masked hand. The average magnitude of the shift in hand pointing is 4.7 mm with the hand masked. In this visual condition Ae increases from 5.1 to 7.2 mm. The magnitude of the shift in pointing observed immediately after vibration (T0) remains approximately the same up to 10 min. after vibration with the hand masked, while no significant changes are observed when the hand is visible (Figure 1). Ev increases by more than 60%after vibration exposure when the hand is masked. This increase persists up to 10 min. after exposure. Ev is not affected after vibration exposure when the hand is visible.

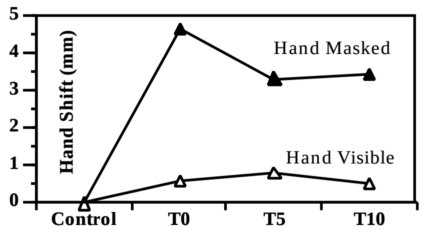

Figure 1. Average shift in hand pointing position observed after vibration exposure.

Eye movements. The average magnitude of gaze shift are 0.35° and 0.25° when the hand is not masked and masked, respectively. These shifts mostly correspond to target undershoot when the hand is not masked, while they are not specifically oriented when the hand is masked. Ce was larger for 100 Hz than 200 Hz vibration only when the hand was not masked. Abe increases by 0.17° and 0.13° immediately after 100 Hz vibration exposure when the hand is not masked and masked, respectively.

Discussion

There were four major findings in this study. First, impairments of hand pointing and eye gaze show that hand vibration can affect the precision of hand movement and eye-hand coordination. This finding, which agrees with previous results concerning visuo-manual control, confirms the influence of hand proprioception on eye-hand coordination (1,2). Second, hand and eye movements are generally more strongly affected by 100 Hz than 200 Hz vibration. Third, changes in performance observed during and after vibration exposure when the hand is masked underline the role of the visual feedback in vibratory environments. Fourth, the persistence of the constant error of the hand movements 10 min after vibration exposure only when the hand is masked indicate that vibration may lead to a loss of the proprioceptive reference that is not compensated by a visual input. These remarks are of particular importance in the design of the workplace and powered hand tools.

Acknowledgment

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Shoulder and elbow musculosceletal disorders in forest workers exposed to hand-arm vibration

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In epidemiologic studies, there has been found a relationship between shoulder musculosceletal disorders and posture or repetition. There is insufficient evidence about vibration as a risk factor for shoulder musculosceletal disorders. In this study we examined 106 forest workers, out of which were elected 73 forest workers, who had worked over 1500 hours in a three-year period (min. 1540, max. 3750, SD 512.1 hours). Total exposure varied from 6690 to 32 620 h, SD 6080 h.

In 1990, 22% of forest workers (n=124) had pain in their upper limbs and 34% had pain in neck. Five years later, percentages were 22.6 and 28.6% respectively, according to the questionnaire.

When the lumberjacks were examined, 17.6 % had shoulder musculosceletal disorder on the right side and 7.8% on the left side. Epicondylitis was found in 17.1 % of forest workers in the right arm and in 6.7% in the left arm. Tinell's sign was negative, but carpal tunnel syndrome is known to be rather common. In 1990, CTS was diagnosed in 20% of the forest workers population by electroneuromyography.

There was a relationship between total exposure and numbness ($r=0.3$, $p=0.008$, $n=64$). There was also correlation between total exposure and right-sided shoulder musculosceletal disorders ($r=0.3$, $p=0.004$, $n=74$), and almost significantly between total exposure and left-sided shoulder musculosceletal disorders ($r=0.2$, $p=0.076$, $n=76$).

There was no correlation between total exposure and right elbow musculosceletal disorders, mainly lateral epicondylitis, ($r=0.1$, $p=0.26$) or left-sided epicondylitis ($r=0.1$, $p=0.43$, $n=67$). There was no significant correlation between shoulder or elbow musculosceletal disorders and upper limb functional tests.

Conclusion

Hand-arm vibration seems to have association with shoulder musculosceletal disorders. However, shoulder musculosceletal disorders are multifactorial. No association was found between hand-arm vibration and elbow musculosceletal disorders.

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A study of the effects vibration of and noise on heart rate variability and mean artery blood pressure in drilling workers in gold mine

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Introduction

HRV analysis is currently regarded as an important sensitive index in evaluating autonomic nervous functions (1,2). It has been known that hand-arm vibration and noise can result in hyperactivity of sympathetic nervous system and hypoactivity of parasympathetic one. However, there is a disagree so far if vibration and noise cause hypertension (3,4). In order to evaluate the autonomic function and the relationships between HRV and MABP under vibration and noise, HRV and MABP in 38 gold rock drilling worker were measured and compared with that in 18 control workers.

Methods

38 male rock drilling workers in gold mine were separated into two groups: 16 workers with VWF as groups I (the average duration of exposure: 3.2-13.2 years), 22 workers with hand symptoms but without VWF as group II (the average duration of exposure: 2.5-11.8 years). 18 healthy workers who were non-exposed to vibration and noise were as control group.

The parameter of vibration and noise were measured in running rock drills. The average daily exposure time was measured for each drilling worker. HRV and MABP of each worker were got in the same room temperature (20 ±2°C) and at same time (8-l0 a.m.).

Results

1. The average exposure time was 2.72 ±0.19 h/d. The energy-equivalent frequency-weighted acceleration for a period of 4h[$a_{hw(4)}$] measured in running drills was 30.76 m/s^2. The level of noise was 94 dB(A).

2. In rest state, SDANN and MABP of each group were listed in Table.1

Table 1. The comparing of SDANN and MABP between each group.

	group I	group II	control group
SDANN ($\bar{x}$±s, ms)	2.9 ± 0.6*	3.0 ± 0.7*	3.4 ± 0.4
MABP($\bar{x}$±s, kPa)	15.39 ± 3.14**	15.22 ± 2.79*	14.87 ± 2.25

*: P<0.05, **: P<0.01, compared with control group
: P<0.05, compared with group II

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3. There was a significant negative correlation between SDANN and MABP in three groups, whose ”r” were 0.6783 ($P<0.05$), 0.7435 ($P<0.01$), and 0.8001 ($P<0.01$) respectively.

Discussion

SDANN is one of the most important and common index of HRV analysis, which mainly reflects the function of parasympathetic nervous system: with the decreasing of parasympathetic function, SDANN decreases accordingly.

Comparing with control group in rest state in workers, SDANN in group I and group II decreased greatly, in the meanwhile MABP increased highly. MABP increased more highly in group I than that in group II, but SDANN between them had no difference.

Conclusion

Long-term exposed to vibration and noise can result in dysfunction of autonomic nervous system; accordingly, the blood pressure has an enhancing tendency. With the emerging of VWF, the enhancing of sympathetic nervous activity become more serious than that prior to emerging of VWF. There was a significant negative correlation between SDANN and MABP in three groups: with the decreasing of SDANN, MABP increased accordingly.

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Quality of life and work- in nickel miners and smelter workers: symptomatic and aesthesiometric correlates

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Introduction

Increasingly, there is recognition by clinicians and policymakers of the importance of considering health-related quality of life issues in decision-making on patient management and policy (3), and their place in disease impact modelling (2). These interests have extended to the occupational health setting (5). The impact of hand-arm vibration exposure on symptomatic status and work function remains a major concern (6,7).

Accordingly, the purpose of this project was to analyze indicators of quality of life and work gathered in the course of earlier research (4), especially in terms of the contribution of symptoms associated with hand-arm vibration exposure and of aesthesiometric measurements.

Methods

165 smelter workers and 286 nickel miners exposed to hand-arm vibration (drillers, drift drillers, stope leaders) were evaluated by questionnaire, depth sense (DS) and two point discrimination (2PD) aesthesiometry (1) and Purdue pegboard (PP)(12), All measurements were done at the beginning of shifts. As indicators of "Quality of life and work", subjects were asked if finger whitening (FW), tingling (FT) or numbness (FN) interfered with: sleep, social activities, or work ("sleep/social/work interference"), or had led to quitting a social activity or job ("social/job cessation"); they were asked if they had trouble with buttoning, telling hot objects from cool ones, or losing grip ("button/temperature/grip trouble"). Of 15 questions about the frequency of FW, FT and FN, the following 6 were most explanatory of these indicators at the bivariate level and are analysed further here: occurrence of FW in the past 2 years, or the previous January, and of FT or FN at least once per week, or usually in the morning. Subjects were classified as beyond the worst quartile, or otherwise, of DS and 2PD averaged across digits 2 to 5, and of PP, averaged across both hands. Backward elimination logistic regression was used to examine the influence of FW, FT, FN, DS, 2PD and PP on the 8 quality of life and work indicators, controlling for age, years of education, handedness, and smoking status. Models were identified on criteria of explanatory contribution, parsimony and fit.

Results

Sleep interference was reported by 18% of subjects; social or work interference by 21% and 16% respectively. The rates of social or job cessation were 12% and 2.2% (10 subjects). Trouble with buttons, temperature or grip was reported by 18%, 12%, and 24%. The rates of FW in the past 2 years, or the previous January were 28% and 23%. FT at least once per week, or usually in the morning were reported by 37% and 21%, and FN by 30% and 20%, respectively. The cutpoints for the worst quartile for DS and

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2PD were rounded to 70 and 95 mm and for PP: 9 pegs placed in 30 sec; 28%, 27% and 16%, respectively, fell in the worst category. 397 of 451 subjects were examined by DS, 2PD, and PP.

The Table shows the models that were identified, with corresponding odds ratios:

	FW	FT	FN	DS	2PD	PP	OTHER
Sleep interference		5.6[d]	8.0[c]				
Social interference	5.7[b]		9.5[c]	2.8			
Work interference	b,c		c,e		2.6		Education [f]
Social cessation	4.8[b]		7.0		3.5		
Job cessation			14.3[d]				Education [f]
Trouble with:							
buttons	4.0[b]	5.6[c]	5.1[d]			g	
temperature	6.0[a]		4.0[d]		2.6		
grip	4.5[a]	2.8[c]	5.2[c]				

a: in past 2 years; b: the previous Jan.; c: at least once/week; d: usually in morning;
e: interaction FW/FN: OR's: FW+, FN+:7.0; FW+, FN-:0.8; FW-, FN+ 1.2; FW-, FN-: 1.0; f: risk decreases with years of education; g: p=0.09.

Discussion and conclusion

Self-reported finger sensory alteration is strongly associated with interferences and social/job cessation, especially numbness. The lesser frequency categories exert influence, eg., "at least once/week". It is not necessary for symptoms to be "usual" for interferences to be associated.

Finger whitening also contributes strongly to interferences. Aesthesiometric alteration, especially in 2PD, exerts an independent influence as well. PP contributed only weakly to dexterity interference after symptoms were accounted for. These results underscore the social and work impact of vibration-associated symptoms and the importance of preventing them.

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1. ORAL PRESENTATIONS

Session 1.3
EXPOSURE-RESPONSE RELATIONSHIP AND EPIDEMIOLOGY

Epidemiologic aspects of the exposure-response relationship in the hand-arm vibration syndrome

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Disorders induced by hand-transmitted vibration

Prolonged exposure to hand-transmitted vibration from powered processes or tools is associated with an increased occurrence of symptoms and signs of disorders in the vascular, neurological and osteoarticular apparatuses of the upper limbs. The complex of these disorders is called hand-arm vibration (HAV) syndrome. The vascular component of the HAV syndrome is represented by a secondary form of Raynaud's phenomenon known as vibration-induced white finger (VWF); the neurological component is characterised by a peripheral, diffusely distributed neuropathy with predominant sensory impairment; the osteoarticular component includes degenerative changes in the bones and joints of the upper arms, mainly in the wrists and elbows. An increased risk for upper limb muscle and tendon disorders, as well as for nerve trunk entrapment syndromes, has also been reported in workers who use hand-held vibrating tools. The vascular and osteoarticular disorders caused by hand-transmitted vibration are included in a European schedule of recognised occupational diseases (90/326/EEC). Several epidemiological studies have been conducted to establish exposure-response relationships between hand-transmitted vibration and disorders of the upper extremities. The relation between white finger and vibration exposure has been extensively investigated, while there is a shortage of exposure and epidemiologic data for vibration-induced neurological and osteoarticular disorders.

Exposure-response relationship

Vibration-induced neuropathy

There is epidemiological evidence for a greater prevalence of digital paraesthesias and numbness, deterioration of finger tactile perception, and loss of manipulative dexterity in vibration-exposed worker groups than in non-exposed control groups. A significant trend for a reduction of fingertip tactile sense with the increase in daily and lifetime vibration exposure has been reported in forestry workers (2), platers and assemblers (7). However, owing to the unspecific character of the sensory disturbances, the role of potential confounders and/or effect modifiers linked to individual characteristics (age, drinking habit) and some diseases (metabolic disorders, injuries of the cervical spine, polyneuropathies), and the cross-sectional design of most epidemiological studies, to date the available epidemiologic data are insufficient to outline the form of a possible exposure-response relationship for vibration-induced sensorineural disorders (7).

Bone and joint disorders

An excess risk for wrist osteoarthrosis and elbow arthrosis and osteophytosis has been reported in workers exposed to shocks and low frequency vibration of high magnitude from percussive tools (pick, riveting and chisel hammers, vibrating compressors) (5). It is thought that, in addition to vibration, joint overload due to heavy manual work and constitutional susceptibility play an important role in the etiopathogenesis of degenerative bone and joint disorders in the upper limbs of users of percussive tools. A slight but not significant trend for an increasing prevalence of wrist osteoarthrosis and olecranon spurs with the increase of daily vibration exposure has been reported in a cross-sectional study of foundry workers (1). However, at present there are no epidemiological studies that may suggest, even tentatively, an exposure-response relation for bone and joint disorders in vibration-exposed workers.

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Vibration-induced white finger

Annex A to the International Standard ISO 5349 (1986) proposes an exposure-response relationship for VWF in which the exposure is expressed in terms of $a_{hw(eq,4h)}$ ($m \cdot s^{-2}$) and the outcome is the latent interval (years) for VWF in selected percentiles of the exposed population. The ISO proposal has been a matter of controversies in the last decade because of problems linked to the appropriateness of the ISO 5349 frequency-weighting curve to assess vascular effects, the reliability of the original exposure and epidemiological data used to construct the prediction model, and the finding that the latency time for VWF is an outcome strongly subject to recall bias (6). Moreover, epidemiological studies have shown disagreement between predicted and observed latencies for VWF in several occupational groups. It is also to be considered that the introduction of administrative, technical and medical measures in the workplace to improve the work conditions with vibrating tools has determined a reduction of the occurrence of vibration-induced disorders in the last two decades. As a result, an update of the exposure-response relationship for VWF is urgent as the current ISO proposal is derived from investigations carried out from 1946 to 1978. A revision of the standard ISO 5349, annex A included, is currently in preparation in ISO/TC 108/SC 4/WG 3. In the revised ISO annex, the exposure-response relationship is restricted to a 10% prevalence of VWF and the probability of developing finger blanching symptoms in such a percentage of exposed workers is modelled as a function of the 8-hour energy-equivalent frequency-weighted component acceleration sum, $a_{hws(eq,8h)}$ in $m \cdot s^{-2}$, and the group mean total (lifetime) exposure duration, Dy in years. The new proposal of ISO exposure-response relationship is very similar to that derived from the results of a recent epidemiological study of forestry workers (4) in which the following power relation could be estimated: $VWF(\%)=0.354 \cdot (a_{hws(eq,8h)})^{1.05} \cdot (Dy)^{1.07}$. However, it should be noted that the estimated regression equation is restricted to specific exposure conditions (chain saw work) and the extrapolation to different occupational groups may not reflect the actual risk of adverse health effects arising from other types of vibration exposure. The findings of recent epidemiological studies of stone workers (3) and dockyard workers (8) suggest that the risk for VWF may be modelled by different exposure-response relationships and that the current ISO 5349 frequency-weighting curve may be unsuitable for certain types of vibration. Intensive laboratory and epidemiologic research is still needed to improve the methods for predicting the severity of vibration exposures and to outline reliable exposure-response relationships for hand-transmitted vibration.

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A long term follow up study of vibration induced white finger in chain saw operators in the Japanese state forest

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Introduction

The prevalence of vibration induced white finger (VWF) among Japanese state forestry workers using chain saws was reported in 1976 (1) and the results of a longitudinal study involving the same subjects in 1984 (2). The current status of those subjects who had been affected by VWF was observed to follow so far possible the consequence of VWF after the use of chain saws had ceased.

Subjects and methods

A total number of 496 workers (31.3% of the total number of the chain saw operator) who were affected by VWF during 1955-82 was followed up to observe the consequence of VWF. These subject were selected from a total of 1,586 chain saw operators who had used a chain saw as a professional operator during some of the years from 1955 to 1982 in the state forest of Kyushu Island, Japan. VWF and these consequences was certified by asking each person to complete a questionnaire and by verifying the answers by comparing them with inquiries and the medical records made by the regional forest office and with the results of compulsory annual medical examinations conducted by a physician that began from 1965 until now. The work history of the subjects was confirmed by examining routine production records kept by the regional forest office. In 1997 we had verified the current status and course of VWF in 496 workers by direct interviews (small number by mail). A life table Product Limit method analysis of the VWF prevalence was carried out to describe the consequence of VWF from the time the use of chain saws ceased. For each worker it was determined whether or not VWF had disappeared. The observation time then ran from the starting time to the date of disappearance or, if VWF did not disappear, to the end of the corresponding follow up period. The statistical significance of the percentage prevalence curves was assessed by the difference in the chi-squared goodness of fit statistic using the Mantel-Haenzel procedure.

Results and Discussion

In a total subject of 496 workers, 488 workers (98.4%) could be followed the current status. 481 (96.6%) workers had retired from national forest work and 124 workers (25.4%) were deceased until the beginning of 1997. The rate of prevalence of VWF fell continuously after the use of chain saws ceased to a final value of 18.8% after more than 20 years observation. The changes of Stockholm Workshop Scale from the time the use of chain saws used to the last observation period is shown in table 1. Table 2. shows the course of VWF at the latest observation period. Of all the subjects who had been affected by VWF, 47.0% showed improvement, 46.3% were unchanged, and 6.7% aggravated at the latest observation period. Fig.1 shows the prevalence rate of VWF from the time of cessation of exposure to vibration according to the cohort group which time when chain saw use was begun. On the other hand, it was noteworthy that 44 severe cases of VWF remained in the more than 20 years' group after the use of chain saw ceased. It was also observed that the percentage prevalence depended significantly on the severity at the time the use of chain saw ceased as I have reported previously (3). Earlier studies had suggested that the severe VWF case was irreversible (4,5,6) and this could still be corrected according the results of this more than 20 years long term follow up.

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Table 1. Change in severity of VWA during study period

(Stockholm Workshop Scale)

	the time the use of chain saw used (1955-1982)	the latest observation period (1982-1997)	at the beginning of 1997. (except death cases)
VWF 0	1,122 (70.7%)	1,288 (81.2%)	unknown
1	28 (1.8)	54 (3.4)	51
2	325 (20.5)	184 (11.6)	146
3	111 (7.0)	60 (3.8)	44

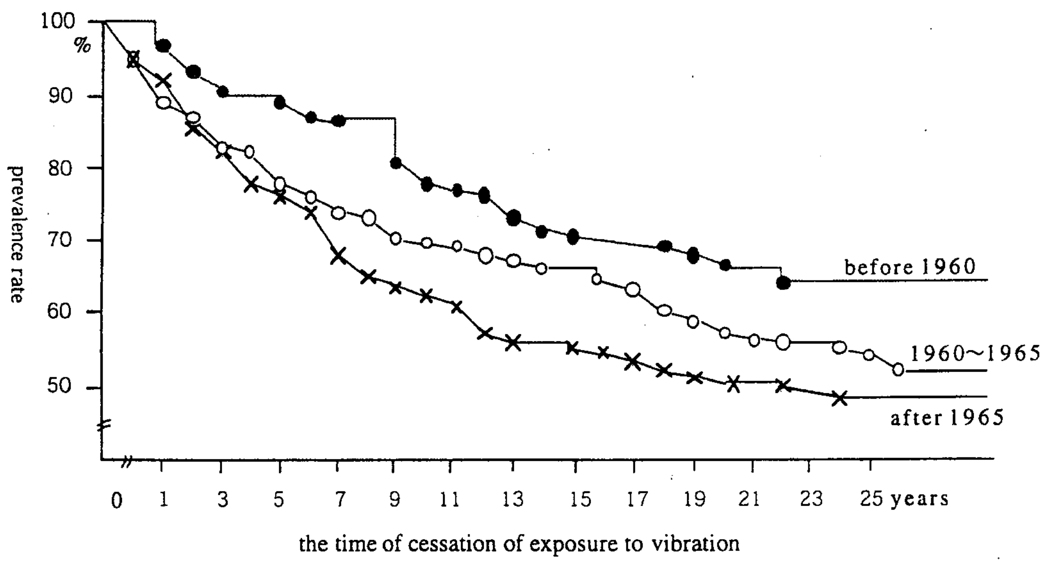

Fig. 1 The prevalence rate of VWF from time exposure vibration ceased accord to the cohort group which time when chain saw use was begun.

Vibration syndrome among Swedish workers: a follow-up study from 1989-1995

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Introduction

It is well known that the use of hand held vibrating tools can cause circulatory disturbances resulting in white fingers and neurological disturbances such as carpal tunnel syndrome and finger neuropathy (1). In spite of increasing knowledge about risk factors and production of modern tools that vibrate less, this is still a big patient group at our clinic. By minimising continued exposure to vibration, the development of injuries might be arrested and in some cases even improve (2,3,4). When vibration-related white fingers are diagnosed the patient is recommended to minimise the exposure for vibrating tools and stop the use of tobacco products (cigarettes, snuff). If carpal tunnel syndrome is diagnosed, the patient is referred to a hand surgeon as well as recommended to stop using vibrating tools even if this means a change of job. During the years a number of patients returned to the clinic some years later with progressive deterioration of their symptoms and it has then become evident that they have continued to work with vibrating tools and not followed our recommendations.

The purpose of this investigation was to study (i) if the subjects had followed the recommendation to reduce or stop vibration exposure (ii) the progression of symptoms and functional disturbances in relation to continued or ceased work with vibrating tools and (iii) what type of support that is needed in connection with diagnosis to make the prognosis as good as possible.

Methods

The study was initiated with a questionnaire about vibration exposure and symptoms sent out to all 79 patients that diagnosed during 1989 for vibration syndrome with white fingers and/or neurological disturbances. Of these patients 3 were diseased, 6 had changed address and could not be reached and 4 did not answer. Of the 66 that answered 28 still worked with hand held vibrating tools and 24 described symptoms with increased cold sensitivity and/or numbness. 37 were interested in a follow up examination, which was performed by a clinician. This was followed by a repeated neurophysiological examination including vibrametri (5) and thermotest (6) in 35 subjects (2 declined for personal reasons). For those that had acquired new symptoms of white fingers, a cold provocation test was performed (7). All subjects were interviewed by a social therapist to reveal which effect the vibration diagnosis had on the patient's professional and social life.

Results

Medical examination: The results of this study show that 17 of 37 subjects (46%) had ceased working with hand held vibrating tools (including 5 subjects 1-2 years before follow up). Ten subjects (27%) had reduced the exposure for vibrating tools to at least

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half the time within 3 years after diagnosis. As many as 10 (27%) were still working with hand held vibrating tools to the same extent that had caused disturbances earlier.

Prognosis: Symptoms with increased numbness and decreased hand force were seen in 17 subjects. In 9 subjects a new neurological disturbance was diagnosed (carpal tunnel, neuropathy) and in 2 subjects a progress of neurological disturbance was seen. All of these subjects were still working with hand held vibrating tools. None of those who had stopped working with vibrating tools showed a progress of neurological disturbance or showed a development of white fingers. In 33 out of 37 subjects white fingers was diagnosed already 1989. All of those reported unchanged or progression of symptoms. One showed the development of white fingers and 3 reported no increased cold sensitivity.

Social therapist interview: Fear of unemployment, dull jobs with less pay and difficulties in accepting the risk with continued exposition to vibration were reasons why so many continued to work with hand held vibrating tools after diagnosis. These fears however, did not come true for those who managed to change assignment.

Discussion

To continue to work with hand held vibrating tools after diagnosed vibration syndrome results in the development of new and progression of existing symptoms and increased disturbances in neurological function and hand circulation. Twenty subjects still used nicotine, which might explain why so few had improved in circulation, and only 3 had managed to stop.

Conclusions

It is important to minimise or cease vibration exposure if disturbances on circulation and/or nerves are diagnosed. Patients have often difficulties to change their work situation themselves and need support from doctors and those who can affect the work situation. All of those that managed to stop or minimise vibration exposure thought that the social effects would be worse than they really were.

Acknowledgement

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Comparison report for japanese mailmen who used motor bikes daily

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Introduction

In Japan about 70 000 mailmen have used motorbikes for mail delivery. Typically, they drive motorbikes 5-6 days per week, about 2 hours a day, and the distance ranges from 20 km to 60 km traveled.

The vibration at the handle grips has been in the range from 1.0 m/s^2 to 2.5 m/s^2 in the 8 hours equivalent value of frequency weighted acceleration, in the vector sum of the three orthogonal directions. They constitute good examples of exposure to long-term, low intensity vibration in an occupational group.

The purpose of the present study was to make a view of the data of White Finger complaints of the paper questionnaire in 1995 and establish a level of vibration exposure below which white finger symptoms are less likely to occur in the population studied.

Methods

Vibration measurement

Measurement of vibration at handle grips of motorbikes and vibration exposure for one full day driving (4-6 hrs) were conducted in 1978, 1979, 1992, and 1994.

In the first measurement, the vibration at handle grips of anti-vibration type motorbikes was measured and compared to several old types. In the second measurement, engine revolution, driving speed and the vibration at handle grips on a day's work were recorded and the relationship among them were analyzed. The last measurement was conducted at the road area covered with thick snow utilizing tire chain.

Health examination

Since 1982, health examinations for Japanese mailmen who used motorbikes have been conducted periodically. The fourth examination was done in 1995. In the first step of the examination, subjects answered the questionnaire in the method of the marked sheets. The data of the questionnaire was recorded.

Results

Distance travelled daily was related to vibration exposure in the term of 8 hour equivalent value of vibration acceleration closely.

The rate of subjects who complained White Finger was about 1% in the group with less than three years experience and 6% who had over 30 years experienced. The rate could not reach to 4% after 20 years driving even in the group having exposed the most (about 2.5 m/s^2). The rates correlated to their age rather than driving years. Above the age of 45 the rates were affected by the daily distance travelled.

In the rates of White Finger, about 60% of them complained of White Finger symptoms in the thumbs or symmetrical fingers. Among them the prevalence rate of White Finger in thumbs or symmetric fingers increased rapidly also after age of 45.

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Discussion

In 1980, the new anti-vibration type motorbikes were introduced. By this vibration proof, their vibration exposure reduced to about two thirds or half of that of the old type. The reduction was greater for mailmen who had driven longer and having greater vibration exposure daily correlated to greater vibration exposure. Only in the data of mailmen who had driven more than 15 years, the effects of the vibration reduction could be expected. But those effects were not clear behind the age effect.

It was known that White Finger was found frequently in thumbs or symmetric fingers in the primary Raynaud' phenomena. In Japan, the rate of White Finger from 0.5 % to 3 % has seen among non-vibration exposed people as the primary Raynaud' phenomenon or other types of non-vibration induced white finger. Then the major part of White Finger symptoms in mailmen could be thought of as non-vibration induced phenomenon. But in older mailmen age of above 40-45, exposure to cold and/or vibration could be one of the main factors of White Finger symptoms.

Vibration white finger and finger systolic blood pressure after cold provocation in chain saw operators: a follow up study

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Objectives

The aim of this follow up study was to investigate the changes in the occurrence of vibration white finger (VWF) and in the cold response of the digital vessels in a group of chain saw operators who underwent a first clinical examination in 1990 and then were re-examined in 1995.

Subjects and methods

In February and March 1990, the prevalence of VWF and the cold response of digital vessels were investigated in four groups of chain saw operators working in the district of Amiata (Siena, Italy). The overall study population included 92 vibration-exposed workers. In January 1995, 68 of the previously studied chain saw operators (74%) participated in a follow up study. Of the 24 subjects lost during the five year follow up period, 8 had changed their place of residence, 8 refused to participate in the follow up, and 8 could not be identified. Among these workers, 16 were asymptomatic, 6 complained of sensorineural disturbances in the fingers and hands, and 2 were affected with VWF at the time of the first examination. The chain saw operators underwent a medical interview, a complete physical examination, and a cold provocation test that were performed by the same occupational health physicians in both 1990 and 1995.

To study the course of VWF symptoms and signs, the subjects were divided into three groups according to the allocation design used by other researchers (2): *group A* (n=27): active workers without VWF in 1990 and continuing to use chain saws; *group B* (n=29): workers without VWF in 1990 and retired before 1995; *group C* (n=12): active (n=8) or retired (n=4) workers with VWF in 1990. The chain saw operators were interviewed on their work history, state of health, and use of tobacco, alcohol, and medicine. The diagnosis of VWF was based on the following criteria: a) positive history of cold provoked episodes of well demarcated blanching in one or more fingers after excluding primary Raynaud's phenomenon; b) first appearance of finger blanching after the start of occupational exposure to hand-transmitted vibration and experience of VWF attacks during the last two years; c) abnormal digital arterial response to cold provocation.

The cold test consisted of strain-gauge plethysmographic measurement of finger systolic blood pressure (FSBP) during local cooling to 30 and 10°C. The result of the cold test was expressed as the change of systolic blood pressure in a test finger at 10°C ($FSBP_{t,10°}$) as a percentage of the pressure at 30°C ($FSBP_{t,30°}$), corrected for the change of pressure in a reference finger during the cold test ($FSBP_{ref,30°}$ - $FSBP_{ref,10°}$):

$$FSBP\%_{10°} = (FSBP_{t,10°} \cdot 100)/(FSBP_{t,30°} - (FSBP_{ref,30°} - FSBP_{ref,10°}))$$

In the first study in 1990, the cold test was also performed in 99 manual workers not exposed to vibration. In these control subjects, FSBP%10° averaged 93.8% (SD 12.1%). For epidemiological purposes, the finding of FSBP%10° < 70% (mean-2SDs in the controls) was considered to be an abnormal response of the digital vessels to cold provocation.

In the chain saw operators, vibration exposure was assessed in terms of lifetime vibration dose: $\Sigma(a_{hw})^2t$, where a_{hw} is the frequency-weighted acceleration of chain saws ($m \cdot s^{-2}$) measured according to ISO 5349 and t is the total operating time with chain saws (h).

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Results and discussion

In *group A*, one case of severe VWF (stage 3 of the Stockholm scale) occurred during the follow up period. Of seven active workers without VWF symptoms but with abnormal FSBP%$_{10°}$ (<70%) in 1990, three subjects improved, two were stationary, and two deteriorated at the cold test in 1995. None of these workers complained of white fingers at the second examination. In *group B*, two retired workers with abnormal FSBP%$_{10°}$ in both 1990 and 1995 reported finger blanching symptoms (stage 2) at the medical interview in 1995. The two subjects experienced Raynaud attacks before the retirement from saw work. Four retired workers without VWF symptoms had an abnormal cold test in 1990: of these, three were stationary and one improved in 1995. In *group C*, six subjects (four active and two retired) recovered from VWF symptoms and showed FSBP%$_{10°}$>70% in 1995, while the remaining six men with VWF (four active and two retired) did not aggravate, but were still affected with finger blanching attacks and showed an abnormal cold test in 1995 (exact McNemar test: $p<0.05$). The two retired workers who recovered from finger blanching had been classified as VWF stage 3 in 1990. The percentage of workers who had used non-anti-vibration (AV) chain saws in the past was significantly greater in group C (33.4%) than in group A (18.5%) and B (3.4%), ($p<0.05$). The table reports the changes in FSBP%$_{10°}$ (medians and interquartile ranges) in the three groups of chain saw operators during the follow up period (p-values are from the Wilcoxon's matched pairs signed ranks test):

Year of survey	*Group A* (n=27)	*Group B* (n=29)	*Group C* (n=12)
1990	85.6 (19.3)	79.2 (21.5)	47.2 (14.6)
1995	89.1 (17.2)	94.4 (24.7)	67.8 (48.4)
	$p=0.45$	$p<0.001$	$p=0.16$

The relation between the changes in FSBP%$_{10°}$ during the follow up and several independent variables (age, smoking habit, finger blanching symptoms, lifetime vibration dose, and a term for either the follow up time in the active workers or the time from the cessation of work in the retired workers) was assessed by the generalised estimating equations method for longitudinal data in order to account for the correlation between repeated measures of FSBP%$_{10°}$. In the group of all active chain saw operators (n=35), FSBP%$_{10°}$ showed a significantly inverse relation with VWF symptoms only ($p<0.001$). In the group of all retired workers (n=33), FSBP%$_{10°}$ was negatively related to age, lifetime vibration dose and VWF symptoms ($0.001<p<0.05$), and positively related to the time from the cessation of work with chain saws ($p<0.01$). The results of this follow up study seem to be consistent with those of previous investigations which reported that VWF may be reversible in chain saw operators (1,2). Our findings indicate that the reduction or the cessation of exposure to vibration may have a beneficial effect on finger blanching symptoms, even though a few new cases of VWF occurred during the follow up period in workers who had used AV chain saws only. On a group basis, the length of time after stopping the use of chain saws was the major predictive variable for the improvement of the cold response in the digital vessels of the retired workers.

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1. ORAL PRESENTATIONS

Session 1.4
PREVENTION STANDARDS AND MODELING

Standards for the evaluation of hand-transmitted vibration and the prevention of adverse effects

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Introduction

The risk of developing disorders caused by hand-transmitted vibration is commonly predicted using ISO 5349 (1986). This paper identifies assumptions in the current standard and the implications to the prevention of effects of hand-transmitted vibration. A balance between limitations of incomplete knowledge and misdirection arising from over-confident guidance is suggested.

Current standards, guides and directives

Current standards use one frequency weighting to quantify the severity of hand-transmitted vibration in each of the three axes of vibration: from 16 to 1000 Hz the 'effective acceleration' is inversely proportional to the vibration frequency. An 'energy' concept is used so that any exposure pattern during the day can be represented by the equivalent continuous r.m.s. acceleration over 8 hours (4 hours in ISO 5349, 1986): the 'energy-equivalent acceleration' is proportional to the 'effective acceleration' and proportional to the square root of the daily exposure duration (1,4).

In ISO 5349 (1986), assessments of vibration severity are based on the expected occurrence of finger blanching (i.e. vibration-induced white finger, VWF); it might be assumed that the prevention of VWF will also prevent other disorders. The predicted prevalence of finger blanching is: (i) proportional to daily exposure duration, (ii) proportional to the square of the years of exposure, (iii) proportional to the square of the acceleration magnitude, (iv) inversely proportional to the square of the vibration frequency (from 16 to 1000 Hz).

The evaluation method might be justified as a general representation of the dependence of hand responses on vibration frequency and other variables: it is not proven to represent the extent to which different frequencies, axes, durations etc. of vibration cause damage to the peripheral vascular system, or the neurological and articular systems. The dose-effect guidance in ISO 5349 (1986) is necessarily based interpolation, extrapolation and simplification of available information: the percentage of affected persons in any exposed group will not necessarily match closely to that predicted by the standard.

The Machinery Safety Directive of the European Community requires that instruction handbooks for hand-held and hand-guided machinery specify the effective acceleration if it exceeds a stated value (2.5 ms^{-2} r.m.s.). A proposed Directive of the Council of the European Communities suggests that hand-transmitted vibration should be reduced to the lowest achievable level, with the aim of reducing exposure to below a threshold level. A threshold level ($a_{hw(eq,8h)}$ = 1.0 ms^{-2} r.m.s.), an action level ($a_{hw(eq,8h)}$ = 2.5 ms^{-2} r.m.s.), and an exposure limit value ($a_{hw(eq,8h)}$ = 5.0 ms^{-2} r.m.s.) are defined. It is proposed that for exposures exceeding the 'threshold level' workers must receive information concerning potential risks; the 'action level' identifies conditions in which training in precautionary measures is required, an assessment of the vibration is to be made, a programme of preventative measures is to be instituted, and workers have the right to regular health surveillance, including routine examinations designed for the early detection of disorders caused by hand-transmitted vibration; if the 'exposure limit

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value' is exceeded, health surveillance would be required by Member States to control the harmful effects. The Machinery Directive and the proposed Physical Agents Directive are based on ISO 5349 (1986) and, therefore, dependent on consensus within committee more than scientific observation: other standards could represent current knowledge equally well.

Prevention

To minimise the risks of vibration injuries, the vibration magnitude and exposure duration should be minimised, and warning, education and medical monitoring of those exposed may be required. Current standards place higher emphasis on reducing tool vibration magnitude than reducing the daily exposure duration, but the effects of hand-transmitted vibration may not be well-predicted by the 'energy' time-dependency: a different allowance for daily exposure duration, intermittent exposures and shocks may be more appropriate. The frequency weighting is such that frequencies above about 250 Hz rarely contribute to the 'effective acceleration', while tools with low frequency vibration have relatively high magnitudes of 'effective acceleration' (2). The evaluation method has major implications on the selection of optimum tools and the use of 'anti-vibration' devices, such as suspensions and gloves (3, 5).

Some of the problems with the current standards

There are problems with all of the physical variables associated with the evaluation of hand-transmitted vibration: frequency (the weighting is not supported by epidemiological or experimental studies), direction (the same method may not be valid in all three axes), duration (the two different methods for daily and lifetime duration are unproven), area of contact with vibration and the contact force (grip force and push force may be expected to affect exposure severity), the environment (e.g. temperature may be important). Large inter-subject variability and a large intra-subject variability should also be expected.

Conclusion

It is desirable that standards should be understood, and not merely accepted without comprehension. The basis of all guidance should be indicated and quantitative guidance should be accompanied by a statement of the possible error; test methods should have been proven to provide repeatable and useful results. With limited evidence for currently standardised methods, changes are anticipated as research reveals the mechanisms of the various effects of vibration.

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Certified safety by European co-ordination and co-operation of notified bodies for machines and personal protective equipment

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Introduction

The European Directives 89/392/EEC (1) for machinery and 89/686/EEC (2) relating to PPE stipulate harmonised safety requirements for the member states within the context of the European internal market. The two of them contain provisions in terms of vibration emission and vibration reduction. In connection with machinery these provisions concern the manufacturer's duty to indicate the amount of vibration introduced into the hand-arm system; as concerns PPE, provisions refer to the obtainable reduction of vibration exposure by use of protective gloves, a quality which must be certified by a notified body. By affixing the CE-label, the manufacturer confirms compliance of his product - machine or PPE - with the requirements of the corresponding EU Directive.

In accordance with the New Approach, only basic safety requirements are stipulated by the Directives. The European standardisation organisations CEN and CENELEC were commissioned by the European Commission to define operating and test conditions for the large number of machines causing emission of hand-harm vibration and the numerous protective gloves with damping properties. Although a big deal of standardisation work is still under way, many test standards were passed and are used by accredited laboratories and notified certification bodies to conduct official tests.

As anticipated by the standardisation experts, standards are interpreted differently by the laboratories and certification bodies; in exceptional cases this may result in the negative testing of a product which had obtained positive test results in another laboratory before. To preserve the test bodies' capacity to act and to avoid the impression of incompetence on the manufacturers, efficient European structures of co-operation and co-ordination between the test and certification bodies were established in the meantime.

Method

The structures of co-operation and co-ordination between the notified test bodies for product safety in the European internal market are the same for machinery and PPE. In the following they will be described for the example of PPE, whose safety must generally be certified by a notified body.

The application of the test standard EN ISO 10819:1996 (3) relating to the anti-vibration properties of protective gloves has already lead to diverging test results in a couple of accredited test laboratories. This paper, however, won't go into the reasons why there is controversial interpretation. Similar problems experienced by other test laboratories in connection with mechanical or chemical protection qualities of protective gloves had resulted in the creation of a task force entrusted with the organisation of an experience exchange and round-robin tests and in a joint effort to improve test procedures. Since its foundation five years ago, the European task force for the testing and certification of protective gloves has elaborated lots of standard interpretations and put forward numerous proposals for modification which were diffused as "Recommendations for Use" to all accredited test laboratories. It was thus possible to solve many of the problems related to the harmonised application of standards without

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changing the existing standards themselves. Only now, at the end of the first five years' period, first standards are being revised on the basis of the large number of Recommendations for Use.

In order to avoid conflicts with the market control authorities in this phase of mutually agreed divergence from the standardised test procedures, all Recommendations for Use are made available to the European Commission for further diffusion to the Member States. Nowadays the European co-ordination and co-operation between notified bodies receives financial aids on a regular basis by the European Commission which bears the costs related to the Technical Secretariat of the Horizontal Committee of all notified bodies for PPE.

Co-ordination and co-operation in connection with the application of harmonised safety standards between the notified bodies for machinery is organised in the same way. The two organisations can also be contacted by manufacturers whenever problems with respect to the interpretation of standards arise. Representatives of the manufacturers are regularly invited to the meetings of the Horizontal Committees.

Conclusion

With the establishment of a European co-ordination and co-operation in the context of the EU Directives for PPE and machinery, the notified bodies succeeded in furthering the harmonised application of European standards. Agreements relating to divergence from standardised test procedures or to lacking test details are laid down in the so-called Recommendation for Use sheets and are made available both to the European Commission and the market control authorities of the Member States. It is thus possible to ensure the best possible application of standards in the period preceding the standards' revision which will allow for an inclusion of all modifications agreed so far.

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How to transfer knowledge from the laboratory to the field: training of factory inspectors for the measurement of vibration in the workplace

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Introduction

Despite the sale on the French market of anti vibration tools such as some models of rammers, grinders, sanders etc. the protection of operators against vibration hazards progresses slowly in factories contrarily to the forest workers which are now generally equipped with suspended chain saws and medically follow. This is because of the absence of regulation or limit in France on hand transmitted vibration and ignorance by most users and employers about the risk associated with the use of traditional tools (only 25 VWF compensated cases are claimed yearly compared to several thousands in the UK or hundreds in Italy or Sweden). At the beginning of the 90's INRS came to the conclusion that low vibration tools will not be widely bought (and used) as long as users and associates are not aware of the vibration hazards and relays trained to transfer the information (1). A strategy into three points was therefore elaborated to reach that level :

a) Information to users on hazards associated with the use of vibrating tools and methods to reduce the hazards of repeated exposure.

b) Training of relays.

c) Help to manufacturers for the development of low vibration tools. INRS actions on points a and c were previously presented in various articles (2,3).

The purpose of this paper is to report the method developed for training specialist factory inspectors.

Method

There are in France eight laboratories (CMP) which are making physical measurements (noise, light, ventilation, etc.) for the twelve Regional Sickness Insurance Funds (CRAM). Five to seven specialist factory inspectors are working in each laboratory. A three day training session on how to measure human vibration was organised at the beginning of the 90's. But this action was too isolated to be efficient.

In 1995 a group of ten specialist inspectors convened by INRS experts was created with the purpose to elaborate three guides on the vibration measurement at the workplace (whole-body, hand-arm and building vibration) (4). Firstly the three days training sessions was repeated and many measurement on tools were made in the laboratory. Each inspector was then asked to prepare one chapter of the guide, the proposals were then discussed by the group and the revisions made by another inspector. In parallel joint measurements with INRS were made in about 20 different sites for different purposes: comparison to select low vibration tools, exposure assessment for epidemiological research, survey of the different tools to identify the main vibration hazards, etc. The different laboratories were equipped with similar measurement and analysis equipment and a common calibration system was bought. Also INRS is collaborating with a manufacturer to develop a basic and cheap vibrometer to simplify the measurements in the future.

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Content of the guide

The guide is designed to be practical on the site (4). It follows the action chronology:
- What should be known before going in the factory. Chapter 1 is a synthesis of present knowledge on hand-arm vibration (effects, standardisation, sources and exposure). Chapter 2 is devoted to the measurement equipment, chapter 3 to the preparation of the field measurement (information to be asked to the factory, choice of equipment).
- During the factory visit. Chapter 4 regards the examination of the working procedure, chapters 5 and 6 the organisation of the vibration measurement and exposure time assessment.
- After the visit. Chapters 7 and 8 report respectively on the analysis of measurements, calculation of the daily vibration exposure and life dose. A brief chapter presents measures for vibration hazards reduction and is completed by an appendix which provides information on low vibration tools.

Conclusions

The three years program organised for the specialist factory inspectors enabled:

- to make them aware of the problem of hand - arm vibration,
- to make them able to assess vibration exposure for most conditions,
- to make them acting for the reduction of vibration hazards (promotion of low vibration tools or modification of processes, information of other relays, etc.)

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Progress in persuading British industry that effective management of exposure to hand-arm vibration results in good health and good business

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Introduction

The Health and Safety Executive (HSE) advises and enforces standards of health and safety in British industry. For over a decade HSE has applied the results of research to investigate the risks arising from exposure to hand-arm vibration to the preparation of guidance to industry, the development of enforcement policy, and negotiation of Standards and proposals for legislation.

This paper reports progress with application of research to reducing the risk of hand-arm vibration injury in the British workforce.

Methods

HSE's programme of research into hand-arm vibration injury and its prevention has focused on a range of issues including - where people are exposed, the consequences of exposure, and means of preventing or reducing exposure. Subsequent guidance is being promoted through a national 'Good Health is Good Business' (1) campaign.

Research is continuing into issues including: review of the number and distribution of workers exposed; the correlation of manufacturers' declarations of equipment safety with risk of vibration injury; the accuracy of assessing risk of injury; and the performance of anti-vibration gloves.

Results

National campaign

The campaign draws attention to the financial and other rewards that management of health risks can bring. HSE guidance (2) recommends management of exposure to hand-transmitted vibration consistent with harmonised European legislation applicable to many health hazards. The campaign is a combination of guidance, media articles, workshops with industry, and targeted workplace inspections in construction, foundries, ship building, and agriculture industries.

People at risk

Review of the number and distribution of workers exposed to hand-transmitted vibration (3) has found that around 4 million people use vibration hazardous equipment and that over 1 million people are exposed in excess of HSE's criterion level for action (2.8 m/s^2 A(8)). New data appears consistent with earlier surveys (4) but indicates that many people are significantly exposed to vibration in occupations not previously studied. There may be 170 000 people with symptoms of vascular vibration injury including around 20 000 cases of advanced disability.

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Manufacturers' data

Evaluations of vibration test standards have shown that they assist provision of consistent and comparable information concerning reduction in risks resulting from vibrations but the emission levels alone are usually insufficient to represent risk, and ranking is crude. Improved Standards appear possible.

Risk assessment

Employers may assess risk with sufficient accuracy for the purpose of identifying preventive measures through many means including reference to published data, use of databases, or measurement of personal exposure. Likely errors in the various methods have been partially quantified and estimation of exposure time and weaknesses in the dose-response relationship are important issues.

Anti-vibration gloves

Testing of anti-vibration gloves has indicated that such gloves can amplify or attenuate the transmission of vibration to the hand depending on the particular circumstances of use. An improved Standard appears possible.

Conclusions

HSE is campaigning to raise employers awareness of the risk of vibration injury and means of its control through national media and workplace inspection campaigns. A number of issues require further research if harmonised European legislation is to be applied to maximum advantage for the benefit of vibration exposed workers.

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Investigations in the precision of vibration measurements for the declaration of emission values for hand-held machines

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Introduction

The assessment of the parameters of vibration emission of hand-held machines in accordance with the EC Machinery Directive has to be carried out according to harmonized European standards (e.g. the relevant parts of EN 28662 and EN 50144). A recently issued European Norm (EN 12096) regulates the procedure for the declaration and verification of emission values. According to this in addition to the emission value *a* the individual deviation *K* has to indicate in the manuals or similar technical documents of the machine. The most important basic quantity for the assessment of the individual deviation *K* is the standard deviation of reproducibility σ_R which should be found in the test codes in the relevant standards for the particular family of machines. The standard deviation of reproducibility includes all measuring uncertainties which originate from the measurement in different laboratories with different measuring technologies and different operators.

Since the current available test codes make no statements about the standard deviation of reproducibility and since the existing quantitative measurements of uncertainties are already some years old, the standard deviation of reproducibility was determined in a Round-Robin-Test for the most important families of machines.

Method

The investigations were carried out for 2 chipping hammers, 3 breakers, 3 hammer drills, 1 electric impact drill and 3 chain saws. Eleven measuring laboratories are involved in the investigations, which however did not investigate all machines in any case. In addition some of the machines were measured by the laboratories of 7 manufacturers of hand-held machines. The measurements at the machines were carried out strictly in accordance with the respective test codes in EN 28662 or EN 50144. No information about the order of magnitude of the expected vibration emission were given to the laboratories before the measurements. The measuring results were documented in uniform test reports together with photos of the measurement situation, of the posture of the operators and of the coupling of the accelerometers. With the assessment of a measurement value for a mechanical reference generator in every laboratory the judgement of the comparability of the used measuring technology (e.g. calibration) was possible. The investigations are not yet finished completely, so that the results in this abstract are to be considered as temporarily.

Results

In almost all laboratories measuring and/or analysing errors occurred for one or more machines. These errors were noticed either by the laboratory itself and corrected by measuring again or were noticed not until the comparison with the results of the other laboratories. Even after correction of these evident errors considerable deviations still remain. The standard deviation of repeatability σ_R (same operator) amounts usually between 0,1 and 0,5 m/s^2, however may lay beyond 1 m/s^2 at certain machines. The demand in some test codes (parts of EN 28662) for a variation coefficient less than 0,15

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was fulfilled always in these measurements. The values of the standard deviation of the operating persons σ_R (equal laboratory, 3 operators) exceeds the standard deviation of repeatability only a little. The standard deviation of reproducibility (different laboratories) for the most machines amounts between 1,3 and 2,8 m/s^2. The following figure shows the results for the investigated machines except the chain saws.

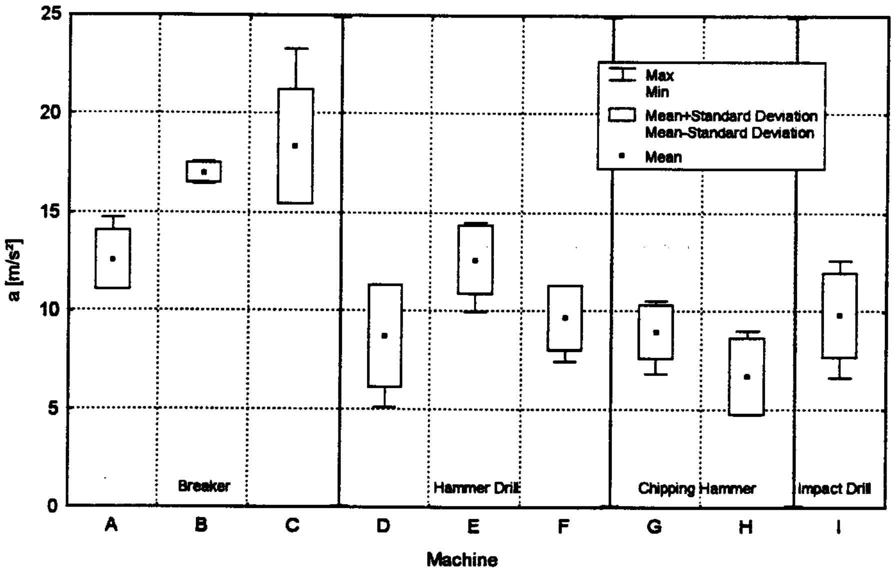

Figure 1. Means and standard deviations for reported values of different machines

Discussion

Referring to the repeatability and comparability of results vibration measurements at hand-held machines are still problematic tasks. The influence of the measuring technology appears nowadays no more a very large problem except for measurements at machines with very short and strong strokes like pneumatic hammers. A more serious problem appears to be the kind and the point of the fastening of the accelerometer. Also the operators with their individual mode of operation and their applied operating forces have large influence. The efforts of the standardization in the past years has been reduced the influence of many factors of more technical and technological nature (absorber, material, tools ...) on the deviation of the measuring results. However considerable measurement deviations still remain. So for instance the declared value for the hammer drill D has to state as $a = 9\ m/s^2$ and $K = 4{,}3\ m/s^2$ (K = 1.65 σ_R) what means that the individual deviation of that particular machine amounts to about 50% of the measuring value. These deviations can be enlarged dramatically by measuring errors which may not be detected immediately. As the investigations showed, also certificated laboratories with long experiences and practice in vibration measurements of hand-held machines show no smaller measurement differences and are not free from measuring mistakes.

Conclusions

There is the need for further investigations of the uncertainties of vibration measurements of hand-held and hand-guided machines as well as for the standardization of the measuring procedures. In addition efforts should be undertaken to remove the persons as operators of the machines from the measuring process in emission measurements.

Usefulness of vibration emission declarations in the management of hand-arm vibration risk at the workplace: grinding machines

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Introduction

The Directive of the Council of the European Communities (EC) on the approximation of the laws of the Member States relating to machinery (89/392/EEC, 91/368/EEC) requires that manufacturers and suppliers of hand-held tools supply, among other information, the vibration emission of their tools, if the frequency-weighted root mean square acceleration value exceeds 2.5 m/s^2. When the acceleration does not exceed 2.5 m/s^2, this must be mentioned. The main purpose of such declaration should be to make purchasers aware of potential risks of vibrating tools on the market according to the aim of the reduction of the risk from hand transmitted vibration, as stated by the EEC Directives on safety and health at the workplace. In this context test codes used by manufacturers in declaring emission values should be able to provide *" accurate and reproducible results as well as results which are as far as possible in agreement with results measured under real working conditions "*, as the ISO 8662-1 standard (2) states in the foreword of general part.

This paper reports the findings of an investigation on grinding and polishing machines to assess whether vibration emission declarations are adequate to compare vibration exposure from different machines in order to allow purchasers to single out the most effective tools with respect to the risk reduction expectation in actual work conditions.

Methods

Ten grinders, six die grinders, and two polishers were investigated. Field measurements took place at five different sites. Vibration measurements were carried out during actual working conditions making use of grinding or polishing tools. Main activities of companies engaged were carriage refurbishment stone manufacturing and stone carving. Two skilled operators performed 30-s series of five grinding, cutting or polishing operations of marble, granite, or steel plates, artificially created to represent actual vibration exposure conditions. Triaxial acceleration measurements were performed according to the recommendations of the International Standards ISO 5349 (1).

Results

For purpose of comparison between declared vibration values (3,4,5) and the frequency-weighted acceleration measured in the field, the vibrating tools were divided into two categories: those with declared values <2.5 m/s^2, and those with declared values >2.5 m/s^2. Tables 1 and 2 report a summary of the frequency-weighted accelerations declared by the manufacturers and those measured during actual operating conditions.

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Discussion and Conclusion

More than 65% of tools with declared values <2.5 m/s^2 provided field values >2.5 m/s^2. In particular the range of vibration field measurements of grinders with declaration values <2.5 m/s^2 extends up to 6 m/s^2. As a result of these findings, emission declaration values <2. 5 m/s^2 do not seem to be reliable with respect to the aim of risk reduction.

The vibrating tools with declared values in the range 4.5-5.5 m/s^2 seem to provide better agreement with the results obtained in real operating situations. However the survey pointed out that the uncertainty of vibration field measurements, associated with the variability of work conditions, makes difficult to estimate vibration exposure differences from tools with declared values in the range 4.5-5.5 m/s^2.

Further research seems to be needed to obtain standard test codes adequate to allow comparative evaluation of vibration exposure from tools in actual working conditions.

Table 1. Frequency-weighted acceleration for tools with declared values <2.5 m/s^2.

Tools	No. of tools with $A_{wsum>}$ <2.5 m/s^2	No. of tools with A_{wsum} >2.5 m/s^2	Field measurements (A_{wsum} in m/s^2, range)
Die grinder	3	3	1.0-3.7
Grinders	1	6	1.0-6.0
Polishers	0	2	2.8-3.5

Table 2. Frequency-weighted acceleration for tools with declared values >2.5 m/s^2.

Tool	Declared value (m/s^2)	Support handle (m/s^2)		Throttle handle (m/s^2)	
		A_{wz}	A_{wsum}	A_{wz}	A_{wsum}
Angle grinder	5.5	4.8	5.6	3.3	4.5
Angle grinder	4.5	4.1	5.1	2.5	3.1
Angle grinder	4.5	2.0	2.6	1.0	2.0
Angle grinder	4.5	5.0	6.2	4.0	4.3
Angle grinder	4.5	4.4	6.0	2.5	3.0

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Vibration emission of road breakers: Comparison of emission test data with vibration in real use

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Introduction

The provision of information relating to the vibration emission of machinery is a requirement of the Machinery Directive (3). Declaration of such information allows purchasers/users of machinery to make informed choices regarding safety and occupational health. Standards exist in the ISO 8662 series which define vibration emission test codes for a range of hand-held machinery. Often these tests are based on simulated working conditions, for the purposes of repeatability and reproducibility. There is concern that the results of vibration emission tests may not relate to the vibration produced by the same tools under real working conditions.

The purpose of this study was to examine the ISO 8662 Part 5 (2) test for road breakers for reproducibility, and to investigate the relationship between ISO 8662-5 emission value, and vibration emission under real working conditions for the same tool.

Method

Eleven road breakers were obtained from manufacturers and from INRS, France. All tools were supplied with vibration emission data; either declared emission values from manufacturers, or emission test data from INRS. To gain some indication of the reproducibility of the ISO 8662-5 emission test, a test rig for road breakers was constructed following the requirements of that standard, and the vibration emission of the eleven tools was measured using the rig. The following quantities were measured using 15 separate tests, with three tool operators;

- vibration emission value, *a*, from the mean value of the 15 results, and
- uncertainty *K*, an indication of spread of vibration emission in production.

The declaration standard EN 12096: 1997 (1) states that manufacturer's declared emission should include both *a* and *K*, although in practice many declare the *a* value only. The term *a(K)* is defined as *a* plus *K*.

The eleven road breakers were then taken into a range of typical work situations, where their vibration emission was measured under real working conditions. Four work situations were used, allowing a combination of tool bit, operator, ground type and operation to be studied.

Results

The results of the vibration emission tests on road breakers are shown in Table 1. Measured emission refers to the emission tests carried out for this study. Declared emission refers to the manufacturer's supplied data, or the test result from INRS where indicated.

The field measurements, summarised in Table 1 by minimum and maximum observed vibration magnitudes, show a large variability on the same tool used by different operators under different conditions. Increases in vibration magnitude from variations in feed force, pulling on the tool, and 'bottoming' of suspended handles were noted;

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these are aspects of typical use of this type of tool which are not reproduced in the emission test. An apparent lowest practical limit for breaker vibration under real use, of about 6 m/s^2, was observed.

Tool	Vibration emission (m/s^2)				Field vibration(m/s^2)	
	Measured		Declared			
	a	a(K)	a	a(K)	Max.	Min.
F	13.5	15.3	13	19.5*	13.7	10.5
G	3.3	4.9	3.5	6*	8.9	7.3
H	18.4	25.3	10	14	14.0	12.8
I	17.9	19.9	15	17*	21.4	15.3
J	3.2	4.5	3.5	5.3	12.1	8.8
K	6.6	8.7	8.5†	11.9	9.1	7.3
L	12.2	15.3	9.5	13.3	14.0	12.8
M	5.5	8.0	4.9	7.4	14.2	6.3
N	12.9	15.9	7.8	10.9	16.9	6.1
O	16.9	18.3	37.2‡	52.1	13.6	8.9
P	9.8	12.4	5.5	7.7	18.0	9.1

† Value from INRS test, not manufacturer
* K value declared. Other K are based on 0.4 or 0.5x a
‡ Manufacturer acknowledges incorrect value

Table 1. Breaker vibration, emission and field

Discussion

Statistical analysis of the relationship between measured and declared vibration emission suggests that there are significant differences between the measured and declared *a* values. According to the criterion in EN 12096 for verification of declared emission of a single machine, the declared emission *a(K)* is verified by the measured *a* emission in 6 of the 10 cases, excluding tool O.

The relationship between field vibration and emission was studied according to the site at which the measurements were made, the type of tool bit, and for all data. There is no evidence to suggest a general relationship between field vibration and vibration emission. There is some evidence of a relationship between field vibration and tool bit, independent of vibration emission. This is a factor which is not allowed for in the ISO 8662-5 test code.

Conclusions

The application of the ISO 8662-5 test produced measures of vibration emission which validated declared emission values in 6 of the 10 cases where vibration emission was declared correctly. It is noted that the test measures vibration under 'steady-state' conditions, and does not take into account factors such as variations in feed force, off-load running of the tool, different types of tool bit, the material being worked or material/ tool interaction, many of which can influence vibration during use.

The test code does not produce values which can in general be related to the vibration of the same tools under real operating conditions. The large variation in vibration magnitudes from individual tools under different work conditions makes the use of a single emission value to characterise a tool difficult to justify.

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Health surveillance of forestry workers exposed to hand-arm vibration in Wakayama in Japan from 1974 to 1996

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Introduction

The occurrence of vibration syndrome had been increasing as the various types of vibrating tools, including chain saws, spread to a wide range of industrial fields in a short time since the latter half of the 1960's (1). In Wakayama, the first case suffering from vibration syndrome was reported in 1970's (1). The occupational medical examinations were first carried out in 1974, and the regional occupational health care system on vibration syndrome has been established in Wakayama since 1975 (Figure 1). In this report, the health conditions of private forestry workers have been surveyed to clarify the trends in the number and the severity of vibration syndrome in Wakayama for the past 23 years.

Methods

The subjects examined were 4 652 (a total of 9 920) workers in the private forestry industry who received occupational medical examinations for vibration syndrome under the regional occupational health care system in Wakayama from 1974 to 1996.

The medical examinations for vibration syndrome consist of working career, working conditions, and physical examinations of the subjects concerned. Considering the results of the medical examinations, the diagnoses are classified into three health conditions for vibration syndrome; Class A (no abnormality in medical examinations), Class B (periodical clinical observation required), Class C (medical treatment required).

In this report, the records of the medical examinations for vibration syndrome of all subjects were analyzed to clarify the trends in the number of the subjects and the severity of vibration syndrome experienced by the subjects examined.

Results

The number of the subjects who took medical examinations for vibration syndrome and their health conditions are shown in Figure 2. In 1978, the number of the subjects was a maximum of 1 242. After that, the number decreased, but it was still over 500 until 1983. From 1988, it remained at about 300 or less.

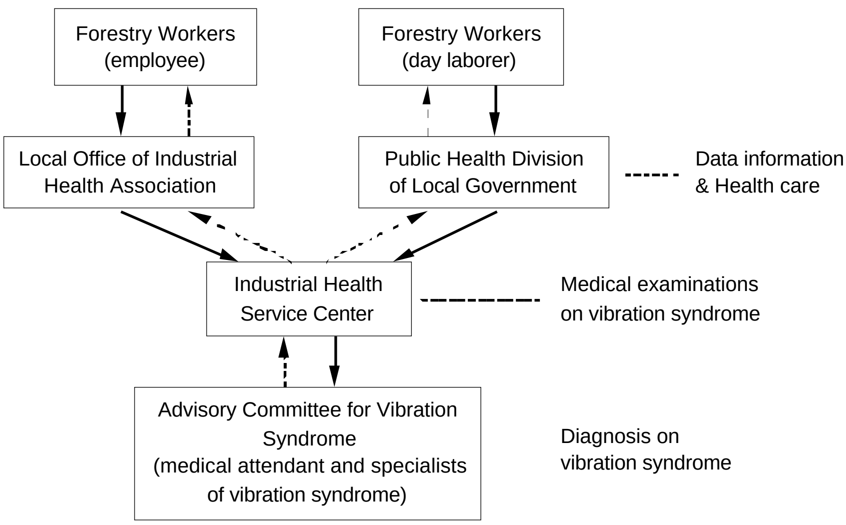

Figure 1. Diagram of the regional occupational health care system

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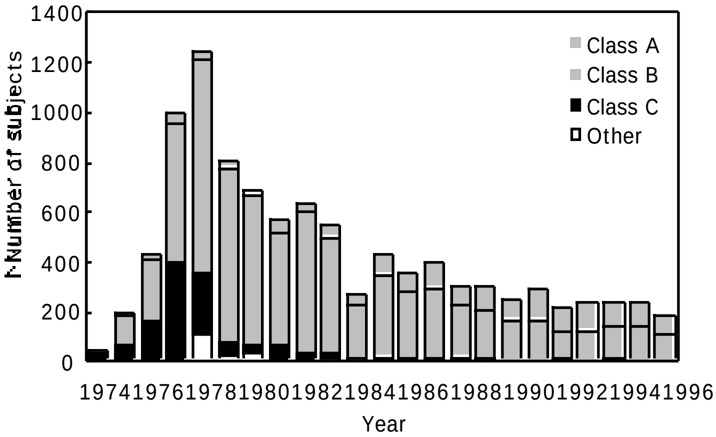

Figure 2. Trends in the health condition of the sub-, jects by medical examinations for vibration syndrome

The rates of workers undergoing medical examinations to forestry workers in Wakayama were between 12.3 % (1990) to 18.7 % (1980) since 1980.

Class C workers were more than 30 % of subjects examined before 1977. In 1978 and 1979, they drastically decreased and then made up less than 10 %. In the last 5 years the proportion of Class C workers was 2 %. On the contrary Class A workers totalled less than 10 % of subjects before 1983. Since then, they have been increasing year by year. In the last 5 years, the proportion of Class A workers was 42 %. The rates of workers complaining a vibration induced white finger were 25.9 % in 1978, 25.7 % in 1988 and 15.1 % in 1996, respectively. The rates were decreasing and answering to the trend.

Discussion

Vibration syndrome commonly occurred in Wakayama. The number of cases suffering from vibration syndrome peaked in Wakayama in 1977. Concerning the background on the frequent occurrence of vibration syndrome in Wakayama, we can point out the following: ① There were so many private forestry workers. ② They have been working in small scale industries. ③ Wages have been calculated according to work output. ④ Working environments were uncomfortable.

The regional occupational health care system for vibration syndrome has been active in Wakayama since 1975. It is a result of combining the occupational health care system with the regional health care system. It matched the occupational health of small scale industries in local area, and was effective against vibration syndrome.

The health surveillance card has been introduced since 1975. It enables us to observe longitudinal changes of circulatory function, nerve function, motor function and symptoms of hands, and them to keep an eye on health and work conditions. It has probably contributed to the decrease of or prevention of the occurrence of vibration syndrome in Wakayama.

An improvement of acceleration levels of chain saw handles (3-7G in 1974 – 1.5G in 1980) (2) as well as other vibrating tools has also played an important role in decreasing vibration syndrome.

Conclusion

The regional occupational health care system, including the health surveillance card was effective against vibration syndrome.

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Evaluation of the test procedures specified for the testing of anti-vibration gloves in ISO Standard 10819 and recommendations for modifications to the standard

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Introduction

ISO Standard 10819 specifies a test protocol to be used to measure the vibration transmissibility of antivibration gloves. This protocol was evaluated at the Center for Mechanical & Environmental Systems Technology at the University of Nevada in Las Vegas, Nevada, in the USA as it related to different test systems. Based on this evaluation, several modifications have been proposed for the standard.

Method

The test protocols specified by ISO Standard 10819 were evaluated for a small electro-dynamic shaker system that does not use a vibration "feedback" controller and a larger electro-dynamic shaker system that does use a vibration controller. Observations were made relative to the effects that the test subjects and the instrumentation had on the overall results associated with tests that were conducted according to the standard at three different laboratories.

Results

The following observations were made:

- The test subjects had a significant effect on the test results. Proper posture during a test was important. There were some subjects that had consistently high transmissibility values, while there were some that had consistently low transmissibility values. Proper training of a test subject was necessary to obtain reliable test results.
- Some test subjects that had consistently high transmissibility values could individually result in a glove not meeting the requirements of the standard for classification as an antivibration glove.
- It took training and great care to ensure that the accelerometer adapter was properly placed between the hand and glove during a test.
- It was extremely difficult to generate the medium and high frequency vibration input spectra within the amplitude band limits specified by the standard without the use of a vibration "feedback" controller.
- For those test systems that used a vibration controller, low-level residual vibration outside of the lower band limit of the controller for the high-frequency transmissibility tests could result in a glove to fail the test.
- Even though ISO-weighted vibration transmissibility values can be used to determine whether or not a glove can be classified as an antivibration glove, these values understate the overall vibration transmissibility values of the gloves in the test frequency bandpasses. Linear vibration transmissibility values must be measured to obtain the overall vibration transmissibility values of a glove.

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Conclusions and recommendations

Overall, ISO Standard 10819 is a good standard. It can be improved and made easier to use if the following proposed modifications are made:

- The standard should recommend the proper training of test subjects relative to the importance of posture and the placement of the accelerometer adapter between the hand and the glove. Test subjects should go through several practices tests before they participate in a test for glove vibration certification.
- Only trained test subjects should be used for glove vibration certification tests.
- Consideration should be given to increasing the number of required test subjects from three to either four our five.
- The allowable amplitude band limits for both the medium- and high-frequency input spectra should be increased to $\pm$ 2 dB for all frequencies.
- A frequency bandpass filter should be placed before each ISO weighting filter for the processing of the ISO acceleration signals from the accelerometers on the handle and in the accelerometer adapter. The upper and lower filter frequency band limits should be 16 Hz and 400 Hz for the medium-frequency test and 100 Hz and 1,600 Hz for the high-frequency test.
- The glove medium- and high-frequency linear vibration transmissibility values should be measured and reported.

Measurement and evaluation of attenuation effectiveness of antivibration gloves

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Introduction

The use of gloves to reduce the transmission of vibration to the hand has considered in many countries. The published literature indicates that several investigators have conducted the efficiency measurement on antivibration gloves (1,2,3). The objective of the present study was to (i) establish a national standard on measurement and evaluation of efficiency of antivibration gloves and (ii) examine the effectiveness on antivibration gloves available.

Twelve samples of gloves commercially available in the market, which were made by ten companies of four countries(US, Canada, Japan and China) were examined. The experiment was performed in the laboratory under the conditions analogous to typical use at actual workplace.

Methods

Two types of vibration signals (spectra M and H according to ISO/DIS 10819) were simulated in an electro-dynamic shaker (D-100B). The shaker was driven by a power amplifier and signal processor (UD 320). A special handle for measuring the grip force and a device to measure the feed force were equipped on the shaker. The grip force and feed force were displayed and alarmed for operator to monitor and maintain both forces within the required limits. One small accelerometer (Endevco 22) was built into the handle for measuring the accelerations of the reference point; another was mounted into an adaptor to measure the accelerations at the palm of the hand. The signals from two accelerometers were amplified with charge amplifier (DHF-10) and fed to a tape recorder (TEAC R81) and frequency analyser (CF 880) which was connected with a computer for calculating the mean corrected transmissibility.

Three operators had been instructed to control the grip and feed force within the specified range (30N±5N) for grip force and 50N±8N for feed force). Three sets of measurements for each operator were performed in the spectra M (31.5-200Hz) and H (200-1250 Hz), one of which without glove(bare) and twice with glove. Operator standed on a platform. The forearm was directed in the axis of vibration with the elbow bent 90° and wrist angle kept 0°-40°. The mean corrected transmissibility was calculated in accordance with ISO/DIS 10891 (4).

To compare the results of the mean corrected transmissibility of the gloves and the transmissibility of their liner resilient materials when loaded by hand-arm system (ISO/DIS 13753) (5), eight liner materials of gloves were tested.

Result and discussion

Table 1 presents the mean corrected transmissibility of twelve samples of antivibration gloves for spectra M and H. The mean corrected transmissibility curves with spectra M and H are illustrated in Fig.1 and Fig.2 respectively. The outcome shows that the mean corrected transmissibility are from 0.81 to 1.03 for spectra M and from 0.39 to 1.03 for spectrum H. According to the criteria of ISO/DIS 10819, about half of samples shall not be considered as antivibration gloves. The results from this study also indicate that the

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mean corrected transmissibility of gloves and the transmissibility of their liner materials do not lead to a consensus.

Table 1. Mean corrected transmissibility for spectra M and H

Glove	1	2	3	4	5	6	7	8	9	10	11	12
TRMm	0.965	1.021	0.998	1.034	0.982	1.002	0.903	0.902	0.875	0.839	0.811	0.838
TRHm	0.964	0.906	0.964	0.958	0.605	1.032	0.497	0.651	0.523	0.503	0.420	0.393

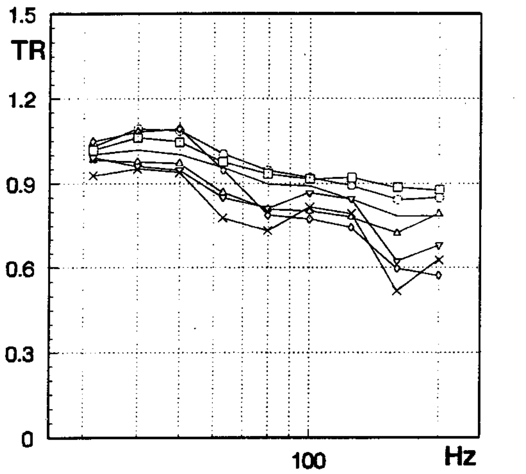

Fig .1 Transmissibility curves of glove
1, 2, 3, 5, 7, 9, 12 for spectrum M
— -1, o - 2, ◇ - 3, □ - 5, △ - 7, ▽ - 9, × - 12

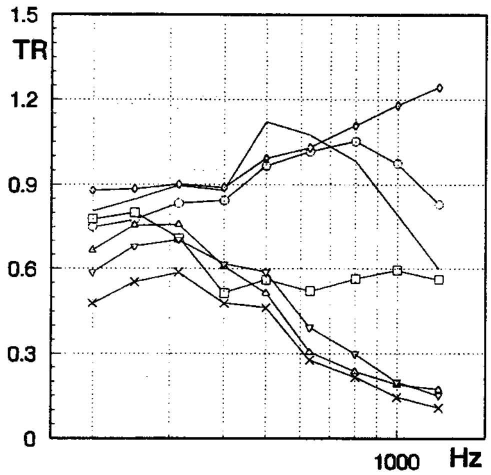

Fig .2 Transmissibility curves of glove
1, 2, 3, 5, 7, 9, 12 for spectrum H
— -1, o - 2, ◇ - 3, □ - 5, △ - 7, ▽ - 9, × - 12

Acknowledgement

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An attempt to construct antivibration gloves on the basis of information on the vibration transmissibility of materials

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Introduction

Because occupational exposure to hand-transmitted vibration causes various kinds of injuries in the human organism, it is necessary to look for different measures to minimise this physical agent. Effective protection against vibration usually requires a combination of measures. It is supposed that some reduction of the risk of vibration damage could be achieved among others by using antivibration gloves. Minimum criteria, which must be met in order to claim antivibration properties for a glove, are specified in ISO 10819 (2). Some results of testing gloves offered on the markets as AV gloves (3,4) show that most of them do not fulfil the established requirements.

This paper presents and discusses the experimental results of investigating the vibration transmissibility of materials and gloves intended for protection against vibration. The main focus of the investigation was to establish the qualitative and quantitative relations between the vibration transmissibilities of resilient materials and the vibration transmissibilities of gloves made of these materials and, subsequently, to construct gloves which could minimise the risk of developing Vibration White Finger (VWF) for workers exposed to hand-arm vibration.

Methods

The material and glove tests were performed according to the methods described in two international standards: ISO/DIS 13753 (1) and ISO 10819 (2). The vibration transmissibility of materials was determined at the one-third octave band centre frequencies between 10 and 500 Hz. In the case of the glove tests, two values for each glove were determined: the corrected vibration transmissibility TR_M for the frequency range 31.5 – 200 Hz and the corrected vibration transmissibility TR_H for the frequency range 200 – 1250 Hz. Additionally, the transmissibility of gloves was measured as a function of frequency.

Results

For the material tests, about 80 types of multilayer compositions were chosen. The obtained results showed that among all compositions that had been tested, 10 types only performed well in the material test. Their vibration transmissibility was less than 0.6 at most frequencies from the range 50 – 500 Hz, which is a condition to suppose that the material can probably provide attenuation in a practical situation (for example in the case of using it for making antivibration gloves). So, the 10 selected material compositions were used for constructing 10 types of prototype full-three-finger gloves. All prototype gloves were tested according to the procedure stated in the glove standard (2). The glove test results are shown in Table 1.

Table 1. Vibration transmissibility of gloves made according to own designs.

Glove	1	2	3	4	5	6	7	8	9	10
TR_M	0.967	0.875	0.849	0.833	0.835	0.870	0.908	0.801	0.819	0.805
TR_H	1.030	0.805	0.657	0.651	0.715	0.798	0.883	0.641	0.664	0.607

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Discussion

On the basis of the glove test results it is necessary to find that none of the prototype gloves fulfils the condition TR_H < 0.6 stated for antivibration gloves in the glove standard (2). On the other hand, all prototype gloves fulfil the condition TR_M < 1 stated in the same standard. However, according to the standard, gloves can be classified as antivibration gloves if they fulfil both of the already mentioned criteria. So, it is necessary to say that none of the pattern of the prototype gloves can be considered antivibration gloves.

In case of the 5 prototype gloves (types: 3, 4, 8, 9, 10) the values of their mean corrected vibration transmissibility TR_H are comprised in the range from 0.607 to 0.664, so they are close to the minimum required value. But the best of the prototype gloves tested (type 10, TR_H = 0.607) was made of a material composition which was not the best among the materials selected according to the material standard (1).

Because none of the patterns of the prototype gloves can be classified as AV gloves although all of them were made of material compositions classified as perhaps useful for constructing AV gloves, it was decided to check the performance of the material composition used for making gloves which meet the minimum criteria for AV gloves. This composition was tested according to the material standard (1). The results of the measurements showed that transmissibilities of the material are greater than 0.6 almost at all frequencies up to 500 Hz. So, in view of the material standard, this composition should be classified as useless for making AV gloves. However, the glove made of it is an AV glove in view of the glove standard.

Main conclusions

1. It seems that maybe the material standard (1) is not sufficiently correlated with the glove standard (2). On the basis of investigations carried out according to these standards it is very difficult to find relations between the transmissibility of a material and the transmissibility of a glove made of this material. Explaining this problem requires further studies.
2. It is not easy to find materials or their compositions that perform well in the material test and at the same time that perform well after using them for making AV gloves.
3. Having in mind the narrow assortment of real antivibration gloves on the markets it is argued that it is necessary to seek new solutions of such gloves that will fulfil the stated criteria.

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Effect of push force on the transmission of shear vibration through gloves

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Introduction

International Standard 10819 (2) specifies a procedure for testing the vibration transmission properties of gloves and determining whether a glove can be considered to be an 'anti-vibration glove'. The direction of vibration considered within the standard is perpendicular to the palm of the glove and the hand. The vibration on tools generally occurs in all three translational axes and there are situations where the principal direction of vibration is in the shear direction relative to the surface of the hand and glove (i.e. the vibration is parallel to the palm of the hand). International Standard 10819, does not consider this type of vibration.

The purpose of this study was to determine the effect of push force on the transmission of vibration in the shear axis through a selection of gloves.

Equipment and procedure

A handle, comprising a steel bar of diameter 32 mm and length 102 mm was attached to a Derritron type VP30 electrodynamic vibrator such that the grip of the hand would be horizontal and in line with the axis of vibration.

Acceleration was measured on the vibrating handle and between the palm of the hand and the glove using a palm adaptor of the type specified in ISO 10819. The accelerometers were of piezoelectric type (B&K type 4374) with a mass of 0.65 gram. The acceleration signals were passed through charge amplifiers (B&K type 2635) and acquired into a computer-based data acquisition and analysis system.

The subjects stood on a horizontal surface and applied a downward force with the right hand on to the laterally vibrating handle. The gloved hand was placed on the handle such that the metacarpal bones were horizontal and at right angles to the axis of vibration. The subjects held their forearms horizontal at an angle of 90° to the axis of vibration with the elbow having an angle of approximately 180° between the forearm and the upper arm. There was no contact between the elbow and the body during the measurements. Three downward push forces of approximately 20, 40 and 60 N were applied during the measurements; no grip force was applied. The order of presentation of the three forces was balanced across the subjects.

Ten gloves were tested (9 commercially available, see (3) for details of gloves). Eight right-handed male subjects participated in the study (mean age 28.7 years; mean weight 71.3 kg; mean height 1.78 m). Each subject was exposed to the vibration eleven times: once with the ungloved hand and once with each of the ten gloves.

A commercial data acquisition and analysis system, *HVLab*, developed at the Institute of Sound and Vibration Research, was used to conduct the experiment and analyse the acquired data. A computer-generated Gaussian random waveform having a nominally flat acceleration spectrum was used with a frequency-weighted acceleration magnitude of 5.0 ms^{-2} r.m.s. at the handle (frequency weighting W_h as defined in British Standard BS 6842 (1)). The frequency range of the input vibration was 6 Hz to 1800 Hz. Acceleration signals from the handle and the palm adapter were passed through signal conditioning amplifiers and then low-pass filtered at 1800 Hz via anti-aliasing filters. The

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signals were digitised into a computer at a sample rate of 6097 samples per second. The duration of each vibration exposure was 5 seconds.

Transfer functions were calculated between acceleration on the handle (i.e. the input) and acceleration measured at the palm-glove interface adaptor (i.e. the output). The 'cross-spectral density function method' was used. Frequency analysis was carried out with a resolution of 5.95 Hz and 124 degrees of freedom.

Results and discussion

Figure 1 shows, as an example for one glove, the effect of push force on the median transmissibilities between the handle and the palm adaptor for the 8 subjects pushing the handle with 3 different forces. Increases in push force from 20 N to 40 N and from 40 N to 60 N increased vibration at the palm adaptor, indicating that the increased force increased the vibration transmitted through the glove at medium and high frequencies.

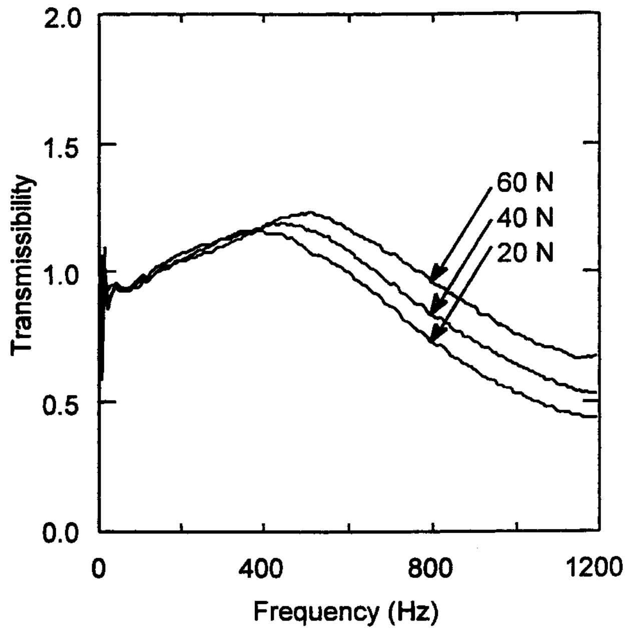

Figure 1. Median shear transmissibilities from handle to palm adapter with three push forces.

The effect shown in Figure 1 for one glove was more prominent for some gloves and at some frequencies than others. The increased transmission occurred predominantly at high frequencies which contribute least to the frequency-weighted acceleration on many powered hand tools.

Vibratory tools often require high grip forces. The force obtained by pushing in this experiment could also be applied by gripping. If grip and push forces are not sufficiently high, the control and operation of a vibratory tool may be difficult or inefficient, but increased force (grip or push) will increase the vibration transmitted to the hands through gloves.

Conclusions

Increases in push force increase the transmission of shear vibration through gloves to the palm of the hand.

Acknowledgement

This work has been supported by the United Kingdom Health and Safety Executive.

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Soft handle surfaces on powered drills

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Introduction

It is often recommended that the grip surface of a handle should be slightly compressible (2-4), this since it distributes the pressure better in the hand and attenuates vibrations. On the other hand, the surface should not be too soft because sharp objects might be embedded in the grip, which may cause injuries. Furthermore the produced grip force may increase (1).

A minority of powered hand tools such as drills have handles with rubber back, but only very few or none of them have handles which are completely covered with rubber. For other types of tools, such as garden tools, rubber handles are more common.

The aim of the study was to further investigate the advantages of rubber covered handles.

Methods

The handles of four impact drills (Bosch PSB 450 R, maximal non-load rotation speed: 2600 rpm, impacts frequency: 693 Hz) were covered with 3 mm rubber (approximate hardness, shore): 13-17° (foam rubber), 35-45°, 55-65° and 90-95° (almost incompressible). The rubber was covered with a thin layer of tape in order to make the surfaces similar. Ten male (median values, range; age: 34, 25-38 years, stature 183, 175-189 cm, weight: 85, 69-110 kg) and ten female (age: 34, 18-50 years, stature 168, 162-183 cm, weight: 63, 58-79 kg) unprofessional tool users drilled one hole with each drill. Afterwards they were asked to rank the handles depending on comfort.

The design of the test resembled the standard for testing impact drills (ISO 8662-6), using a 6 mm concrete drill. In contrary to the standard the subjects drilled in a concrete block instead of a wall, and the push force (80 N) was displayed as deviation from the target value.

Furthermore the vibration between the hand and the handle was measured (x, y, z-directions) when six males (age (median value, range): 34, 28-54 years, weight: 76, 74-89 kg, posture: 182, 176-193 cm) drilled holes with the four rubber covered drills and a drill without rubber cover. The vibration was measured with accelerometers (Brüel & Kjær 4374) attached on an aluminium holder, which was placed between the hand and the drill (rear side of the handle). The signals were analysed on a digital frequency analyser (Brüel & Kjær 2131, 1/3 octave band) and also with custom made software (Vib 2131) developed at our institute.

Results

Six male and nine female subjects ranked the foam rubber handle as the most comfortable (table 1). Seven male and five female subjects ranked the hardest rubber handle as the least comfortable.

The vibration measurements showed that there was a peak in the 1/3-octave band spectrum at 31,5 and 63 Hz but also in a higher frequency range between 500-800 Hz.

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These peaks determined to a large extent the frequency weighted vibration level. In table 1 vibration results for the five handles are shown.

Table 1. Results from the ranking (number of rankings) of the rubber covered handles and the vibration measurements on these handles and also an original handle (mean).

Handle hardness (shore)	Rank (most comf. = 1)				Vibration (m/s^2 rms)			
	1	2	3	4	X	Y	Z	Sum
13 –17°	15	2	3	0	8.6	7.5	6.1	12.9
35 – 45°	1	5	8	6	6.4	10.4	9.0	15.2
55 – 65°	3	10	5	2	6.4	9.5	8.8	14.4
90 – 95°	1	3	4	12	11.1	11.1	9.3	18.2
original handle	–	–	–	–	10.3	10.0	7.0	16.0

Discussion

The results show that foam rubber on the handle was rated as more comfortable than harder rubber. The results from the vibration measurements showed that the foam rubber decreased the vibration exposure. One way of evaluating the vibration characteristics of different handle materials is to measure the transfer function of the material. We found that this was to severe to accomplish due to too small surfaces for fastening of accelerometers. There are also some factors in the experimental set-up which may have caused bias when ranking the handles:

- the foam rubber handle was a little smaller (since the foam rubber is compressible), this may have given it an advantage compared to the others
- the hardest rubber was not as well formed over the handles as the others (since was stiffer).

However, the results indicates that foam rubber is the most preferable covering material in terms of comfort and vibration attenuation. The effects from rubber covers on the pressure distribution and produced grip force, need to be investigated before recommendations can be determined. This is currently done.

Cylindrical handle with exchangeable foam rubber grips (in different sizes), would be an attractive solution. The additional advantages of this solution are that the handle shape could fit each individual user better and a worn or damaged grip could easily be replaced.

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Measurement of vibration isolation of gloves and resilient materials

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Introduction

Vibration exposure from power tools is known to involve a risk of the development of Vibration White Finger (VWF) for heavily exposed workers. ISO 5349 provides in an annex what is believed to be the best knowledge on the dose response relationship. The EU Machinery Safety Directive (89/392/EEC and 91/368/EEC) states that

"*The instructions must give the following information concerning vibration transmitted by hand-held and hand-guided machinery:*
-the weighted root mean square acceleration value to which the arms are subjected, if it exceeds 2.5 m/s^2 as determined by the appropriate test code ...."

This statement leads to international standardization efforts to determine what "appropriate test codes" could be and, for a number of tool types, test codes have been defined, e.g. ISO EN 8662 series with 14 parts for different tools. However, even if manufacturers today succeed in decreasing vibration emission values, the situation remains that a number of work processes involve vibration exposure of a potentially dangerous nature. As for any other physical agent, the question of Personal Protective Equipment (PPE) is therefore relevant. With regard to vibration, the PPE could be gloves, and today a number of standards and standard proposals provide information on procedures of how to measure and evaluate Anti Vibration (AV) gloves. In addition, there exist EU rules and regulations for PPE, and these are given in Directive 89/686/EEC with the later amendment 93/68/EEC. This paper describes the situation for gloves and resilient materials. A number of problems with the test method for gloves are pointed out and suggestions for changes to the standard are given.

Methods

The two methods dealt with by this paper are:

Glove test:	EN ISO 10819 (1)
Materials test:	EN ISO 13753 (2)

Problems

A number of European laboratories have worked with the glove tests and a group of experts have been gathered in order to resolve a number of problems. The obvious main problem has been of interpretational nature. In one interpretation the glove standard presents a method that is able to identify gloves with no AV- properties, but not able to identify a glove with good AV-properties. In another interpretation this is not the case. The paper describes this matter together with a number of more technical matters.

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Recommendations

The paper suggests that the future standard for transmissibility of gloves should be altered from the present determination of transmissibility for two excitation spectra to determination of transmissibility per octave band. This will eliminate the interpretation problem and, furthermore, bring the glove standard in better agreement with the materials testing standard.

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Main parameters influencing damping performance of resilient materials

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Introduction

Resilient materials are used for handles on hand-held and hand-guided machinery and for anti-vibration gloves. The aim is to reduce vibration transmission. ISO 13 753 (1) defines a measuring method for the laboratory to determine material damping characteristics which provide quantitative information about the expected reduction of vibration (2,3). First round-robin tests (CIOP - BIA) showed that the obtained test results were largely heterogeneous.

The most important parameters and their effect on vibration reduction were investigated in order to make sure that laboratory test results can actually be transferred to practical applications and to enhance the reproducibility of the test results.

Method

The tests were carried out in accordance with the method referred to in ISO 13 753. This method is based on the determination of material impedance in the frequency range between 10 and 500 Hz; in addition account is taken of the hand-arm-system by including a standardised hand-arm-impedance characteristic in the calculation.

Three different materials, viz. natural rubber (sample A), polyurethane (sample B) and cellular polyether urethane with a mixed cell structure (sample C), served to analyse the influence of temperature, moisture absorption and material ageing as follows:

Temperature

A special test facility was developed to investigate the temperature influence in the range between 5 and 35°C, which is particularly important for practical applications.

Moisture absorption

Moisture absorption is determined in accordance with DIN 53472 (4). The sample weight was controlled every time moisture absorption had changed.

Material ageing

Testing with regard to material ageing was conducted as described in DIN 50 016 (5).

Results

The results show that the effect of the three investigated parameters depends on the material. On the whole, damping properties are reduced in the case of a temperature drop as far as the medium frequency range is concerned.

In the framework of humidity absorption testing, little differences in weight were found between the unconditioned samples and the dried materials; humidity absorption as a result of the water bath, however, was very different depending on the material (see table below).

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sample	weight normal	dry	after water bath	increase
A	10,63 g	10,63 g	12,5 g	18 %
B	7,52 g	7,49 g	13,79 g	84 %
C	3,81 g	3,80 g	9,99 g	163 %

It was shown for all the materials that humidity absorption results in a lower oscillation on the one hand and an increased resonance ratio on the other. Besides, vibration transmission on account of the hand-arm-system is especially affected in the upper frequency range.

Results relating to material ageing are not yet completely available.

Discussion

The investigated parameters, viz. temperature, moisture absorption and ageing, do have a distinct effect on the test results obtained for resilient materials on the basis of ISO 13 753. Consequently, additional testing with respect to these parameters is necessary for the determination of handle and glove material characteristics as referred to in the relevant standard. In addition, test standards must be more precise to ensure a better reproducibility of test results. With certain reservations, the same applies to the test standard for anti-vibration gloves ISO 10819 (6).

Conclusion

The effects of temperature, humidity absorption and ageing on the properties of resilient materials were analysed by choosing three material examples.

It could be shown that more precise specifications in ISO 13 753 are indispensable, particularly if we want to make sure that laboratory results can actually be transferred to practical applications.

The described test facility to determine the transmissibility at different temperatures and the presented methods for humidity absorption testing and ageing could serve as a basis for the revision of the standard.

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Use of air bladder technology to solve hand tool vibration problems

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Introduction

Many techniques have been used in an attempt to reduce the transmission of vibration from hand-held power tools to the hands of tool operators. These have included the re-design of the tool to reduce tool vibration and the use of resilient materials in the tool handles and in gloves worn by tool operators to attenuate the vibration transmitted from the tool to the hands of the tool operator. This project focused on the investigation of the vibration attenuation characteristics of several resilient materials used in gloves worn by tool operators. Vibration transmissibility tests indicated that most viscoelastic materials are ineffective in reducing vibration transmitted to the hands. The use of air bladder technology, initially reported at the 7th International Hand-Arm Vibration Conference in Prague, in gloves reduces the vibration energy directed into the hand by 40% in the ISO 10819 medium frequency range and by 70% in the ISO 10819 high frequency range.

Method

A patented air bladder technology was developed that can be used in gloves and on tool handles to reduce the vibration energy transmitted into the hands of tool operators. The test procedures specified in ISO Standard 10819 were used to compare the effectiveness of this technology to the effectiveness of viscoelastic materials used in gloves in attenuating vibration directed into the hand from vibrating hand tools. The medium- and high-frequency ISO weighted transmissibility values and linear vibration transmissibility values were measured for air bladders and for several viscoelastic materials that are used in gloves. The third-octave band vibration transmissibility values were also measured, using the appropriate test procedures specified by ISO Standard 10819. The ISO weighted vibration transmissibility values for an air bladder glove were measured at Delta Acoustic & Vibration in Copenhagen, Denmark, and at BIA in St. Augustin, Federal Republic of Germany.

Results

The results of the ISO weighted and linear vibration transmissibility measurements are:

Glove Material		ISO Weighting	Linear
Sorbothane	TH_M	0.95	0.96
	TH_H	0.99	1.00
Viscolas	TH_M	0.92	0.93
	TH_H	1.00	0.97
Akton	TH_M	0.92	0.92
	TH_H	1.00	0.89
Gelfom	TH_M	0.79	0.76
	TH_H	0.76	0.50
Air Bladder	TH_M	0.78	0.60
	TH_H	0.51	0.30

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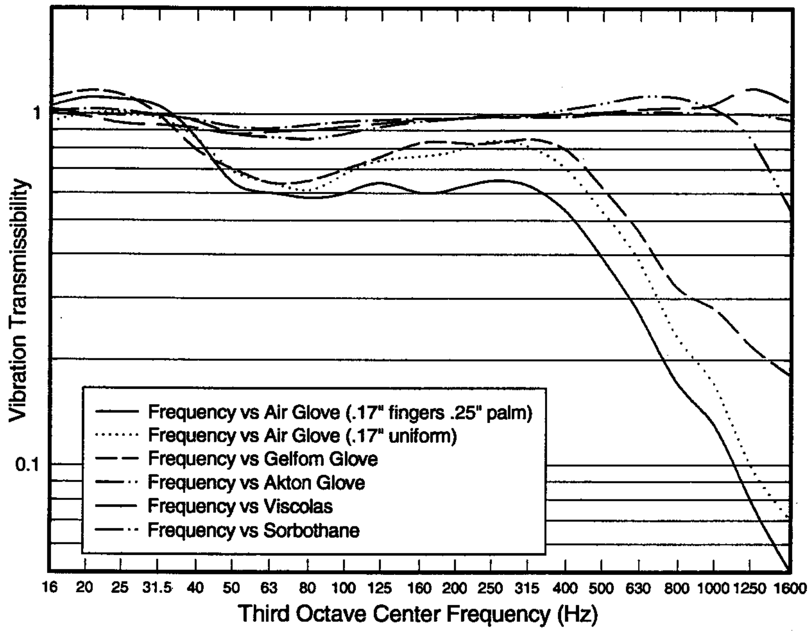
The comparative results of the ISO weighted transmissibility values for the air bladder measured at the Center for Mechanical & Environmental Systems Technology (CMEST), Delta and BIA are:

Glove Material		**CMEST**	**Delta**	**BIA**
Air Bladder	TH_M	0.78	0.72	0.87
	TH_H	0.51	0.51	0.58

The results of the third-octave band vibration transmissibility tests are shown in Figure 1.

Figure 1



Conclusions

Gloves with Sorbothane, Viscolas and Akton materials provided virtually no vibration attenuation. Relative to the gloves with viscoelastic materials, the glove with Gelfom performed the best. With respect to all of the gloves that were tested, gloves with an air bladder performed the best. Test results from three separate laboratories (one in the USA and two in Europe) indicate that the air bladder gloves meet the requirements of ISO Standard 10819 to be classified as an antivibration glove.

Auto-Balancing on angle grinders

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Introduction

This is a summary of tests carried out by Lindholmen Utveckling to establish the function of Auto-Balancing by means of reducing transmitted vibrations to the operators of hand-held angle grinders.

There are many other parameters which are of interest for the product Auto-Balancing, for instance energy consumption, efficiency, quality of work, cost savings due to service and repair, extended life and noise exposure. Many of these parameters have been investigated but will be dealt with in another forum.

Methods

There is one official method for measuring vibrations from angle grinders. The full details of this method can be obtained in the international standard ISO 8662-4 (2), which is based on the most important standard for this subject, ISO 5349 (1).

Our aim was to investigate the efficiency of Auto-Balancing, not only according to standards but also when grinding in an actual working situation. Therefore, as a complement to the standard test (2), an additional testing method was developed, which was designed in compatibility with the standard test. For this method a swing was constructed with a 50 cm (19,7") long piece of railway track fixed at one end and a load cell connected via a string to the base of the test rig at the other end. This made it possible to measure the download feed force during grinding. The swing was adjustable in height to simulate different working heights and to adjust for taller or smaller operators.

In the standard ISO 8662-4 the positions for the sensors are described in two different sections. The sensors can either be mounted on each handle at a certain distance from the outer ends of the handles, approximately at the mid points of the handles, or at other positions found on the handles with higher vibration levels. In this case the sensors were mounted on the outer ends next to the placement of the little fingers on each handle. The majority of the measurements were made using three-axial accelerometers.

The main unbalance factor for angle grinders is the grinding disc. Discs are manufactured with various quality. For this reason the grinding discs were classified and sorted into ten unbalance groups. In the measurements presented here, discs from the worst group and from a middle group were used.

The tests were carried out on several angle grinders, both air powered and electrically powered. Each angle grinder was to be compared with and without the Auto-Balancing unit attached. In the cases where the Auto-Balancing unit was not attached, it was replaced by a dummy unit.

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Results

Both the standard test and the complementary test method showed decreased vibration for the investigated angle grinders equipped with Auto-Balancing. The reduced vibration is visible both in the vibration spectrum and in the hand-arm weighted vibration value. The efficiency of Auto-Balancing is substantial at the revolution frequency (80-100 Hz, depending on the machine size).

The $a_{h,w}$ values obtained from real grinding differs from those obtained with the ISO 8662-4 tests. The differences also depend on manufacturer and machine size. However, the relative vibration reduction obtained with Auto-Balancing was higher when measured using the ISO test, than with the complementary method. High $a_{h,w}$ values were also detected in the X and Y direction. For one of the grinders, an even higher value was detected in the X direction than in the Z, ISO 8662-4 prescribed direction.

The $a_{h,w}$ values obtained in these measurements are relatively high compared to the values normally declared. One of the reasons for this is that the rms-values are calculated from measurements in three directions. Another reason is the choice of measuring points. As a result of this, the presented values can be as much as twice as high as normally measured.

The results are presented as a reduction in percent, calculated from the hand arm vibration value, $a_{h,w}$ [m/s^2]. The measured reduction varied from approximately 10% to more than 70%.

Discussion

The measured $a_{h,w}$ is very sensitive to the choice of measurement position and direction. Since the standard is quite liberal regarding the accelerometer placement, very different vibration values can be measured on the same item. The standard also requires that vibration values are measured in the Z direction only, but our measurements show that vibration values in the X and Y directions are frequently in the order of 50% of the measured value in the Z direction.

With this in mind, the question arises whether it is necessary to revise the standards for hand-arm vibration measurements. Is it possible to predict injuries from vibrating machines using today's standard? Are the CE-declared values trustworthy?

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Driving-point mechanical impedance of the hand-arm system at exposure to stochastic vibration

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Introduction

When designing vibration-controlled power tools and developing the hand model and test rigs, also mechanical properties of the human hand-arm system in response to various types of the vibration should be taken into consideration.

The purpose of this laboratory study was to determine the driving-point mechanical impedance of the hand-arm system under different experimental conditions at exposure to stochastic vibration under different experimental conditions.

Methods

The free mechanical impedance was measured in a group of 18 male volunteers (mean age 44.5 ±8.6 years), in the directions of vibration in the axes X_h, Y_h and Z_h in accordance with the co-ordinate system of the hand ISO 5349 (1), at the angle of the elbow of 90° and 180°. The basic parameters of the measurements were the grip force (25 N, 50 N, 75 N and 100 N) and the feed force (30 N, 60 N and 100 N). For the study, a measuring handle equipped with two force transducers and one accelerometer was used. The grip force was transduced on the handle. The feed force was transduced by the measuring platform on which the subject was placed.

The frequency responses of the mechanical impedance were determined in the frequency range from 8 Hz to 800 Hz at the excitation of stochastic vibration with constant level of velocity 8 mm/s and 20 mm/s. A two channel FFT frequency analyser connected directly to the computer was used. The impedance data were stated from the cross-spectrum and autospectrum of the force and velocity signals. The measuring signals were integrated for 60 s and the tests were repeated four times. The results were corrected with respect to the impedance of measuring handle. The average responses and standard deviations were computed for the whole group.

Results

The mean driving point mechanical impedance frequency responses of the hand-arm system in 18 subjects show a slight resonance dependence, see Figure 1 as an example. The hand response is significantly dependent on the direction and frequency of vibration. The posture change of the hand-arm system reveals substantial change in its mechanical response. Generally, with the higher grip or feed force, it is possible to follow the increase in the mechanical impedance and the frequency shift of resonances. This is also documented on the phase responses. The effects of both force types on the mechanical response of the hand are very similar. The hand and arm responses do not differ significantly in the velocity range from 8 mm/s to 20 mm/s.

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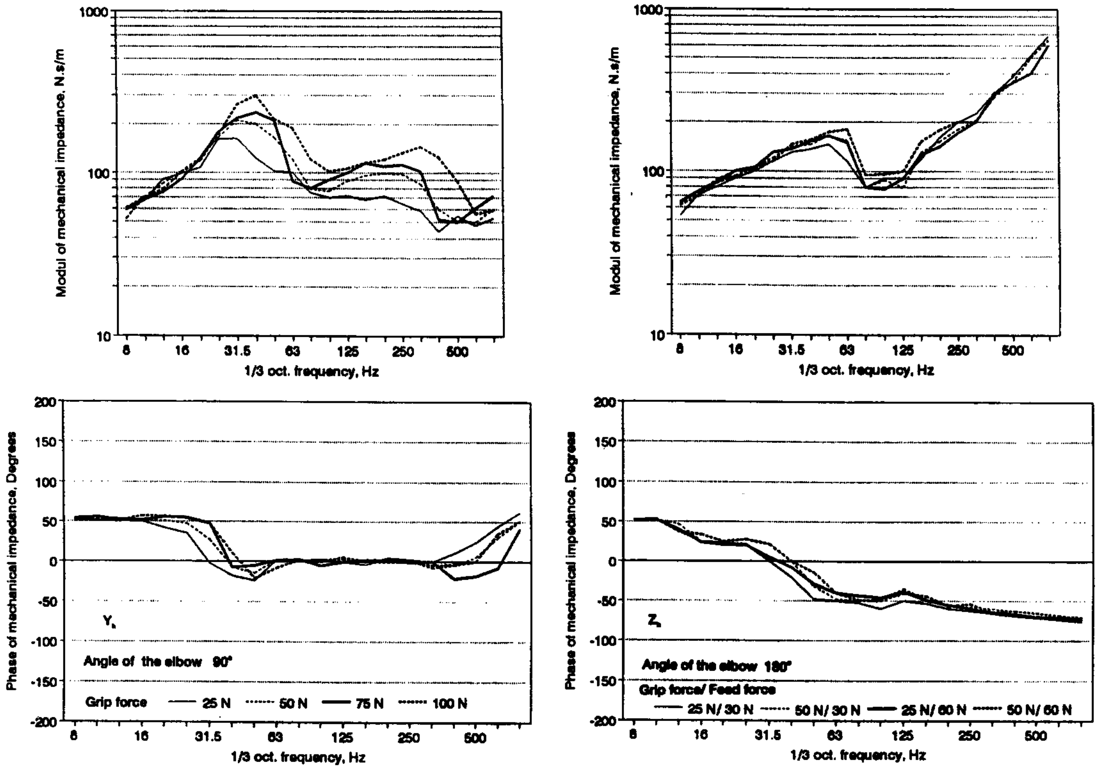

Figure 1 Mean quotient magnitude and phase of the free mechanical impedance of the hand-arm system at Y_h and Z_h direction.

Discussion

The response of the hand-arm system at exposure to stochastic vibration differs from that observed with shock type excitation (2); the phase responses are very similar but the module of impedance is three times lower at a random excitation. This supports the assumption of the non-linear behaviour of the hand-arm system (3,4).

Conclusions

The effect of stochastic vibration on the hand-arm system is strongly dependent on several dynamic (guiding forces, posture and angles in hand and arm) and physical parameters of exposure.

Acknowledgement

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Health and risk factor surveillance for hand-arm vibration

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Health and risk factor surveillance: in brief

Systems for health and risk factor surveillance (HRFS) aim for early detection of signs and symptoms of an incipient work-related disorder, e.g. due to hand-arm vibration exposure (HAVD). A surveillance system can for instance be a part of a health and safety programme or a stand alone activity. HRFS is therefore an important tool to preserve or improve health and productivity in the working life (3).

Surveillance has been defined as:
”The ongoing systematic collection, analysis and interpretation of health and exposure data in the process of describing and monitoring a health event. Surveillance data are used to determine the need for occupational safety and health action and to plan, implement and evaluate ergonomic interventions and programs” (adapted from Klaucke et al., 1988)(4).

Hagberg 1996 (2) states nine goals of surveillance that are linked to the use of surveillance data in prevention activities; 1) Identify new or previously unrecognised problems, 2) Determine the magnitude of the work-related disorder, 3) Identify occupational groups, departments, work sites to target control measures, 4) Track trends over time, 5) Describe health and risk factors for management and work sites to initiate preventative changes, 6) Identify potential control measures by observing low risk groups, 7) Basis for prioritising preventative actions, 8) Evaluate the progress of preventative actions, and 9) Generate hypotheses for research.

Surveillance aim for early detection of work-related symptoms and disorders and their risk factors. For the purpose of HAVD surveillance it is therefore of outermost importance to decide upon both risk factors and surveillance case definitions as they may vary considerably. According to Last, 1986, data collection instruments for surveillance purposes can be characterised by their practicality, uniformity and rapidity rather than their complete accuracy (5). There is in principal two methods for collecting surveillance data, characterised as ”passive” or ”active”. Passive health surveillance uses existing data such as company case books, insurance records, workers’ compensations records, absentee records, grievances etc. Passive risk factor surveillance uses for instance retrospective data collected earlier at the work site in question, at a comparable work site elsewhere or surrogate measures. This method is predominantly used to survey health outcomes. Application of an active health and risk factor surveillance method imply seeking information more ”actively”, by using checklists, interviews, questionnaires, physical exams, job analysis etc. Analysis and interpretation of surveillance data requires tools and methods good enough to lead to appropriate action as well as follow-up. Individuals responsible for accomplishing a HRFS programme also require training to ensure a proper administration.

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A model for HAV health and risk factor surveillance

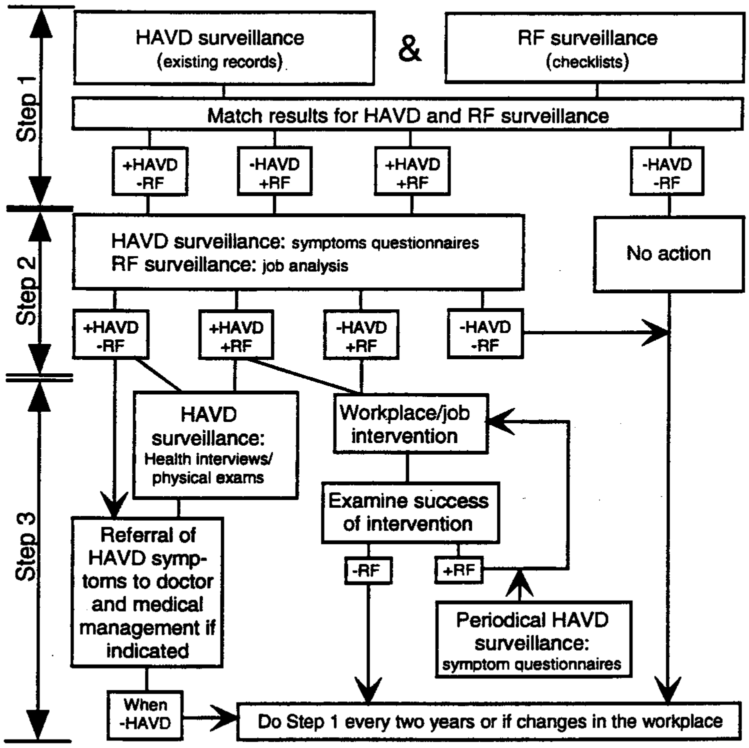

Figure 1. Draft process model for HRFS with respect to HAVD. Presence/Absence of risk factors = ±RF; Presence/Absence of HAVD = ±HAVD.

Comments

It should be noted that this HRFS model shall be considered only as a first draft. Most elements in the model requires extensive discussions and consensus before a final HRFS model can be realised. Among other important matters to discuss in this context are reporting of surveillance results as well as ethical and legal issues. The reporting of surveillance results can be done in many different ways. From a simple oral report to the employer to an extensive written report and/or detailed discussions with employer and employees in order to initiate and promote preventative measures. The ”International Code of Ethics for Occupational Health Professionals”, published by the International Commission on Occupational Health 1994 (1), provides some guidance for ethical and legal aspects on HRFS.

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2. POSTER PRESENTATIONS

Non invasive testing of disorders of autonomic nervous system in non-smokers and smokers workers exposed to vibration by spectral analysis of heart rate variability

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Introduction

Previous studies (2,4,5,6) have reported parasympathetic (PASY) dysfunction of heart rate regulation in workers exposed to vibration mainly in subjects with white finger attacks (5).

Smoking as one of environmental factors acting on the subjects has depressive effects on autonomic nervous system (ANS) regarding to PASY responses (5).

Goal of the present study was to evaluate spectral parameters of the heart rate variability - HRV measures in very low (VLO), low (LO) and high (H) frequency bands in the subjects with long exposure to vibration (EV) and to estimate differences between subgroups of non smokers (EV-NS) and smokers (EV-S).

Methods

The study population comprised 34 males EV (age 40,4 ± 1,7 years), all worked on average 18,7 ± 1,7 years, 4 hours daily with pneumatic casting hammers and pneumatic grinders in foundry steel-alloy industry. All subjects were without diseases and drugs which could modify the values of HRV (1,3). The study group was divided to subgroup of non smokers (EV-NS, 11 males), and to subgroup of smokers (EV-S, 23 males). Mean number of the consumed cigarettes was 100.753 ± 17.676 per 1 smoker. The subgroups were matched for age and duration of the exposure to vibration.

Examination of HRV was performed by using of system VariaPulse TF3 (fy Sima Medla Olomouc, Czech Republic) after complete clinical examination. The system provides spectral analysis of HRV in three frequency bands (VLO related to fluctuations in vasomotor tone through sympathetic and hormonal systems, LO reflecting baroreceptor activity, HI determinated by PASY) and automatic evaluation of cardiovascular tests (orthostatic test and test of deep breathing).

Values are expressed as the arithmetic means and standard errors of the means (X±SEM). The values in EV-NS were compared with subgroup EV-S values by Students t test. Significance was accepted at $P < 0.05$.

Results

The HRV parameters *in the whole EV group* were not different to standard values. However evaluation of the parameters in the subgroup of nine workers with the longest exposure to vibration (20,9 ± 1,9 y) showed the decrease in PASY activity (power HI and CCV HI) and the increase in the sympathetic activity (rise in % VLO and decrease in MSSD).

Similarly, in the whole EV group the orthostatic reaction (RR max/ RR min.) and the response to the deep breathing (I-E a 1/E) were not different to reference values.

Abnormal values were found only in the same 9 workers with abnormal results of the spectral analysis.

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Spectral power VLO, LO, HI

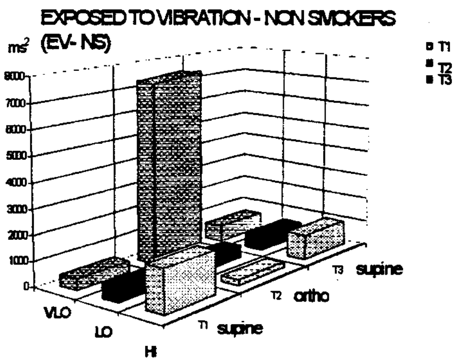

Figure 1a

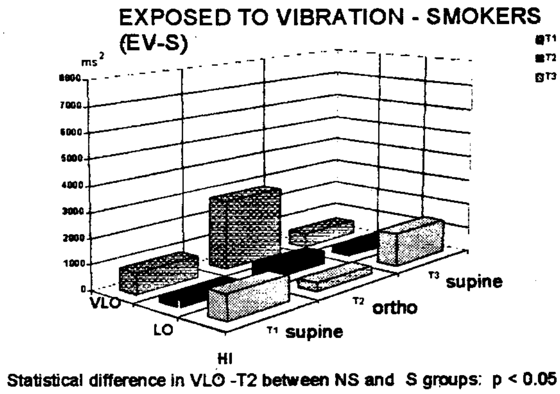

Figure 1b

The comparison of the HRV parameters in the subgroups of *non-smokers and smokers* exposed to vibration showed (Fig 1a, b): the values of HI power (PASY) in the initial supine position were in EV-NS in comparison to EV-S higher and in the EV-NS subgroup was higher reactive VLO power in orthostasis. In the EV-S subgroup was higher initial sympathicotonic activity (power VLO), but their reaction to the head-up position was in the VLO band diminished ($P < 0.05$).

The positive correlation was found between the total count of the consumed cigarettes and the coefficient of variation in very low frequency band (CCV VLO) as an indicator of activity of sympathetic nerves.

Conclusions

The results presented in the study suggest that 20 years lasting exposure to vibration in dressers and grinders of steel alloy can be accompanied with a decrease in PASY activities and with a tendency to the increase in VLO (SY) band, even in the subjects without any signs of Raynaud phenomenon positivity. It was found negative correlation between the duration of exposure to vibration and MSSD, total power of the HRV and HI (PASY) values.

Smoking habit significantly influenced ANS reactions to orthostasis (decrease of total spectral power and diminished sympathetic reaction in smokers in comparison to the non-smokers subgroup). The presented effects of smoking should be taken into consideration of the spectral analysis results of the heart rate variability in subjects including EV workers.

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Hand-arm vibration and vibration disease in Latvia

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For the time being there in Latvia has not been paid necessary attention to hand-arm vibration as a problem of occupational health. During the time of Soviet occupation it prevailed here the tendency of reducing the number of registered occupational diseases aimed to make distorted view of high occupational culture here in Soviet Union.

In spite of existing limits on hand-arm vibration (1) here in Soviet Union, these norms and regulations have not been met. Unfortunately, this situation did not change up to now.

There in Latvia more than a hundred cases of occupational diseases were registered annually. Approximately 20% of cases were diagnosed as vibration disease (see table 1).

Table 1. Occupational diseases in Latvia.

Year	Primary registered all occupational diseases, morbidity	Primary registered vibration disease, morbidity	%
1994	188	19	10,1
1995	180	38	21,1
1996	119	29	24,4

Approximately 1/5 of cases vibration disease (23,7% in 1995 and 13,8% in 1996) were hand-arm type. In total there in Latvia were registered about 160 vibration disease's sufferers, from which about ten people were chain-saw operators. However, it is thought, that the numbers shown above in reality were some 5-1 0 times higher, because many sufferers did not ask the medical help.

As vibration disease's sufferers inform, existing regulations and limits were violated in most of all cases. For instance, people involved in forestry logging work were using antiquated, low qualitative chain-sawing equipment without specific gloves. They usually worked more than 14 hours daily without regular rest heated indoors. Besides were not carried out regular medical control to give a chance diagnose vibration disease in early stages.

There in Latvia by 1996 was established the Technical Committee "Acoustic. Mechanical vibration and shock". It intends to create and implement new methods and ways to evaluate and to control noise, vibration effects in conformity with European and International Standards.

At present the ISO 5349 (2) is prepared to legislate as a National Standard and also the relevant regulations are under consideration to put it in force in Latvia.

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Vascular and nerve damages at exposure to vibrating tools related to the ISO norm 5349, appendix A

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Introduction

The use of hand-held vibrating tools is common in many different professions and the tools vary in size, weight, acceleration amplitude and frequency. Exposure to vibrating tools may cause a variety of symptoms depicted as the Hand-Arm Vibration Syndrome (HAVS). The symptoms may be of vascular, neural, and muscular origin and may appear as digital vasospasm (vibration white fingers; VWF), sensorineural disturbances, and/or as muscular weakness and fatigue (1). The interindividual susceptibility, however, varies considerably and the dose-response relationships are not fully clarified. The aim of the study was to compare different ways of exposure estimation and their relationships to the ISO norm 5349 (2).

Methods

The study comprises 19 male workers with more than three years of exposure to hand-held vibrating tools from five small metal repair workshops in Malmö, Sweden. Through a structured interview the exposure was estimated for all workers (type and number of tools, exposure time for each tool etc.). The individual vibration dose was calculated in two ways: 1) From the subjective estimation by the workers and 2) From registered grinding wheel consumption and measured vibration levels from the equipment used. For some work-tasks, the level of vibration and typical working positions were documented by video tape recordings (PIMEX-method). All workers passed the following neurophysiological investigations at the Malmö University Hospital: 1) EMG with fractionated nerve conduction velocity measurements. 2) Skin temperature thresholds. 3) Tactilometry in fingers, dig II and V (measurement of vibrotactile thresholds using seven fixed frequencies from 8-500 Hz). Comparison was made with an occupationally unexposed reference group, previously studied at the department of Occupational and Environmental Medicine, Lund University Hospital.

Results

The 19 platers/grinders had a mean-age of 43 years (range 29-60 years) and a median exposure-time of 20 years (range 3-47 years). Thirteen of the workers showed neurophysiological signs of neuropathy and five of them also showed signs of VWF. Of the remaining six workers, two had developed vibration related white fingers (VWF) without concurrent symptoms and signs of distal neuropathy, four had no clinical symptoms. The subjective estimation of the mean daily exposure-time to vibrating tools by the workers was 192 minutes (range 18-480 minutes), while the estimated mean exposure-time calculated from the consumption of grinding wheels was 42 minutes

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(range 18-60 minutes). The measured frequency-weighted acceleration levels from the 10-12 tools used varied between 121 and 145 dB (1-17 m/s^2). The measurements showed variations up to 10 dB for the frequency-weighted acceleration level during work with grinding wheels.

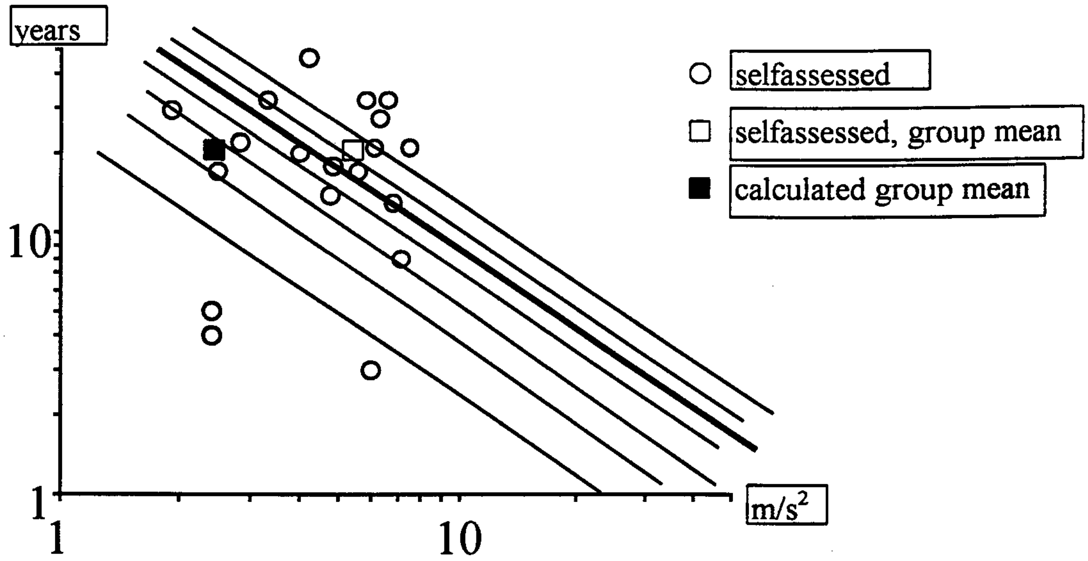

Figure 1. Risk assessment for the 19 workers according to ISO 5349, Appendix A as individuals (○), as well as group means, based on self assessment (□) of the daily exposure time respectively calculated (■) time.

Discussion and conclusions

The level of frequency-weighted acceleration varied with a factor of 2-3 during work with grinding wheels. The outcome of the risk assessment based on the ISO norm 5349, appendix A, was dependent on the method of estimation of the exposure dose. The subjective estimation of the exposure time was about four times longer than the calculated and/or measured time of exposure to the tools, and gave compared to the ISO norm 5349, appendix A, an overestimation of the risk.

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Can new materials give a better protection from hand-arm vibration exposure?

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Introduction

Long-term use of vibrating tools may cause vascular and neuromuscular symptoms, commonly named the Hand-Arm Vibration Syndrome (HAVS). The sensorineural symptoms usually start with intermittent tingling and numbness of the fingers. If the exposure continues, the symptoms will become constant, and impaired tactile sensitivity, and temperature sense, as well as reduced manual dexterity may follow (1,2). Dental technicians commonly work with high-speed grinding machines giving vibration frequencies at about 500 Hz and higher. Motor mechanics usually use impact wrenches with an impact frequency around 10 Hz and with a high energy content at frequencies above 1 kHz. To diminish the risk for developing HAVS, different personal protective equipment, e.g. gloves, may be used. It has, however, been shown that traditional gloves do not provide Anti Vibration (AV) properties (3). Thus, different types of protective materials have been developed, which may be used in protection gloves.

Methods

In this study, two hand-held vibrating tools were tested: 1) a high-frequency grinding equipment used by dental technicians (EWL K9) and 2) an impact wrench (Scorpio) used by motor mechanics. The first instrument was tested, in order, with A) no protection material, B) a new gel foam protection material, C) a commercially available protection material named Sylomer, and D) Cool-grip, a protective material frequently used at dental clinics and laboratories in Sweden. The second instrument was tested with A) no protection material and B) a new gel foam protection material. Measurements on the work objects were performed with a small accelerometer (Brühl & Kjær 4374) glued to a thin metal plate that was attached to the handle of the object by hose clamps (test situation A). In test situations B-D the protective material was placed between the handle of the instrument and the metal plate with the accelerometer, which was attached with the hose clamp. The results were analyzed by the Viblab program enabling FFT analysis as well as hand-arm weighting according to ISO 5349.

Results

For the studied instruments the outcome of the testing (Table 1, 2) was as follows:

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Table 1. Vibration levels for a high-frequency grinding equipment by use of different types of damping protection materials.

Instrument EWL K9	H-A weighted acc. level L_{aw} dB re. 10^{-6} m/s^2	un-weighted acc. level $L_{a\,lin}$ dB re. 10^{-6} m/s^2
A	105.3	142.8
B	105.6	142.4
C	105.1	143.2
D	108.4	140.9

Table 2. Reduction of vibration levels for an impact wrench by use of gel foam protection material.

Instrument	Octave band, un-weighted acceleration levels in dB re. 10^{-6} m/s^2			
Scorpio	< 1kHz	2kHz	4 kHz	8 kHz
B	0	15.4	14.8	7.3

Discussion and conclusion

The testing shows that high frequencies are especially reduced by these new protection materials, and this may be of importance to prevent the HAVS. As evident from the results section, the hand-arm weighting is not giving a fair picture of this improvement. One example is the results from the well-known and frequently used Cool-grip protection material, which actually gave an increase of the hand-arm weighted vibration level when tested on the grinding equipment. As evident from Table 1, Cool-grip gave the most efficient decrease of the vibration levels at higher frequencies (see dB linear). These results must, however, be interpreted with some caution, as the use of hose clamps to attach the materials tested to the handle may interfere with the damping properties of the material. This gives a considerably higher pressure on the material, as compared with a hand-hold situation. Accordingly, it is reasonable to expect that these new protection materials will also give some reduction of the vibration levels at frequencies below 1 kHz. More experiments are, however, in progress to further clarify these mechanisms.

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Passive mechanical systems and actuators for reducing vibration emission

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Introduction

If no primary method of vibration reduction is practicable, vibration isolation handles represent a suitable possibility of reducing the hand-arm vibration caused by hand-held tools. Due to the wide range of possible variation, e.g. the spring stiffness, the damping rate or the geometry, vibration isolation systems can be adapted only in consideration of the vibration characteristics of the respective machine. For this purpose a universal test rig was built.

Methods

To simulate the different vibration isolation handles on the test rig in combination with various hand held tools, an electromagnetic shaker was used. The vibration characteristics of the tools were generated by several signal generators. Using this rig, it was guaranteed that the power input for the vibration isolation system was constant for all different handles. The measurement of the weighted acceleration was only performed in z-direction on the inside of the handle in the middle of the palm. The power of the shaker was sufficient to produce a range of the weighted acceleration values comparable to real machines.

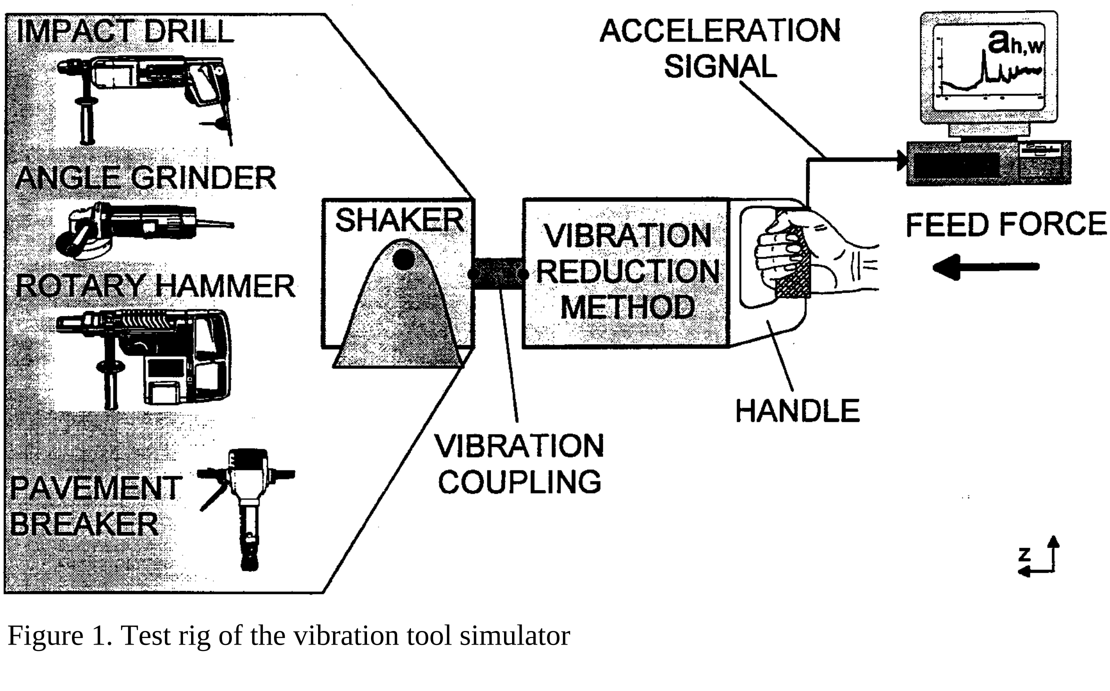

Figure 1. Test rig of the vibration tool simulator

The investigation was divided into two separate sections. First, the mechanical models of different vibration isolation handles were simulated on a PC in combination with the machine excitation data and the mechanical impedance of the hand-arm system. Second, the systems were reproduced on the test rig and measured.

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The tests included the following vibration isolation handles:

- a simple isolation system with spring and damper,
- an isolation system with spring, damper and absorber mass,
- an isolation system with spring, damper and a specially coupled “integrated“ absorber mass and
- three differently controlled hydraulic actuators.

The choice of the actuator was based on the requirements for the vibration displacement, the acceleration forces, the accuracy and the control rate. The most important working range of the actuator was defined to be the lower frequencies. The first actuator system was simply tuned to the impact frequency. The second actuator system had an analogue PID-controller, the third a PC based fuzzy controller.

Results

The results of the PC-simulation and the measurements on the test rig showed a good correspondence. It was possible to reduce the vibration emission at the handle down to 20 – 30 % of the original values for the impact drill and the angle grinder. The passive isolation handles on the rotary hammer and the pavement breaker were more effective, when an absorber mass was attached. In particular, the coupled integrated absorber mass had a good effect. But none of these passive isolation systems achieved a reduction effect of more than approximately 70 %.

The actuator reduced the weighted acceleration down to 20 % for the rotary hammer and down to 10 % for the low frequency pavement breaker (impact frequency 14 Hz) of the original values.

Conclusions

Passive vibration reduction today is still possible. Simple passive systems archieve a good effectivity for a lot of tools. For lower frequency machines, a controlled actuator is able to reduce the vibration emission with good results. With the development of simpler sensors, low cost controllers and actuators, new ways of vibration isolation systems will be possible.

Vibration white ringer in different groups of workers exposed to hand-arm vibration in metallurgical industry

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Introduction

In metallurgical industry workers use hand-held vibrating tools to prepare forms in moulders boxes and to clean casting. Vibration-induced white fingers (VWF) called Raynaud's phenomenon of occupational origin may occur in the workers (1,3). The probability of appearance of VWF can be calculated from the dose-response relationship showed in the ISO 5349-1986 (2). The aim of the study was to assess the risk of VWF in different occupational groups of workers.

Methods

The study was carried out at seven metallurgical factories. 297 vibration exposed male employees were examined. Among them were 77 grinders, 93 rammers and 127 chippers. An interview was conducted to obtain the full occupational history of each of the workers, past and present medical history and finally the symptoms. The frequency-weighted acceleration magnitudes were measured in three orthogonal directions for the following tools: rammers, chipping hammers, swing frame grinders and portable grinders. For each worker the energy- equivalent acceleration (8h) was calculated.

Results

Table 1 gives the results of vibration exposures at work-places in three occupational groups of workers, namely moulders, chippers and grinders. The mean energy-equivalent acceleration magnitudes at work-places of moulders were almost five times higher than at work-places of chippers and grinders. The mean life time exposure to vibration in years in chippers was about two times shorter than in the two other occupational groups. The observed prevalence of Raynaud's phenomenon has been compared with the expected prevalence according to the ISO 5349. Eighteen percent of the chippers reported blanching symptoms, but only three percent of the rammers and five percent of the grinders had these vascular disturbances.

Table 1. Assessment of vibration-induced white fingers in three groups of workers.

Occupational group (n)	Life time exposure Mean ± SD (years)	Energy equivalent acceleration (8h) Mean ± SD (m/s^2)	Percent workers with vibration-induced white fingers (%)	
			Observed	Expected
Rammers (93)	14.5 ± 12.0	14.1 ± 6.2	3	>50
Grinders (77)	15.2 ± 11.7	2.7 ± 1.2	5	40
Chippers (127)	8.8 ± 7.1	3.1 ± 2.3	18	17

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Discussions

The results of this study showed that the relationship between exposure to vibration and vascular disorders can be predicted quite well using the ISO standard only in one group, that is in chippers. The chippers use usually two type of vibrating tools: chipping hammers and swing frame grinders. They are exposed to low, middle and high frequency acceleration magnitudes. The moulders operate pneumatic rammers which produce the low frequency vibration, below 20 Hz but the grinders are exposed to vibration with dominant acceleration in high frequencies, above 200 Hz.

Conclusions

Not only do vascular disorders in the hand depend on the intensity and frequency of vibration but to a significant extent also on how the vibrating tools are used. It is especially true in cases where substantial grip and push forces have to be applied to the hand-held tools.

Acknowledgement

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Medial plantar nerve conduction velocities among patients with vibration syndrome due to chain-saw working

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Introduction

Some patients with vibration syndrome (VS) complain of tingling and numbness in the lower extremities, especially in the foot (3,4). These symptoms suggest an effect of VS in the peripheral nervous system (PNS) of the lower extremities. In order to clarify the effect of VS on the lower extremities, we reported that sensory nerve conduction velocities (SCV) in the medial plantar nerve (PSCV) in patients with VS was significantly lower than that in the controls, but not the SCV in the sural nerve. In the study, we also discussed the possibility of relation with circulatory disturbance and reduction of PSCV (2). Sakakibara et al reported that patients with VS and VWF showed significant reduction of the skin temperature in the toes compared with those of controls, but patients with VS and without VWF did not significant reduction (5). This fact may suggest that VWF may be an indicator of circulatory disturbance in the feet of the patients with VS.

In the present study, we analysed the PSCV of the patients exposed to vibration due to chain-saw and controls whom we have previously examined in order to clarify the effect of the circulation disturbance on PSCV by the indicator of VWF.

Subjects and methods

***Subjects*:** Thirty-eight patients with VS and 55 control subjects were examined in the summer of 1993 and 1994 and in the spring of 1996 (Table). They were not suffering from other diseases or injuries which might have affected the PNS function, had no past or current exposure to neurotoxicants and were not consuming more than 80 ml of alcohol a day. The patients were divided into two subgroups, one of those with VWF in the last winter [VWF(+), n=19] and the other without VWF in the same season [VWF(-), n=19].

***SCV measurement*:** The subject, in an air-conditioned room with the temperature maintained at 24 to 27°C, were examined PSCV from the first toe (stimulation point) to the medial side of the ankle (recording point) through needle electrodes, orthodromically placed. The evoked nerve action potentials were amplified with a band-path from 2O Hz to 2 kHz using an electromyograph (Sapphire 4EM, Medelec Co., UK). One hundred eight to 256 nerve action potentials were averaged for PSCV. The skin temperature was measured at the midpoint between stimulation and recording points using an infrared ray thermometer Type IT 340 S (Horiba Manufacturing, Kyoto, Japan). The measured PSCVs were corrected for PSCV at 31 C of standard skin temperature using de Jesus' method (1).

***Statistical analysis*:** The differences of PSCVs among 2 patient groups and controls were tested by analysis of variance (ANOVA) with multiple comparison by Scheffe's method.

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Table. Age, duration of exposure to vibration, and of removal from exposure, skin temperature and PSCV among patients and controls (mean ± SD)

Group	Patients			Controls
	n = 38	VWF(+) n = 19	VWF(-) n = 19	n = 55
Age (years old)	60.0 ± 4.62	60.8 ± 4.10	59.3 ± 5.09	59.6 ± 4.07
Duration of exposure (years)	22.8 ± 7.56	23.0 ± 7.82	22.5 ± 7.51	---
Duration of removal (years)	2.63 ± 2.71	1.95 ± 2.35	3.30 ± 2.94	---
Skin temperature (°C)	29.0 ± 1.68	28.7 ± 1.82	29.2 ± 1.53	29.3 ± 1.82
PSCV (m/s)	39.1 ± 4.25	38.1 ± 4.05	40.1 ± 4.30	42.8 ± 3.93

Results

ANOVA of PSCV in 3 groups showed an F=10.647 (dF=2, 89, p<0,0001) with a significant difference between the controls and VWF (+) group (p< 0.0001) and without significant difference between the controls and VWF (-) group (p=0.0503) using Scheffe's method.

Discussion

The results of multiple comparison in ANOVA showed that VWF as an indicator of circulatory disturbance affects PSCV, that is, circulatory disturbance affects reduction of PSCV among patients with VS.

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A comparison of vibration magnitudes of hand-held tools using the dominant single axis and the root sum of squares of the three orthogonal axes method - in Japanese case

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Introduction

The magnitudes of the hand-transmitted vibration, 297 vibrating tools and work-pieces, were measured at the workplace in Japan to control the exposure level and assess the risk of occupational diseases. The present standard for the evaluation of hand-transmitted vibration has been based on dominant axis method; International standard ISO 5349-1986 (1) also in Japanese Industrial Standard JIS B 4900 (2)

According to the proposal of ISO/CD5349-1 (3), the results of measurement (462 points of data) were recalculated by the method of weighted acceleration sum (root-sum-of-squares of the three orthogonal axes). This paper shows the increasing ratio of the application of the weighted acceleration sum method to the dominant axis method.

Method (Measurement and Analysis)

Measuring instruments of vibration acceleration were a vibration pickup (triaxes type, PV-93T RION Co. Japan), a vibration meter (3ch. VM-19A, RION) (4) and a data recorder (4 ch. DAT type, RD-120T TEAC Co. Japan). The pickup was mounted firmly with steel belts and a fitting base on a handle of the object tools (1 point or more measured per tool).

The vibration acceleration signals were analyzed with the data recorder and a one-third octave band real time analyzer (SA-27, RION). The frequency-weighted energy equivalent acceleration levels were obtained by the system. The averaging time varies 30 seconds to 90 seconds depending on types of tools and work conditions (5). Acceleration magnitudes of the tools were determined by ISO 5349 method and Japanese standard JIS B 4900. The weighted acceleration sum is a combined value of three orthogonal axes defined in the following equation.

$a_{hws} = (a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2)^{1/2}$ where a_{hwx}, a_{hwy} and a_{hwz} are frequency-weighted root-mean-squared acceleration magnitude for x, y and z axes.

Results

The ratio of the root sum of squares (rss) to the dominant axis magnitude (dom) is in the table 1.

Table 1. The ratio of the root sum of squares to the dominant axis magnitude. (rss./dom.)

Percussive tools					
Electric hammers	1.31	0.18	1.65	1.07	14
Vibration drills	1.37	0.19	1.73	1.03	15
Impact wrenches	1.27	0.14	1.57	1.05	94
Internal combustion engine powered tools					
Engine cutters (cutting disc)	1.27	0.14	1.55	1.09	12
Plate compactors (asphalt-work)	1.40	0.09	1.55	1.31	6
Mowers	1.37	0.14	1.55	1.14	13
Sod cutters	1.30	0.21	1.61	1.17	4

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Table 1. (Continue)

Grinders					
Hand-held grinders	1.24	0.13	1.55	1.02	66
Pedestal electric cutters	1.32	0.14	1.48	1.12	9
Angle grinders, cutting disk	1.18	0.12	1.42	1.08	5
Sander & polishers	1.22	0.16	1.49	1.03	18
Drills					
Drills (iron-work)	1.34	0.14	1.66	1.04	72
Drills (wood-work)	1.38	0.19	1.73	1.08	18
Drilling machines (fixed)	1.31	0.18	1.58	1.10	5
Screw drivers	1.36	0.14	1.61	1.15	7
Planers, elec. (woodwork)	1.37	0.15	1.56	1.13	10
Routers, elec. (woodwork)	1.37	0.21	1.61	1.03	9
Circular saw elec. (woodwork)	1.31	0.12	1.56	1.14	18
Concrete vibrators	1.47	0.15	1.71	1.10	23
Miscellaneous tools	1.44	0.12	1.57	1.26	9
Work-pieces					
Pedestal grinders	1.36	0.16	1.70	1.12	29
Miscellaneous work-pieces	1.39	0.13	1.52	1.22	6
Total (297 tools)	1.32	0.16	1.73	1.02	462 points

The mean value of rss./dom. ratio (6) is 1.32 per 462 points. The ratio of weighted acceleration magnitude of the maximum axis exceeded twice in other two axes was 20 %. 140 tools were measured two points respectively (i.e. side handle and rear grip) and the estimation point were swapped in 17 tools (12%) by applying the weighted acceleration sum method.

Conclusion

The weighted acceleration sum method gives convenience to measure the hand-transmitted vibration at the workplace where the direction of primary vibration force varied by the condition of working posture, the change of gripping angle, the contact force, the shape of object and others. The present dominant axis method can underestimate the vibration in those variable cases. On the other hand, the evaluation standard should be re-examined by this method.

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Effect of different room temperatures on the recovery of skin temperature, vibrotactile threshold and thermal pain perception in cold provocation test

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Introduction

Many kinds of cold provocation tests were widely used for evaluating the peripheral circulatory function in many countries. Although this method was very useful for screening test for hand-arm vibration syndrome (HAVS) with its simplicity and low cost, the widely acceptable standard of evaluation has not yet been proposed (3). ISO has started to establish an international standard for a cold provocation test as a peripheral circulatory function since 1996 (2). Basic and clinical information concerning this provocation test will be needed. The aim of this study is to clarify the effects of different room temperatures on the physiological indices in the conventional cold provocation test.

Methods

Thirty male medical students with a mean age of 22 yr. (range 20 - 24 yr.) participated in this study. All subjects were healthy without peripheral circulatory and nervous disorders. The subjects were asked to prohibit smoking 2h before the examination. Three conditions of room temperature were applied; 17 °C, 22 °C and 27 °C (relative humidity: constant with 50%). The each room temperature was precisely maintained within ± 0.3 °C using an artificial climate equipment. Before starting the experiment, the subjects were asked to sit on the chair in the artificial climate room for at least 15 min. Cold provocation test with 10 °C -water for 10 min was conducted randomly at each room condition with interval of 2h. Finger skin temperature was continuously measured at the back of the middle phalanx of the 3rd finger using a thermistor before, during and after cold water immersion. The vibrotactile and heat pain threshold as the peripheral neurological functions were examined at the palmar distal phalanx before, immediately after, 5 min, 10 min, and 15 min after cold provocation, respectively.

Results

Significant differences of skin temperature among three room conditions were observed before and 3 min after cold provocation (ANOVA, $p<0.05$) (Figure 1). The skin temperature at the end of measurement at 27 °C of room temperature returned to the previous level in the most of the subjects (95%). On the other hand, 40% and 15% of the subjects only recovered within 15 min after provocation in case of 22 °C and 17 °C, respectively. The changes of the mean heat pain and vibrotactile threshold were strongly influenced by room temperatures (Figure 2 and 3). There was a significant negative relationship between skin temperature and both thresholds except the value of previous vibrotactile threshold. The recovery of vibrotactile threshold was more faster than that of heat pain threshold.

Discussion

Gautherie (1) recommended that well controlled and designed cold provocation test could produce an useful information for the follow-up of asymptomatic patients.

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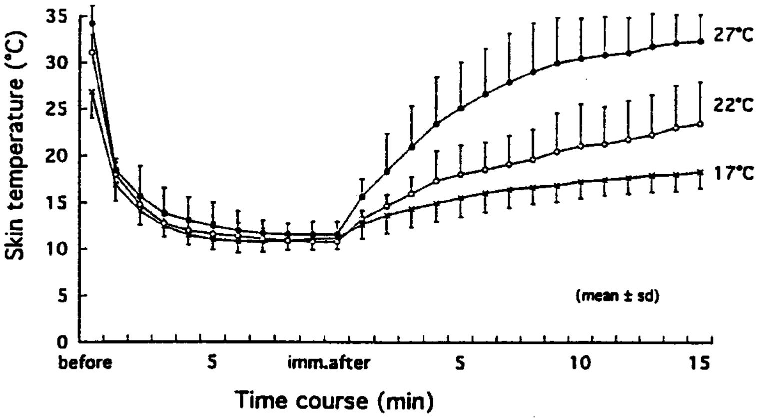

Figure 1 Changes of skin temperature at different room temperature by cold provocation test

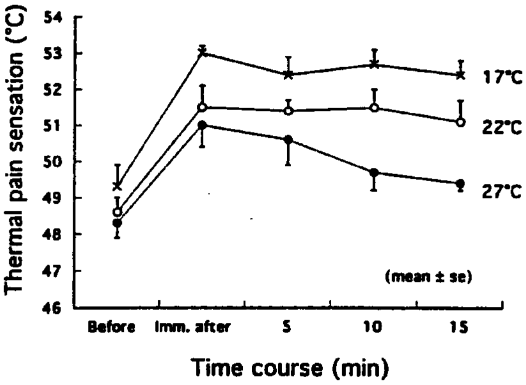

Figure 2 Changes of heat pain threshold at different room temperature after cold provocation test

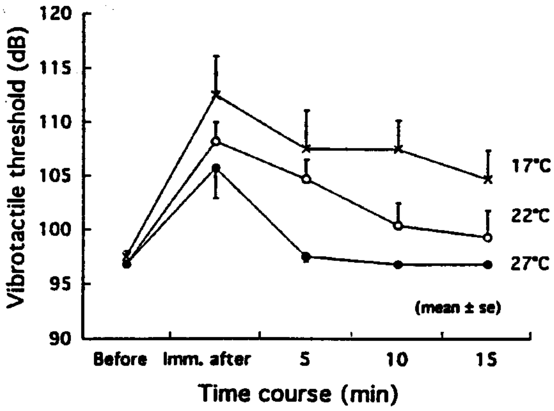

Figure 3 Changes of vibrotactile threshold at different room temperature after cold provocation test

Although all subjects had no complaints concerning the peripheral circulatory function in our study, 60% and 85% of the subjects had a poor recovery of skin temperature in case of 22 °C and 17 °C, respectively. Our result indicates that a possibility of over-estimation for diagnosis occurs if the room temperature was not well controlled. In Japan, the 10 °C -10 min method of cold provocation test is widely used for the screening and follow-up examination on the peripheral circulatory function for subjects with HAVS. Its standard procedures are prescribed in the notifications of Japanese Ministry of Labour. The examining room temperature varies from 17 °C to 26 °C in some reports. The factor of room temperature may contribute to difficult assessment of the peripheral circulatory function. In conclusion, the different room temperatures with the difference of the range of 5 °C can produce strong effect on the peripheral circulatory and nervous functions. Further study will be needed concerning how range of degree may not influence the recovery of skin temperature after cold provocation.

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Sensory nerve function in vibration-exposed workers studied by SCV and SSEPs

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Introduction

The objective evaluation of sensori-neural complaints is one of the essential problems for the diagnosis of vibration disorder (VD, HAV syndrome) especially in the case of worker's accident compensation.

Determination of sensory nerve conduction velocity has a long history and, with the development of signal averaging techniques, it has become possible to analyse the components of the (short-latency) somatosensory evoked potentials (SSEPs) in humans. The capability has been extended to sequences of SSEPs generated in the brachial plexus, spinal cord and subcortical structures. Cervical spondylosis is a common condition after the age of 40 years and SSEPs are subjects to the influence of such a pathological state.

In this report, reference values of antidromic sensory nerve conduction velocity (SCV) and SSEPs components were obtained from healthy control subjects without cervical spondylosis and the degree of sensory disorders in hand-arm vibration-exposed workers was studied in comparison with diabetics as a positive control group.

Subjects and Methods

Two hundred and thirty-seven males aged from 40 to 69 years - i. e. 34 healthy controls, 125 VD and 40 vibration-exposed nonVD, and 38 diabetics (NIDDM) - were studied. In all subjects, 6 plain radiographs of the cervical spine were taken. These subjects were then divided into six groups according to the radiographical findings of cervical spondylosis (CSP); i. e. 47 VD without, 78 VD with, 19 nonVD without, 21 nonVD with, 21 DM without and 17 DM with CSP. All of the 34 healthy control subjects were without CSP.

Electrophysiological studies were carried out in a supine position in a dimly lit shield room using Cadwell CA-7400, (Cadwell Lab Inc, Washington, U.S.A.). The room temperature was kept at 25 - 27°C.

SCV at the palm segment of the right median nerve was measured using the antidromic technique. The electric supramaximal stimuli were delivered by a stimulator at 2/s and the electrical response were recorded at the index finger by a ring electrode. Usually, 32 responses were averaged with a sweep duration of 10 ms. SCV was determined by division of the distance of palm by the latency to the first negativity (m/s).

SSEPs were measured as follows. Electric stimuli were delivered by the stimulator at 2.11/s to the median nerve of the right wrist. N9 potentials at Erb's point, N13 potential

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at C2 point of the cervical spine, and N20 potentials at post-Rolandic area were determined with the reference electrode placed at the standard midfrontal location (Fz).

Usually, 512 responses were averaged with a sweep duration of 50 ms. The latency of N9 and the interpeak conduction times (N9-N13 and N13-N20) were standardized by the body height (ms/m body height).

Results

1. Normal limit values presently adopted were SCV 46.8 (M - 2SD) m/s, N9 6.18, N9-N13 2.77 and N13-N20 4.18 (M + 2SD) ms/m body height, respectively.
2. There was a negative correlation between SCV and N9 (peripheral parameters) in healthy control without CSP (r=-0.391, P<0.05).

Table 1. Statistical difference of parameters between each experimental group vs. healthy control.

Group	CSP	N	SCV	N9	N9-N13	N13-N20
non VD	without CSP	19	52.2* (n.s.)	5.64 (n.s.)	2.56 (n.s.)	3.69 (n.s.)
	with CSP	21	49.4 r **	6.01 t	2.56 q	3.81 p
VD	without CSP	47	51.9 r	5.85 r	2.45 (n.s.)	3.67 (n.s.)
	with CSP	78	50.4 t	5.96 t	2.42 (n.s.)	3.75 p
DM	without CSP	21	49.5 q	5.86 p ùq	2.59 s	3.51 (n.s.)
	with CSP	17	47.7 s	6.34 s û	2.84 s	3.68 (n.s.)
Control (without)		34	55.6	5.64	2.34	3.62

* Mean (S.D. value was omitted in this table);

** P value: p<0.05; q<0.02; r<0.001; t<<0.001

3. Since interrelationships of proximal and central components (N9-N13 and N13-N20) were not consistent between each experimental group and healthy control (Table-1) and taking the above mentioned Results 1 into consideration, peripheral parameters seemed to be useful for the evaluation of sensory disturbance of hand and arm.
4. The majority of cases with impaired peripheral sensory nerve function in VD had slight and/or mild disturbances by our tentative criteria and severely disordered cases were rare.

Conclusion

1. Determination of peripheral parameters (SCV and N9) seems to be useful for the evaluation of sensory disturbance in vibration-exposed subjects.

2. Diabetes mellitus and/or radiographical cervical spondylosis should be examined prior to final evaluation by electrophysiological examinations.

Hand-arm vibration: technical and medical prevention

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Introduction

In Spain, the declared cases of occupational diseases with absenteeism due to vibrations have increased progressively. The hand-arm vibration syndrome refers to the group of disorders associated to vibration exposure of fingers, hands and arms. Among them we have the ostheo-articular diseases and the angioneurology problems.

The prevention of the injuries caused by the vibration transmission to the hand-arm system, requires the implementation of technical, medical and management procedures.

The technical prevention is strongly supported by the European Legislation both in machinery and personal protection. The approximation of the European Legislation in terms of machinery obliges to look for a reduction of vibration magnitude at source. Nevertheless, and taking into account technical progress and the availability of means of reducing vibration, it can be necessary to use personal protective equipment.

As medical prevention, besides the appropriate hygiene measures, we propose a medical protocol whose purpose is to provide laboral physicians with an useful and handy guide to prevent, as much as possible, the hand-arm vibration injuries associated with hand-held, hand-guided and other machinery, and to avoid their worsening.

Development

The processes and machinery which transmit vibrations to the operator's hands and arms are widely extended in several industrial activities.

To develop the technical prevention on hand-arm vibration exposure we have considered all the existing European legislation. The 89/392/CEE Directive and its modification establish the safety and health essential requirements to be demanded to any machine or safety component for its commercialisation, and, in particular, those related to vibration. Moreover, the European Commission and specifically the Technical Committee 231, has developed and is still developing technical standards to make easier the checking of those vibration requirements.

In the case that, after applying all the possible technical measures to reduce vibrations, these are still a risk for the worker, we will have to consider the personal protection. The requirements applicable to anti-vibration gloves, with their limitations as a personal protective equipment, are established in a European Standard.

The medical protocol developed considers important the following items: worker and firm data, work conditions, previous exposition, personal and family background, worker habits, current history including hand-arm neurovascular and articular symtomatology, vascular and articular exploration, complementary explorations and tests, and clinical evaluation.

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Conclusions

With this study we pretend to analyze and summarize all the existing legislation on hand-arm transmitted vibration in order to facilitate the actions of manufactures, designers, employers, prevencionist and workers.

Furthermore, we propose, from the medical point of view, a protocol to assess and control the evolution of the hand-arm vibration syndrome. It will be validated the next year by its application in different industrial companies having work tasks with hand-arm vibration exposure.

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Hand-arm data base on the Internet

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Introduction

Among others, officials from social insurance offices, company health services, clinics in occupational medicine, research departments in the field of occupational health, labour inspectorates, buying departments, engineering industry often asks for information regarding vibration levels measured on handles of specific hand-held power tools. Some reasons for this are a need;

- for health risk assessment due to past and/or present vibration exposure
- to constitute a basis for decisions in worker compensation cases
- to procure ”user friendly” tools in order to prevent vibration-induced disorders
- for data in research and development projects.

A long-felt want has therefore been that reported measurement results should be put together in a data base. The format for such a data base should fulfil at least the following requirements;

- Data must be presented in a clear, understandable and useful way
- The data base should be easily accessible for a large number of interested users
- Measurement data must pass through a quality control before insertion,
- Included data must be based on measurements conducted in accordance with a generally accepted standard, such as an ISO or a CEN standard
- New data inserted in the data base should be accessible for users as quickly as possible
- Corrections and additions must be easy to carry out
- The data base must be easy to manage and maintain and not involve to heavy expenditures.

After considering different alternatives, it was concluded that a data base accessible through Internet would most efficiently comply with the above stated requirements.

Data base content

At present the data base contains vibration data for more than 2000 hand-held power tools, either CE-declared values (i.e. vibration measured in accordance with corresponding parts of the ISO 8662 standard) or measured according to ISO 5349 during normal operation at a work site. CE-declared noise data is also included for many tools of the former category. The data base is available in Swedish and English.

Procedure for search and presentation of results

The search is easily done by following a step by step procedure.

1. The Data base home page, reach by using a suitable web browser (e.g. Netscape Navigator, Internet Explorer), contains some general information for instance about data base content, people and organisations responsible for administration and maintenance and some links to other informative pages.

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2. The next step is to open the Search page. A search for vibration data, CE-declared and/or measured during normal work, for a specific tool or for a category of tools is done by choosing or typing search arguments according to instructions given on this page. The result of this request is then presented on a separate ”Search result” page.
3. Each row on the Search result page indicates type of tool (e.g. grinder, nut runner, drill), name of the manufacturer (e.g. Atlas Copco, Fuji, Bacho) and model. Further information and data for an individual tool on this list is then presented by activating corresponding link to a ”Tool data” page.

The Tool data page show some general information about the tool (e.g. model, manufacturer, weight, power), photograph, reference to the source of information and vibration data. Noise data is in most cases also given for CE-declared tools.

End notes

This hand-arm vibration data base is still in a stage of development. Changes with respect to content and format will therefore most likely be conducted in the near future. An important input to this is viewpoints from different categories of users. It is also likely that this data base will become a centralised European data base which may lead to modifications.

A corresponding whole-body vibration data base, covering earth-moving vehicles, has also been established which is available at the same Internet location as the hand-arm vibration data base.

Internet location

The hand-arm vibration data base is hosted by a web server at the National Institute for Working Life, Department of Technical Hygiene, Umeå, Sweden. The Internet location is: ”http://umetech.niwl.se/”.

Comparison of three different quantitative measures for vibrotactile perception thresholds - Acceleration, force and absorbed power

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Introduction

Registration of vibrotactile perception thresholds (VPTs) is a commonly used method for diagnosis of sensorineural disorders caused by different types of diseases (eg. diabetes, carpal tunnel syndrome) or as result of agents in the working environment (eg. exposure to solvents, mercury, vibration, electromagnetic fields, heavy manual work). VPTs are also an important ingredient for grading of sensorineural disorders in to symptomatic stages (2). Several different methods for VPTs have been developed and used (for an overview, see 5). It is clear that the outcome of a VPT measurement is, for instance, strongly related to measurement set-up, experimental procedure and individual factors. There is also relatively large inter- and intra-individual differences which quite often cause difficulties in the interpretation of obtained results. Clearly, the effect of these factors have to be fully examined before measurement of VPTs can be accepted and established as a tool for clinical diagnostic purposes, for screening, or in research.

The aim of this pilot investigation was to compare three different quantitative measures for VPT, namely acceleration, dynamic force and absorbed power.

Methods

VPTs were measured on the right index finger tip on 10 healthy subjects. None of them had used vibrating hand-held tools professionally.

The experimental set-up for VPT measurements consist of a computer based system (LabView™) for both stimulus excitation at six discrete frequencies (8, 16, 32, 63, 125, 250 Hz) and for data acquisition and analysis. Vibration was delivered as 5 s long bursts which were ramped on and off at the beginning and end, respectively. Between each burst a 3 s long pause was inserted. The acceleration level for following bursts were decreased or increased in steps of 1 dB depending on perceptive responses (by pressing a button on a hand switch) respective lack of perceptive responses from the subject, respectively. A forced choice algorithm for VPT has thus been used.

An impedance head (Brüel & Kjær 8001) was mounted on the shaker which enabled registration of time signals for acceleration a(t) and dynamic force F(t). The collected acceleration signal was integrated to get the velocity v(t). Time-averaged absorbed power (P_{Abs}) was determined as: $P_{Abs} = v(t)\ F(t)$. The static force and skin temperature were continuously monitored during VPT measurements.

The subjects were asked to sit on a chair with their forearm and hand resting extended and relaxed on a testing table. The position of the stimulator probe (diameter: 5 mm; no supporting surround) covered the pulp of the finger. The subject was instructed to press the button on the hand switch as soon as the vibration burst was perceived. The threshold at each frequency was defined as the lowest stimulus level perceived by the subject.

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Results

The results from this pilot study showed VPT curves with different shapes (Figure 1). The graph for acceleration shows a typical shape which is in agreement with most other studies (eg (1, 3, 4). The VPT graph for force indicates that the dynamic force required for perception decreases with frequency. The absorbed power threshold graph shows an inverted U-shaped form which has a peak at 16 Hz. The inter-individual variability is however comparable for all three categories.

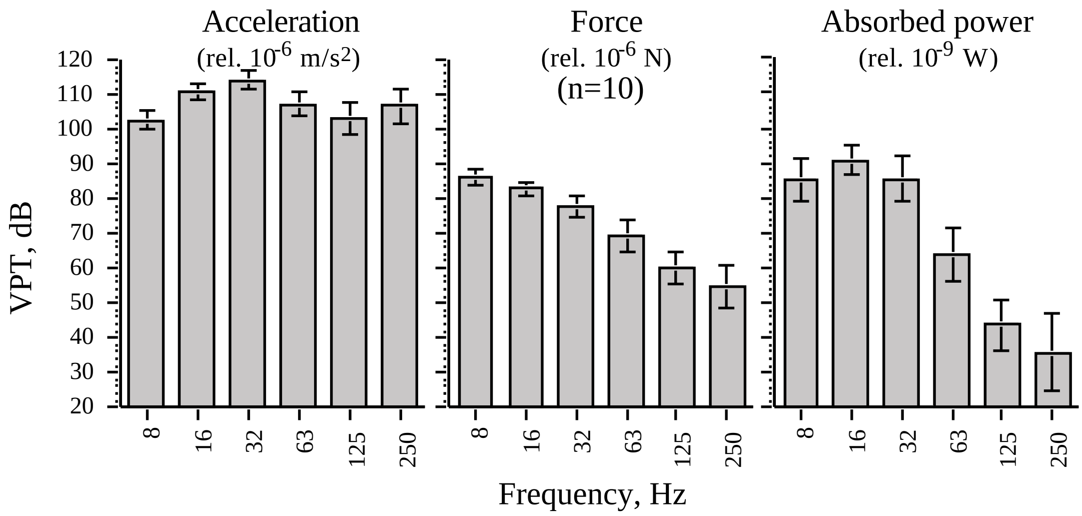

Figure 1. Mean (±1 Sd) VPT quantified as acceleration, dynamic force and absorbed power.

Discussion

The results obtained in this study are based on measurements taken using only ten subjects. To be able to draw any far-reaching conclusions regarding preference for any of the three VPT categories, this study has to be extended, i.e. with respect to number of healthy and symptomatic subjects, influence of age, intra-individual variability, sensitivity, specificity etc. Methods for VPT measurement which include the dynamic force must however be considered as interesting and well worth further exploration since this component mirrors the mechanical coupling and physical strain on tissues in contact with the stimulus probe.

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Design and evaluation of an inexpensive test fixture for conducting glove vibration test per ISO Standard 10819

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Introduction

ISO Standard 10819 requires an excitation system that can provide over 200 N of axial dynamic force. At the same time, the system must sustain a 50-60 N axial static push force while generating an overall input acceleration level to a vibrating handle, associated with a pre-defined vibration spectra, of up to 92.2 m/s^2. Most laboratories use large expensive shaker systems to meet these requirements. A feedback vibration control network is also needed to easily obtain the two input spectra that are specified by ISO Standard 10819. The expense of the electro-dynamic vibration shaker and vibration controller that are necessary to easily meet the above requirements are generally beyond the means of most small laboratories and glove manufacturers that would like to test gloves to determine whether or not they meet the requirements of ISO Standard 10819 to be classified as antivibration gloves.

A project was undertaken at the Center for Mechanical & Environmental Systems Technology at the University of Nevada in Las Vegas, Nevada, in the USA to develop an inexpensive test system that can be used to perform glove vibration transmissibility tests per the test procedures specified by ISO Standard 10819. Related test procedures were developed to obtain the proper input spectra to the shaker handle without the use of a vibration controller and related feedback network.

Method

A small 222 N electro-dynamic shaker was used as the vibration exciter for the ISO Standard 10819 tests. An air bladder was used to enable the shaker coil to resist the 50-60 N axial push force required by the standard. The air bladder provided was a very compliant spring that could be used to resist the push force applied to the shaker handle without significantly changing the dynamic properties of the shaker. The shaker was mounted on a platform that was attached to linear bearings. The platform was connected to “ground” by means of a strain gauge load ring that was used to measure and monitor the push force. The grip force was measured and monitored by means of a strain gauge beam that was placed in the handle. Several test methods were investigated to adjust and maintain the medium and high frequency input spectra specified in ISO Standard 10819 without the use of a vibration controller.

Results

Several gloves were tested using the excitation system developed at CMEST. Some of these gloves were also tested at two European laboratories: Delta Acoustics & Vibration in Lyngby, Denmark, and BIA in Sankt Augustin, Federal Republic of Germany. A summary of the results is shown in the table below.

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ISO 10819 Glove Vibration Transmissibility Test Results.

GLOVE		CMEST	DELTA	BIA
1	TR_M	0.85 (0.03)	0.89 (0.09)	
	TR_H	0.71 (0.01)	0.69 (0.09)	
2	TR_M	0.68 (0.04)	0.73 (0.12)	
	TR_H	0.52 (0.03)	0.52 (0.09)	
3	TR_M	0.65 (0.06)	0.72 (0.07)	
	TR_H	0.51 (0.04)	0.51 (0.07)	
4	TR_M	0.78 (0.03)		0.87 (0.06)
	TR_H	0.51 (0.02)		0.58 (0.03)
5	TR_M	0.82 (0.04)	0.87 (0.09)	
	TR_H	0.80 (0.02)	0.79 (0.11)	
6	TR_M	0.79 (0.02)	0.85 (0.09)	
	TR_H	0.76 (0.04)	0.76 (0.13)	
7	TR_M	0.86 (0.04)		0.93 (0.01)
	TR_H	0.83 (0.04)		0.72 (0.02)

Conclusions

The agreement of the ISO Standard 10819 test results between CMEST, Delta and BIA was very good. Thus, the instrumentation and corresponding test procedures that was developed by CMEST are adequate to perform vibration transmissibility tests per the requirements of ISO Standard 10819.

Measurement and assessment of hand-arm vibration caused by fastener driving tools

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Introduction

The present standards ISO 5349-1 (1) and ISO 8662-11 (3) mention different forms of vibration, whereas they disregard the different sorts of shock-type and non shock-type vibration. The purpose of this study was to measure the stress and the strain of hand-arm vibration caused by fastener driving tools.

Methods

Test subjects worked with different tools (chisel hammer, nailer and pinner) on a test rig. The length of the nailers (5 cm, 9 cm) and the working methods under ISO 8662-11 working conditions (20 impacts per minute - single actuation) and under real working conditions (92 impacts per minute - contact actuation) were investigated. The acceleration on the handle of the tools and on the wrist and elbow of the subjects were measured. Additionally the electrical muscle activity of the m. biceps brachii and of the m. flexor carpi ulnaris were examined. Both fastener driving tools had a special grip force measuring equipment.

Results

The highest acceleration of all tools was measured in the z-direction. The chisel hammer had the strongest vibration of all the tools. The acceleration of the fastener driving tools is between $a_{z,rms} = 10\ m/s^2$ and $a_{z,rms} = 69\ m/s^2$. The vector sum of all directions shows, that the acceleration of the nailer and pinner for the fast working cycle is two times higher than for the slow cycle and the factor of 5 cm nails and 9 cm nails is 1.4 to 1.

The grip force of the nailer is between 59 N (20/min) and 76 N (92/min) and the one of the pinner is between 15 (20/min) and 25 N (92/min).

Figure 1 shows that the length of the nails has no influence on the weighted acceleration. But the relation between the fast and the slow cycle is two to one.

It was found, that the transmissibility to the wrist and to the elbow for the non-impact tool is greater than for the fastener driving tools. The muscle activity of the m. biceps brachii when working with the nailer is two times higher than the muscle activity when working with the chisel hammer. The muscle activity of the m. flexor carpi ulnaris is nearly the same during work with the chisel hammer or with the fastener driving tools during the fast cycle.

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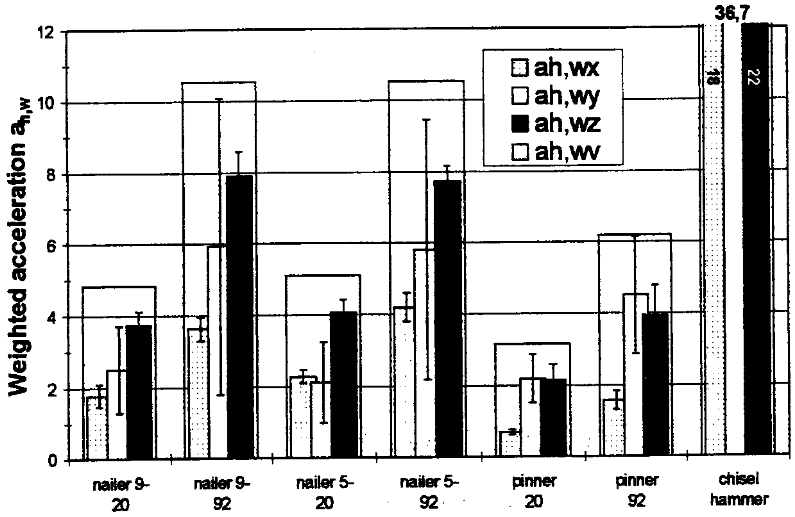

Figure 1. Weighted acceleration a_{hw} of different fastener driving tools.

Conclusion

The results of this study show that there is no difference between shock type vibration stress caused by fastener driving tools and non-shock type vibration stress. In the new standard ISO 5349 Part 2 there is a determination of the exposure time T and the daily vibration exposure A(8) for single impacts. Using this determination the daily vibration exposure will be the same for measuring in fast (real conditions) and in slow cycle (ISO 8662-11).

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Effects of combined exposure to shock-like hand-arm vibration and impulsive noise

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Introduction

In practice many work tasks are connected with exposures to several physical factors. So exposure to noise often is combined with vibration exposure, vibration exposure very frequently combined with noise exposure. The aim of the here described investigations was the clarification of the question, whether the combined effect of impulsive noise and shock-like hand-arm vibration results in a higher strain of the hearing organ as the exposure to impulsive noise alone.

Method

The investigation was carried out at two occupations as a pure field experiment. Altogether 15 levellers in the shipbuilding industry and 6 bolt-gun operators in the construction industry were investigated. The levellers have to even out the unevenness of ship decks, caused of the welding of the ship components, by means of manual beating with 3 kg hand hammers. The hammering causes a shock-like vibration exposure to both hand-arm systems and single, relatively slowly decreasing sound pressure impulses. The bolt-gun operators shoot fasteners and brackets in walls and ceilings of houses by means of bolt driving guns. A recoil directed on the right hand-arm system and a very short intense sound pressure impulse is caused by the shoot process.

Two groups of equal size without the shock-like hand-arm vibration serves as control groups for the both groups of combined exposed workers. The control groups consist of workers, who warm up the ship decks at the levelling points with a welding torch or work as assistants for the bolt-gun operators respectively. Because of the direct local proximity to the combined exposured workers the impulsive noise exposure is about the same in both groups.

Hearing thresholds and sensitivity thresholds at the finger tips were measured before and after about 6 hours exposure. Acceleration and sound pressure signals were stored on magnetic tape and analysed subsequently for peak values of acceleration and peak values of sound pressure in one-third octave bands between 4 Hz and 16 kHz. The acceleration was measured at the handle, at the wrist and at the head, the sound pressure directly beside the ear.

Results

The noise exposure of the levellers shows a peak value spectrum of increasing magnitude with increasing frequency with a maximum of about 135 dB at 8 kHz. The impulse duration is between 100 and 150 ms. The noise exposure of the bolt-gun operators shows a similar spectrum, however with higher levels at the higher frequencies. The maximum lies with 140 dB likewise at 8 kHz, the impulse duration amounts to only 5 to 15 ms.

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The acceleration spectra at the handles of both tools show likewise a similar shape. The maximums lie at 4 kHz between 3000 to 4000 m/s^2. In direction to the wrist and to the head a relatively strong decrease of accelerations up to about 60 dB is to be noticed, which is different however depending on frequency.

The effects of these exposures on the sensory threshold and on the hearing threshold have been determined as temporary threshold shifts TTS. The sensory TTS of the finger tips of the groups with combined exposure is clearly higher than those of the control groups. This is of course the result of the shock-like vibration exposure. But the groups with combined exposure however, show also clearly larger hearing threshold shifts than the groups exposured only to impulsive noise. The differences of the TTS between combined exposure groups and control groups are presented in the following diagram.

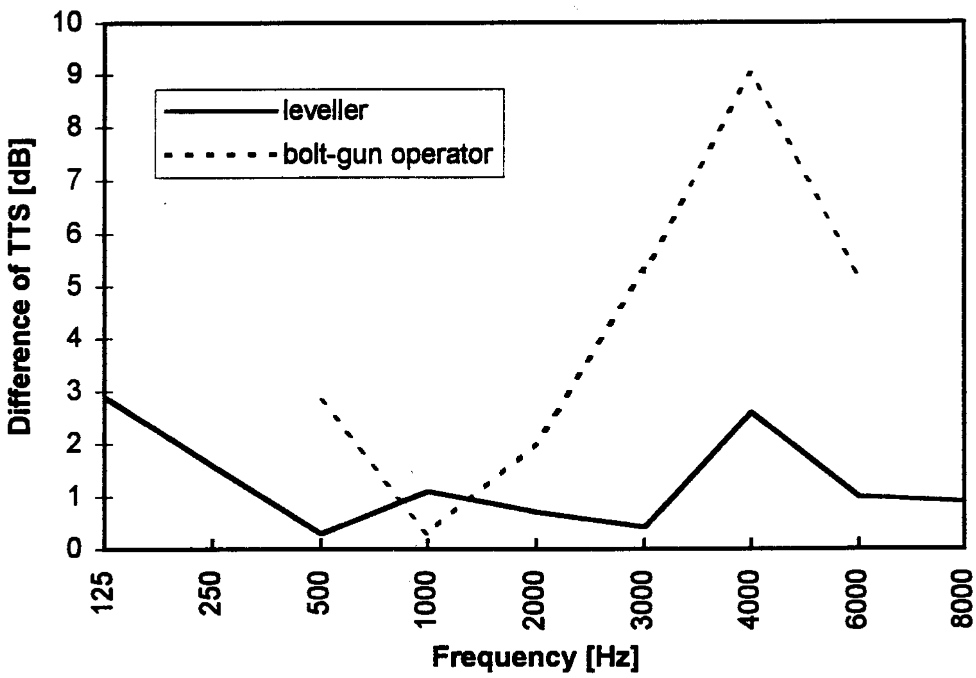

Figure 1. Differences of TTS between combined exposure groups and control groups

Discussion

The combined exposure to impulsive noise and shock-like vibration causes clearly larger temporary shifts of the hearing threshold at certain frequencies than the single effect of impulsive noise exposure. An explanation for this combined effect may be the vibration transmission from the handle along the hand-arm system to the head. Particularly in the frequency region at about 4 kHz a relatively good vibration transfer up to the head appears to exist, possibly supported by resonance phenomena.

Conclusions

If an exposure to shock-like vibration acts in addition to impulsive noise and this happens with slight phase shifts simultaneously, so due to structure-born noise propagation along the hand-arm system a larger exposure of the inner ear is possible. For a long-time combined exposure therefore a higher risk for possibly appearing inner ear damages may be expected.

The use of temporary threshold shifts in vibration perception as a model to assess the effectiveness of anti-vibration gloves

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Introduction

In addition to the long-term health effects of excessive exposure to vibration, commonly known as hand-arm vibration syndrome (HAVS), workers may experience immediate, short term effects in their hands and fingers. These reversible effects are experienced as numbness and tingling in the fingers. Although not proved to be associated with the development of HAVS they may interfere with manual dexterity (1). The short-term effects of vibration exposure on mechanoreceptors in the skin can be measured by a temporary increase in a subject's vibration perception threshold (VPT) immediately following the use of vibrating tools. This increase from a pre-exposure, baseline value is known as a temporary threshold shift in vibration perception (TTS_v) (2). By measuring the TTS_v in the fingertips it may be possible to assess if control measures such as anti-vibration gloves reduce the acute effects of vibration exposure. This purpose of this field study was to measure the TTS, in workers using hand-held rotary, vibrating tools in order to study the potential of one type of anti-vibration glove to ameliorate the TTS_v.

Methods

The study population consisted of 23 employees from four different UK factories, all of whom worked with vibrating hand-held tools for up to 7 hours per day. None had a history of HAVS. The tools used included hand-held rotary grinders (4 inch, 7 inch and pencil), polishers and pedestal grinders. Each employee was tested before commencing work, and a subsequent four times during the working day immediately after they had stopped using vibrating tools from Monday to Thursday of a working week. This regime gave a maximum of 4 pre-exposure and 16 post-exposure results per employee for each week studied. Workers were tested during the first week when not wearing anti-vibration gloves followed by a second week when a standard anti-vibration glove was worn. The work patterns did not vary from week I to week 2 in each factory. The VPT for each employee was tested using the HVLab Tactile Vibrometer (ISVR, Southampton, UK). The index finger of both hands was tested at 31.5Hz and 125Hz.

Results

In order to investigate whether a measurable TTS_v was present after using vibrating tools all results from each employee were standardised to their mean pre-exposure baseline value of I which allows comparison of all employees as one group both before and after vibration exposure. A significant TTS_v was measured in both hands at both 31.5Hz and 125Hz testing frequencies which increased the measured VPT by a minimum of 27.1% (right hand, 31.5Hz test frequency, p<0,0001) to a maximum of

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82% (left hand, 125Hz test frequency, p<0,0001) from the pre-exposure baseline values. When the anti-vibration glove was worn the increase in VPT was reduced to 4.9% (right hand, 31.5Hz test frequency, p=0.0005) and 21.7% (left hand, 125Hz test frequency, p<0.0001) although it was still significantly raised.

To directly compare the effects with and without the anti-vibration glove only the 16 employees who had completed both weeks of the study were considered. The results are shown in Table 1.

Table 1. Amelioration of the temporary threshold shift by wearing anti-vibration gloves. Data were log-transformed before statistical analysis.

	- gloves mean (sd) n	+ gloves mean (sd) n	One-tailed p-value
Right hand 31.5Hz	1.315 (0.694) n=191	1.149 (0.419) n=180	0.07
Left hand 31.5Hz	1.526 (1.065) n=190	1.206 (0.631) n=180	0.0001
Right hand 125Hz	1.558 (1.067) n=187	1.318 (0.782) n=180	0.0316
Left hand 125Hz	1.788 (1.373) n=192	1.217 (0.515) n=181	<0.0001

It is apparent that wearing the anti-vibration glove does significantly reduce the magnitude of the TTSv in both hands at 125Hz and at 31.5Hz in the left hand. However wearing the gloves does not remove the TTSv completely. A significant increase in VPT from pre-exposure baseline values is still present.

Discussion

A reversible effect known as the TTS_v is measurable using vibration perception testing immediately following vibration exposure from hand-held tools. This short-term effect has been described previously in volunteer studies (1,2,3). To our knowledge there are few studies which have measured the TTS_v in a workforce during a normal working week and used the TTS_v as an indicator of the efficiency of anti-vibration gloves to reduce the amount of vibrational energy being transmitted to the hands and fingers. The results presented in this study indicate that a temporary upwards shift in VPT does occur immediately following exposure to vibration from hand-held rotary, vibrating tools. This shift is ameliorated but not eliminated by wearing the anti-vibration glove indicating that the vibrational energy transmitted to the hands by the tools is being attenuated by the gloves. However this does not imply that the gloves will protect against HAVs in the long-term.

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Warm and cold thermal threshold in the vibration syndrome patients compared with healthy controls

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Introduction

Warm and cold thermal thresholds have been known to reflect the function of A-delta and C nerve fibre. Thus measurement of thermal thresholds can be useful to estimate the function of these nerve fibres. Stockholm Workshop 94 has recommended measurement of thermal thresholds as an examination for nervous impairments among vibration-exposed subjects. So we measured warm and cold thresholds of vibration syndrome patients compared with healthy controls.

Subjects and Methods

Subjects were 25 vibration syndrome patients under medical treatment (mean period; 3.2 ± 2.7 yrs.) and 10 healthy controls. Their age in the two groups were from 50 to 65 yrs., so that there were no significant difference in age between the groups. To exclude the effect of neurological diseases, those with diabetes mellitus, alcohol abuse over 80 g/day or any diseases which might affect peripheral nervous system were excepted from the present subjects.

Measurement of warm and cold thresholds on the middle finger of both hands were performed using a thermoesiometer (Hokusin Seiki Kogyo, Japan). In the measurement the temperature to start with was set to the skin temperature of each subject which was measured beforehand, and then it was automatically increased or decreased at the rate of 0.2°C to the point of feeling warm or cold. The measurements were performed twice, and the data closer to the initial skin temperature was adopted as the subject's threshold.

Vibration thresholds (125 Hz) and pain thresholds (needle method) were also measured on the same middle finger of both side of hand.

These measurements were carried out under a controlled room temperature of 27 ± 1°C to keep fingers warm. When skin temperature of the subjects was lower than 30°C, their hands were warmed by a heater to above 30°C and then measurements were performed.

Results

Both of warm and of cold thresholds were significantly impaired more in vibration syndrome patients compared with controls; difference between warm and cold thresholds was also significantly greater in the patient group than the controls. These impaired thresholds tended to be larger in patients with numbness than those without it.

Conclusion

It was clarified that the vibration syndrome patients had impaired warm and cold thresholds as well as vibration and pain thresholds. And patients with numbness tended to have severely impaired thermal thresholds than those without it.

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Thermal thresholds of vibration syndrome patients and controls (mean ± SD).

	control	V-S patient	numbness(-)	numbness(+)
age	N=10 58.3±4.2	N=25 60.0±3.4	N=4 60.8±2.9	N=21 59.9±3.6
[right index finger]				
skin temperature (°C)	32.3±1.1	33.0±1.3	33.6±1,5	32.1±1.2
warm threshold (°C)	36.1±2.5	44.7±3.5**	43.7±3.6**	44.8±3.6**
cold threshold (°C)	27.2±4.0	18.2±7.2**	22.7±7.2	17.4±7.0**
warm t. - skin t. (°C)	3.8±2.4	11.6±3.2**	10.1±3.7*	11.9±3.l**
cold t. - skin t. (°C)	5.2±4.1	14.8±7.2**	10.9±6.5	15.5±7.2**
warm t. - cold t. (°C)	8.9±5.4	26.4±9.6**	21.0±10.1*	27.5±9.4**
vibration t. (dB)	3.8±4.3	23.5±8.4**	18.1±3.8**	24.5±8.8**
pain t. (above 5g)	3(30%)	20(80%)	2(50%)	18(86%)
[left index finger]				
skin temperature (°C)	32.6±0.9	33.0±1.3	33.4±1.1	31.6±1.7
warm threshold (°C)	35.9±1.9	44.9±3.6**	44.5±3.2**	44.9±3.8**
cold threshold(°C)	28.6±3.3	18.3±7.2**	21.2±5.5*	17.7±7.5**
warm t.- skin t. (°C)	3.3±1.7	11.8±3.3**	11.1±3.2**	12.0±3.3**
cold t. - skin t. (°C)	4.1±3.3	14.8±7.7**	12.2±5.4*	15.3±8.0**
warm t. - cold t. (°C)	7.3±3.6	26.6±10.3**	23.3±8.5**	27.2±10.7**
vibration t. (dB)	3.0±3.7	24.0±8.3**	20.6±5.2**	24.6±8.8**
pain t. (above 5g)	3(30%)	19(76%)	2(50%)	17(81%)

*<0.01, **<0.001 (t-test)

Evaluation of threshold of vibratory sensation by cold provocation test for diagnosis of vibration syndrome

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Introduction

Since acceleration levels of vibrating tools have decreased, peripheral circulatory and sensory disturbances in response to long-term exposure to lower hand-arm vibration level should be re-evaluated. We have evaluated finger skin temperature by cold provocation test (10°C 10 minutes method) for the diagnosis of vibration induced white finger (1). In this report, we evaluated threshold of vibratory sensation for the diagnosis of vibration syndrome.

Subjects and Methods

Subjects were male chain saw workers who took special medical examinations on vibration syndrome between 1986 and 1995 and public service workers in Wakayama Prefecture who took special medical examinations on vibration syndrome in 1996.

The subjects were limited to those in the 40-69 year age group in this report. The subjects were classified into 3 groups. If a subject had numbness on either hand, he was assigned to the Numbness (N) group (n=462). A subject who had no symptoms of a white finger and numbness on either hand, was assigned to the No-Symptoms (NS) group (n=217). A subject who did not operate any vibrating tools among the public service workers, was assigned to the Control (C) group (n=40).

The primary medical examination and the secondary medical examination were made on the basis of the notifications of Japanese Ministry of Labour (2). The cold provocation test was conducted with 10°C water immersion for 10 minutes. The room temperature was set at 20-24? The threshold of vibratory sensation at the palmar distal phalanx of the 2nd finger was measured using a vibration sensation meter (Rion, AU-02) at 4 point of the cold provocation test; before, immediately after, 5 minutes after and 10 minutes after a cold provocation test.

The screening points for screening N group from the combined group of NS and C group were obtained from receiver operating characteristic (ROC) curves, which show the accuracy of screening (3). A point of the left top on the ROC curve, so called the cut off point, gives the lowest false positive rate and the highest sensitivity. The point was used as a screening point in this report.

Results

The mean values of threshold of vibratory sensation before and after a cold provocation are shown in Table 1. The mean values in N group were significantly higher than those in NS and C group. Those in NS group was also significantly higher than that in C group.

Table 1. Mean values of threshold of vibratory sensation in each group before and after a cold provocation

Threshold of vibratory sensation (dB)	N group	NS group	C group
Before	12.9*¤	6.5*	-0.2
Immediately after	29.5*¤	23.4*	17.8
5 minutes after	25.3*¤	17.5*	9.4
10 minutes after	22.3*¤	14.4*	5.5

*Significant difference compared with C group $p<0.01$
¤ Significant difference compared with NS group $p<0.01$

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Figure 1 shows the ROC curve from the threshold of vibratory sensation at 5 minutes after a cold provocation for screening N group from other groups. The screening point was 22.5 dB. The screening points of the threshold of vibratory sensation before and after a cold provocation are shown in Table 2.

The thresholds of vibratory sensation by fraction of NS group before and after a cold provocation are also shown in Table 2. The screening point before and after a cold provocation were approximately between 50th percentiles and 75th percentiles in NS group.

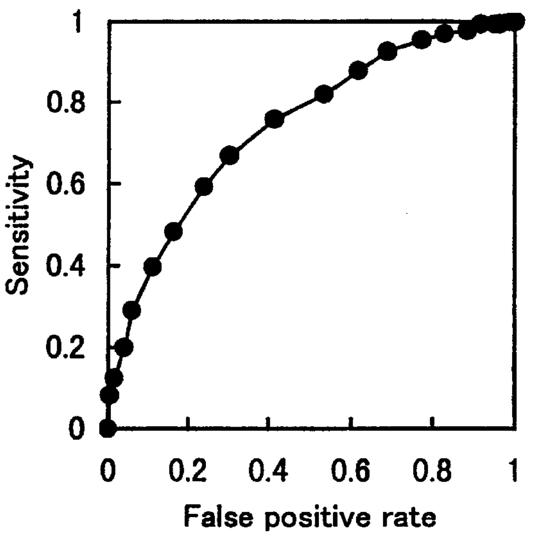

Figure 1. ROC curve from threshold of vibratory sensation at 5 minutes after a cold provocation

Table 2. Thresholds of vibratory sensation by fraction of NS group and screening points.

Threshold of vibratory sensation (dB)	L10	L25	L50	L75	L90	Screening point
Before	-2.5	2.5	5.0	12.5	15.0	7.5
Immediately after	12.5	17.5	25.0	27.5	35.0	30.0
5 minutes after	5.0	10.0	17.5	25.0	30.0	22.5
10 minutes after	0.0	7.5	15.0	21.5	27.5	20.0

Discussion

When compared with the evaluation standard of Iwata *et al.* (4), the 50th percentiles in NS group were lower than their evaluation standard. Their evaluation standard was established in 1978. Thus, in these twenty years the peripheral sensory function of chain saw workers assessed by the threshold of vibratory sensation was less affected.

The screening points were approximately between 50th percentiles and 75th percentiles in NS group. The threshold of vibratory sensation in NS group also should be taken into account to establish evaluation standard values, as well as the screening points, because NS group had a history of exposure to vibration as long as N group.

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Occupational diseases due to hand-arm vibration in the Czech Republic in the year 1997

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Introduction

Occupational diseases due to hand-arm vibration (HAV) rank among the most frequent occupational diseases in the Czech Republic. The purpose of the study was to analyze the cases of occupational diseases due to HAV diagnosed in the year 1997.

Methods

The study was based on data from the Czech Central Registry of Occupational Diseases at the National Institute of Public Health in Prague. Each case of an occupational disease due to HAV diagnosed in the year 1997 was analyzed with respect to sex, age, occupation, duration of exposure, and clinical diagnoses.

Results

In the year 1997 a total of 2,376 cases of occupational diseases were reported in the Czech Republic. Of them 459 cases (19.3%) were due to HAV.

Table 1. Cases of occupational diseases due to HAV, by sex, age, and duration of exposure.

	N	Age (years)	Duration of exposure (years)
Males	440	19-66, 46±8	0.1-44, 19.4±9.4
Females	19	23-54, 44±8	0.1-37, 16.4±10.5
Total	459	19-69, 46±8	0.1-44, 19.2±9.5

Table 2. Industry categories with the highest frequency of occupational diseases due to HAV.

Industry category	Male	Females	Total
Mining	190	0	190
Metal industry	161	11	172
Forestry	32	1	33
Car industry	27	2	29
Construction	14	2	16
Other	16	3	19

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Table 3. Occupations with the highest frequency of occupational diseases due to HAV.

Occupation	Male s	Females	Total
Miners	178	0	178
Metalworkers	60	0	60
Smelters	54	0	54
Sawing machine operators	33	0	33
Bricklayers	32	0	32
Assembly workers	17	6	23
Cutters	13	8	21
Welders	16	0	16
Construction workers	14	0	14
Other	23	5	28

Table 4. Occupational diseases due to HAV, by lesions of vascular, nervous or skeletal system.

	VWF	Nerve lesions	Bone or joint lesions	Total
VWF	60	11	2	73
Nerve lesions	11	302	14	327
Bone or joint lesions	2	14	70	86

Discussion and conclusions

With their proportion of 19.3%, diseases due to HAV represented the most numerous category of all occupational diseases diagnosed in the Czech Republic in the year 1997.

The proportion of females was only 4%. This corresponds to the fact that occupations with risk of HAV are performed mostly by males. The females with an occupational disease due to HAV were on the average 2 years younger than males and the average duration of exposure in females was 3 years shorter than in males. Although the differences did not reach statistical significance, they can be considered as biologically plausible with respect to the supposed higher susceptibility of females to HAV.

Most cases of occupational diseases due to HAV were diagnosed in miners (39%) and in workers in the metal industry (13%). In forestry it was 7%.

Peripheral nerves of the upper extremities were the most frequently damaged system (in 71% of patients). Lesions of peripheral nerves were reported as an isolated finding in 66% of patients. Carpal tunnel syndrome was the most frequently made diagnosis.

Surprisingly, vibration white fingers (VWF) were observed in only 16% of patients (in 13% of patients as an isolated diagnosis and in 3% of patients in combination with a lesion of another system).

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