HAND-ARM VIBRATION
14TH INTERNATIONAL CONFERENCE
21 – 24 MAY 2019 BONN, GERMANY

14th International Conference on Hand-Arm Vibration

21-24 May 2019
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– Abstracts –

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Contents

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The 14th International Conference on Hand-Arm Vibration is organized under the patronage of

- International Commission on Occupational Health (ICOH), Scientific Committee “Vibration and noise” (SCVN)
- International Advisory Committee on Hand-Arm Vibration

The conference is hosted by the Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (IFA).

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Foreword

In May 2019, the Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (IFA) is hosting the 14th International Conference on Hand-Arm-Vibration. The event is organised every four years under the auspices of international expert bodies at changing places. It is aimed at all stakeholders in the subject, whether experts from the occupational safety and health and research communities or management personnel in the areas of manufacture and design.

Mechanized manual work is often associated with exposure to vibration that may impact adversely upon the health and well-being of the affected individuals. Besides impairments to comfort and performance, harm to the hand-arm system, possibly permanent, must be prevented as a matter of priority.

In a world of work that is becoming more and more complex, combined exposures are also becoming increasingly relevant. What influence does hand-arm vibration have in conjunction with noise or whole-body vibration? What contribution can be made by medicine, diagnostics, epidemiology, measurement technology and prevention to the identification and containment of risks, and better still, to their elimination? What is the role of international regulatory activity in this context?

The 14th International Conference on Hand-Arm Vibration aims to address these and many other questions concerning hand-arm vibration, and to find answers relevant to the field.

We thank all participants who contributed to the success of the conference.

Uwe Kaulbars
Ren G. Dong

Programme

Tuesday, 21st May 2019

Start	Title, Chair/Speaker
08:30 am	Registration
10:00 am	Welcome Chair Organizing Committee *Uwe Kaulbars, IFA, Germany*
	Welcome by hosting institute *Dietmar Reinert, IFA, Germany*
	Welcome by Advisory Committee *Ren G. Dong, NIOSH, USA*
	Welcome ICOH *Enrico Marchetti, INAIL, Italy*

Clinical and epidemiological risk assessment I
Chairs: Elke Ochsmann, Universität Lübeck, Germany; Yi Sun, IFA, Germany

10:40 am	**Keynote:** Medical risks due to exposure to vibration *Kazuhisa Miyashita, Wakayama Medical University, Japan*
11:20 am	Epidemiological validation of ISO/TR 18570 methodology for predicting the risk of vibration induced white finger *Massimo Bovenzi, University of Trieste, Italy*
11:40 am	The vibration-induced arterial wall shear stress: a potential groundwork for a new vascular filter? *Christophe Noël, INRS, France*
12:00 pm	Lunch break

Clinical and epidemiological risk assessment II
Chairs: Setsuo Maeda, Reactec and Nottingham Trent University, United Kingdom;
Massimo Bovenzi, University of Trieste, Italy

02:00 pm	Tools of the trade and associated health risks – railway maintenance-of-way workers *Eckardt Johanning, Johanning MD PC, USA*
02:20 pm	Association between myosin light chain 2 (MLC_2) and vascular injury induced from hand-transmitted vibration exposure *Qingsong Chen, Guangdong Pharmaceutical University, China*
02:40 pm	Symptoms and clinical signs among carpenters compared to painters *Eva Tekavec, Lund University, Sweden*
03:00 pm	Risk assessment of musculoskeletal disorders among workers exposed to hand-arm-vibration: design, exposure assessment methods and first results of an epidemiological case-control study *Yi Sun, IFA, Germany*
03:20 pm	Coffee break, product exhibition and poster presentation

Poster topic: Pathophysiology

	Identification of low molecular organic compounds in serum of vibration exposed workers *Per Vihlborg, Örebro University Hospital, Sweden*
	Blood biomarkers for vibration induced white fingers *Kåre Eriksson, Umeå University, Sweden*
	Role of 5-HT1B-receptor in activation of ERK pathway on vascular smooth muscle cells *Maosheng Yan, Guangdong Province Hospital for Occupational Disease Prevention and Treatment, China*

Start	Title, Chair/Speaker

Poster topic: Clinical cases, risk assessment and diagnostic test

	Penile Raynaud's phenomenon in workers exposed to hand-arm vibration: case report and literature review *Alice Turcot, Institut national de santé publique du Québec, Canada*
	Shock and vibration issues in professional sports *Thomas Jetzer, occupational medicine consultants, USA*
	Vibration induced injuries in hands in long-term vibration exposed workers *Lars Gerhardsson, University of Gothenburg, Sweden*
	Assessing the sensorineural component of the hand-arm vibration syndrome (HAVS): Sensitivity and specificity of standardized tests *Ying Ye, University of Southampton, United Kingdom*
	Diagnostic value of high-frequency ultrasonography in testing carpal canal structure in patients with occupational hand-arm vibration disease *Lihua He, Peking University Health Science Center, China*

Clinical and epidemiological risk assessment III
Chairs: Anthony Brammer, University of Connecticut, USA; Tohr Nilsson, Umeå University, Sweden

04:20 pm	Raynaud's phenomenon and cold sensitivity in Northern Sweden – the impact of hand-arm vibration *Albin Stjernbrandt, Umea University, Sweden*
04:40 pm	Dose-response relationships and factors influencing the occurrence of the hand-arm vibration syndrome associated with the grinding of handheld workpieces in a subtropical environment *Qingsong Chen, Guangdong Pharmaceutical University, China*
05:00 pm	Shoulder disorders among workers exposed to hand-arm vibration: A review of literature *Alice Turcot, Institut national de santé publique du Québec, Canada*
05:20 pm	A sentinel health investigation of carpal tunnel syndrome (CTS) in a railway maintenance-of-way worker – International comparison of HAV emission information for hand-tools *Eckardt Johanning, Johanning MD PC, USA*
05:40 pm	End of conference day
06:00 pm	Welcome reception

Wednesday, 22nd May 2019

Outcome measurement and diagnostic test
Chairs: Xing Gao, Capital Medical University, China; Tohr Nilsson, Umeå University, Sweden

08:30 am	Assessing the vascular component of the hand-arm vibration syndrome (HAVS): Sensitivity and specificity of standardized tests *Ying Ye, University of Southampton, United Kingdom*
08:50 am	Cold water immersion test (10°C,10 min) for diagnosing vibration-induced white finger among a group of polishers in a subtropical environment *Bin Xiao, Guangdong Province Hospital for Occupational Disease Prevention and Treatment, China*
09:10 am	Sensory perception testing using monofilaments in workers with HAVS and controls *Jon Poole, HSE, United Kingdom*
09:30 am	Coffee break and exhibition

Start	Title, Chair/Speaker

Technical measures to reduce vibration
Chairs: Ren G. Dong, NIOSH, USA; Gérard Fleury, INRS, France

10:00 am	**Keynote:** Vibration risk assessmant – evaluation of exposure to vibrationcontrol and measurement strategies *Paul Pitts, HSE, United Kingdom*
10:40 am	Vibration reduction on reciprocating tools *Snævar Leó Grétarsson, RISE IVF, Sweden*
11:00 am	A comparison of three bucking bar handles: vibration measured at the tool interface and transmitted to the hand, forearm and shoulder *Peter Johnson, University of Washington, USA*
11:20 am	Testing, on-site pilot trial and assessment of the Bio-Inspired Anti-Vibration Exoskeleton (BIAVE) *Xingjian Jing, Hong Kong Polytechnic University, China*
11:40 am	The effects of exoskeleton vests on hand-transmitted vibration *Thomas W. McDowell, CDC/NIOSH, USA*
12:00 pm	Lunch break and exhibition

Experimental and numeric hand-arm designs and simulation
Chairs: Christian Freitag, IFA, Germany; Hans Lindell, RISE IVF, Sweden

02:00 pm	Numerical modelling of vibration emitted by pneumatic chipping hammers *Gérard Fleury, INRS, France*
02:20 pm	Modeling analyses of the vibration response characteristics of a handheld workpiece in grinding process *Ren G. Dong, NIOSH, USA*
02:40 pm	The rotational mechanical impedance of the hand-arm system – A preliminary study *Andreas Lindenmann, Karlsruher Institut für Technologie (KIT), Germany*
03:00 pm	Biodynamic responses at the fingers and at the palm of the human hand-arm system under different vibration sources *Massimo Cavacece, University of Cassino, Italy*
03:20 pm	Coffee break, product exhibition and poster presentation

Poster topic: Measuring methods and measuring devices, dosimeter

Hand-arm vibration exposure on a test track ride conforming to DIN EN 13059
Christian Freitag, IFA, Germany

Risk assessment for bone and joint diseases by working with motor chain saws
Frank Koch, Landesamt für Arbeitsschutz, Verbraucherschutz und Gesundheit Brandenburg, Germany

Vibration exposure during sausage production – vibration caused by fingers interacting with rotating contact surface
Manfred Söntgen, IFA, Germany

Measurements of exposure to single shocks in firearms testing
Uwe Kaulbars, IFA, Germany

Dosimeter for detecting hand-arm vibration in a laboratory comparison with standard-compliant measurements
Christian Böser, IFA, Germany

Jobs with single shock exposures – an explorative approach
Elke Ochsmann, Universität Lübeck, Germany

Start	Title, Chair/Speaker
	Determination of hand-arm vibration exposure caused by single shocks taking the example of golf as a leisure activity *Fabian Haas, IFA, Germany*
	Testing of new self-measuring power tools that supply the user directly with information on his daily dose *Benjamin Ernst, IFA, Germany*
	Knowledge for performing and evaluation of measurements on human exposure to mechanical vibration (DIN SPEC 45674) *Ulrich Schober, DIN Deutsches Institut für Normung e. V., Germany*
	A study on influencing parameters in measuring hand-arm vibrations applying the international standard *Magdalena Scholz, Technical University of Munich, Germany*
	The impact of contact force on the accuracy of hand-arm-vibration measurement *Eugen Reinelt, Svantelk Deutschland GmbH*
	Tightening tool vibration emissions *Romain Haettel, Atlas Copco Industrial Technique AB, Sweden*
	HAV in motocross: exposure and effects of handlebar characteristics *Marco Tarabini, Polytecnico di Milano, Italy*

Measuring methods and measuring devices, dosimeter – I
Chairs: Paul Pitts, HSE, United Kingdom; Pierre Marcotte, IRSST, Canada

04:40 pm	Measurement of hand contact force on an elastic hand-handle interface *Yumeng Yao, Concordia University, China*
05:00 pm	Hand-arm vibration estimation using a commercial smartwatch *Marian Haescher, Fraunhofer Institute for Computer Graphics Research IGD, Germany*
05:20 pm	Is real-time monitoring effective as a control measure to prevent Hand Arm Vibration Syndrome *Jacqui McLaughlin, Reactec Ltd, United Kingdom*
05:40 pm	End of conference day

Thursday, 23rd May 2019

Measuring methods and measuring devices, dosimeter – II
Chairs: Paul Pitts, HSE, United Kingdom; Antony Brammer, University of Connecticut, USA

08:30 am	Isolated shock events acting upon the hand-arm system – A proposal for a definition *Thomas Schenk, KSZ Ingenieurbüro GmbH, Germany*
08:50 am	Risk for VWF is underestimated in assembly industry using impact tools *Hans Lindell, RISE IVF, Sweden*
09:10 am	Measurement of the exposure of medical personnel to individual impacts during shockwave therapy *Nastaran Raffler, IFA, Germany*

Personal protective equipment, anti-vibration gloves – I
Chairs: Peter Johnson, University of Washington, USA; Douglas Reynolds, University of Nevada, USA

09:30 am	Effect of shelf aging on vibration transmissibility of anti-vibration gloves *Nobuyuki Shibata, National Institute of Occupational Safety and Health, Japan*
09:50 am	Anti-vibration gloves certification: does the laboratory represent what happens in field? *Enrico Marchetti, INAIL, Italy*
10:10 am	Coffee break and poster presentation

Start	Title, Chair/Speaker

Poster topic: Prevention methods and strategies, databases, evaluation of exposure to vibration

	Database KarLA *Detlev Mohr, Landesamt für Arbeitsschutz, Verbraucherschutz und Gesundheit Brandenburg, Germany*
	A new, user friendly design of the Swedish national vibration database to be used for preventive work *Hans Pettersson, Umeå University, Sweden*
	A safety factor for the vibration generated for tools in the construction of hydroelectric project in Costa Rica *Francisco Paniagua, Safety engineer, Costa Rica*
	Bringing together machine weight, hand-arm vibration and noise health risk information in the UK rail industry *Paul Pitts, HSE, United Kingdom*
	Zero vibration injuries by introduction of machines with low vibrations *Eva Troell, RISE IVF, Sweden*
	Strategies for occupational safety and health to prevent the effects of the exposure to hand-arm vibration *Massimo Cavacece, University of Cassino, Italy*
	Hand-transmitted vibration assessment on the human as an indicator of health risk *Leif Anderson, Reactec Ltd, United Kingdom*
	The agreement between subjective and objective estimations of exposure duration among carpenters exposed to hand-arm vibrations *Karin Fisk, Lund University, Sweden*

Personal protective equipment, anti-vibration gloves – II
Chairs: Peter Johnson, University of Washington, USA; Douglas Reynolds, University of Nevada, USA

11:00 am	Correlation between finger dexterity and vibration transmissibility while wearing anti-vibration gloves *Pierre Marcotte, IRSST, Canada*
11:20 am	An evaluation of experimental methods for measuring the vibration transmissibility of vibration-reducing gloves at or on the fingers *Ren G. Dong, NIOSH, USA*
11:40 am	Evaluating the effectiveness of vibration-reducing gloves for attenuating finger vibration from angle grinders *Josefin Blidberg, Y. Berger & co AB / Eureka safety, Sweden*
12:00 pm	Lunch break
02:30 pm	Ship tour on the Rhine
07:00 pm	Conference dinner at Collegium Leoninum

Friday, 24th May 2019

National and international legislation and guidelines
Chairs: Christoph Hecker, Berufsgenossenschaft Holz und Metall (BGHM), Germany; Detlev Mohr, Landesamt für Arbeitsschutz, Verbraucherschutz und Gesundheit Brandenburg, Germany

09:00 am	**Keynote:** Developments in EU occupational safety and health legislation protecting workers from risks of vibration *Jan-Willem Ebeling, European Commission – DG Employment, Social Affairs and Equal Opportunities, Luxemburg*

Start	Title, Chair/Speaker
09:40 am	Predicting the occurrence of vibration-induced white finger using ISO Technical Report 18570-2017 *Anthony Brammer, University of Connecticut, USA*
10:00 am	International consensus criteria for diagnosing and staging hand-arm vibration syndrome *Jon Poole, HSE, United Kingdom*
10:20 am	Coffee break
10:50 am	Requirements for PPE in the European Union *Martin Liedtke, IFA, Germany*
11:10 am	Encouraging the use of vibration efficient tools – a regulatory perspective *Paul Delderfield, HSE, United Kingdom*
11:30 am	Methods for estimating vibration exposure without measurement *Christoph Noel, INRS, France*
11:50 am	Can we prevent HAVs by using declared vibration emission value? *Setsuo Maeda, Reactec and Nottingham Trent University, Great Britain*
12:10 pm	Closing
	Presentation Taylor Award *Ren G. Dong, NIOSH, USA*
	Invitation to 15th Conference 2023
	Closing remarks *Christoph Hecker, BGHM, Germany*
12:30 pm	Lunch break
02:00 pm	IFA Visit

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– Abstracts –

Authors are exclusively liable for the content of their abstracts.

Medical risks due to exposure to vibration

Kazuhisa Miyashita[a, b], Shigeki Takemura[b], Setsuo Maeda[c]

[a] President, Wakayama Medical University, [b] Department of Hygiene, School of Medicine, Wakayama Medical University, [c] Department of Applied Sociology, Faculty of Applied Sociology, Kindai University

Abstract

Hand-arm vibration syndrome (HAVS) is an occupational disease among operators of vibrating tools. Risk factors for HAVS are exposure to hand-arm vibration (HAV) and exposure to the cold environment. Countermeasures to reduce the risks for HAVS should be taken. In the tropical environment, HAVS with Raynaud's phenomenon was not observed. Insufficient work practice management nevertheless could progress symptoms of HAVS. To avoid excessive HAV and to improve work practice management, some simple devices to measure workers' exposure to HAV at the worksite are being developed.

Keywords:

Hand-arm vibration syndrome (HAVS); Raynaud's phenomenon; occupational health; tropical environment

1. Hand-arm vibration syndrome (HAVS): still an occupational health problem?

Hand-arm vibration syndrome (HAVS, vibration-induced white finger, or vibration disorder) became recognized as an occupational disease after the mass production of chain saws and other vibrating tools in Europe in the 1920s, then widely spread over the industrialized countries in the world.

In Japan, the number of newly compensated cases with HAVS rapidly increased in the 1970s, reached a peak over 2500 cases in 1978, and gradually decreased. In recent years, the number fluctuates from 300 to 400 cases (Figure 1). Although the prevalence and severity of Raynaud's phenomenon has been improving in general, severe HAVS with Raynaud's phenomenon is still present. HAVS is still an important occupational health problem not only in Japan but also in the rest of the world.

2. What is HAVS?

HAVS features three kinds of symptoms as follows:

1. vascular: finger blanching (Raynaud's phenomenon) and finger coldness;
2. neurological: pain, dysesthesia, paresthesia, tingling and numbness, and
3. musculoskeletal: pain, loss of muscle power and manual dexterity, and deformity of bones and joints.

Risk factors of HAVS are exposure to hand-arm vibration (HAV) and exposure to the cold environment. The former consists of factors such as type of vibrating tools, vibration magnitude of tools and operating frequency (time per day, days per year, operating year, etc.). The latter consists of factors such as climate, season, temperature and worksite (outdoor or indoor). To prevent HAVS, these factors should be minimized as much as possible.

One of the most characteristic vascular symptoms is Raynaud's phenomenon at the worksite or at the clinic in winter or cold seasons. It is diagnosed with the Stockholm Workshop scale [1]. To evaluate HAVS, a batch of tests are provided: finger skin temperature and nail press test (nail capillary refill test) for vascular symptoms, vibrotactile perception threshold and pain perception test for neurological symptoms, and grip force, pinch force and finger tapping test for musculoskeletal symptoms.

For further evaluation, cold provocation tests are conducted. Details of test conditions are shown in ISO 14835-1 (finger skin temperature) [2] and 14835-2 (finger systolic blood pressure) [3]. Miyashita served as convenor of a working group in the International Organization for Standardization (ISO/TC 108/SC 4/WG 17) to revise ISO 14835-1 in 2016, allowing a variety of study conditions of cold provocation tests (5 min at 12℃, 2 min at 12℃, 5 min at 15℃ and 10 min at 10℃).

Advanced HAVS is often refractory. Therefore, it is important to detect HAVS early in annual health examinations and prevent it by improving the work environment (avoidance to exposure to cold) and the work practice (reduction of exposure to HAV) in response to the result of examinations. The Ministry of Health, Labour and Welfare of Japan demands that the operating time of vibrating tools in a working day should be limited to 2 hours in principle.

3. HAVS in the tropical environment

Exposure to cold is a very important causing factor of HAVS. Most cases of HAVS are reported from the temperate or subarctic zones in the world.

We investigated HAVS of forestry workers using chain saws in Borneo Island, Malaysia [4, 5]. The findings of the study suggested that sensory function deterioration among operators of vibrating tools in the tropical climate environment can occur earlier and become worse than in workers in the temperate climate environment despite a shorter duration of vibration exposure. This could be attributed to the working environment, such as more frequent exposure to vibration, a higher vibration level and lack of control measures in hand-transmitted vibration exposure, especially in developing countries such as Malaysia. Despite deterioration in the sensory function of the hands, the workers tended to have fewer complaints about the symptoms, probably attributable to the absence of a Raynaud's phenomenon attack and provocative factors such as winter seasons.

The dose–response relationship between the hand-transmitted vibration and the HAVS in the tropical environment can be expressed in terms of the neurological outcomes. The severity of the finger tingling, numbness and dysesthesia, and vibrotactile perception threshold was directly related to the vibration exposure dose in a tropical environment.

4. Current topics of prevention for HAVS

How can we prevent the occurrence of HAVS in the world?

EU Directive 2002/44/EC of the Physical Agent Directive (Vibration) demands that employers should take the following measures to prevent HAVS among their employees: (1) select tools with the lowest vibration magnitude, (2) control the operating time of vibration tools for reducing HAVS, and (3) check the vibration magnitude for each worker at the worksite. Among them, (1) is basically important and (2) and (3) are more important, which need to be checked easily and simultaneously.

In Japan, a simple measurement device for HAV at the handle has been developed [6]. This device is designed easily to assess the vibration magnitude of tools at the worksite. The vibration magnitude measured at the tool handle are transferred to the host computer by mobile-phone and the allowable operating time is calculated on the basis of the daily exposure magnitude normalized to an eight-hour reference period A(8). Then the allowable operating time is informed to the worker via mobile phone at the worksite. In practice, it is very effective to control the operating time as well as vibration magnitude at the worksite simultaneously.

In more recent studies [7], a wearable personal HAV exposure monitor is being developed. This monitor measures HAV exposure in the wrist continuously, calculates the cumulative HAV dose in a working day, and shows allowable operating time in that day. That is more practical than the above-mentioned model. It is currently discussed in ISO/TC 108/WG 33.

Conclusion

HAVS is a preventable occupational disease with countermeasures to reduce the risks for HAVS.

References

[1] Gemne G, Pyykkö I, Taylor W, Pelmear PL. The Stockholm Workshop scale for the classification of cold-induced Raynaud's phenomenon in the hand-arm vibration syndrome (revision of the Taylor-Pelmear scale). Scand J Work Environ Health. 1987;13(4):275-8.

[2] International Organization for Standardization (ISO). Mechanical vibration and shock---Cold provocation tests for the assessment of peripheral vascular function, Part 1: Measurement and evaluation of finger skin temperature (ISO 14835-1). Second Edition. 2016.

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[7] Maeda S, McLaughlin J, Anderson L, Buckingham M-P. Necessity of wearable personal vibration exposure meters for preventing hand-arm vibration syndrome. Proceedings of the 25th Japan Conference on Human Response to Vibration (JCHRV2017); 13-15 September 2017; Nagoya, Japan, p. 45-58.

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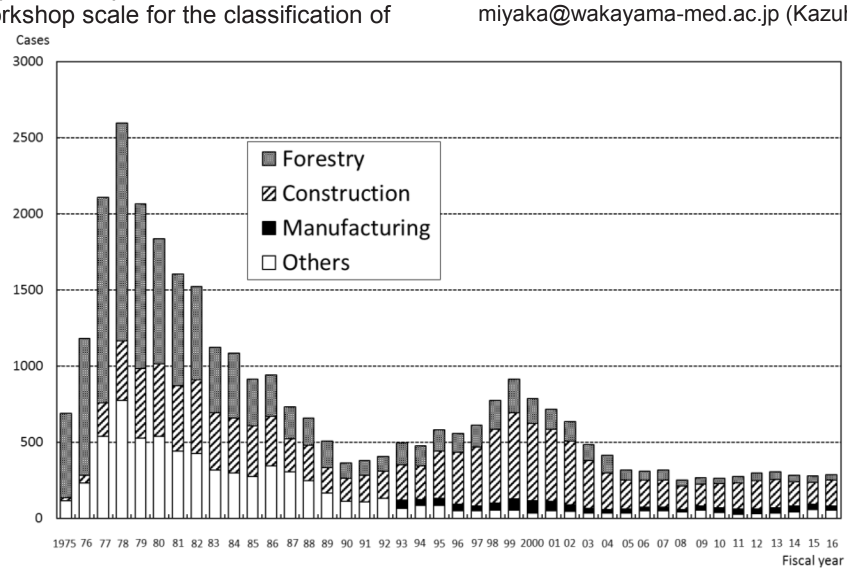

Figure 1: Newly compensated cases of hand-arm vibration syndrome in fiscal years 1975-2016 (Ministry of Health, Labour and Welfare, Japan). Cases in manufacturing were merged into others until fiscal year 1992.

Epidemiological validation of ISO/TR 18570 methodology for predicting the risk of vibration induced white finger

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[b]Physical Agents – Public Health Lab, Local Health Authority Toscana Sud Est, NHS, Siena, Italy
[c]Department of Physical Sciences, Earth and Environment, University of Siena, Siena, Italy

Abstract

In the Italian cohort of the EU VIBRISKS research project, a measure of daily vibration exposure constructed with the vascular weighting W_p according to ISO/TR 18570:2017 performed better for the prediction of VWF than that obtained with the frequency weighting W_h recommended in ISO 5349-1:2001.

Keywords:

Frequency weightings; VWF

Introduction

Annex C to international standard ISO 5349-1 suggests an exposure-response relationship for vibration-induced disorders based on a frequency weighting of hand-transmitted vibration which is said to apply to all biological effects of vibration [1]. Actually, the ISO risk model is based solely on epidemiological studies of the prevalence of the vascular component of the hand-arm vibration syndrome (HAVS), known as vibration-induced white finger (VWF), in groups of workers exposed to tool vibration with selected magnitudes and durations. Over the past decades, several epidemiological studies have reported a poor agreement between the observed occurrence of VWF and that predicted by the ISO standard [2]: (i) overestimation of VWF risk has been observed in worker groups exposed to high magnitudes of low frequency vibration, e.g. from percussive tools; (ii) underestimation of VWF risk has been reported in workers operating tools which generate vibration with middle-high frequency components, e.g. from chain saws, grinders or riveters.These discrepancies have been attributed, at least partially, to the methods of measurement, evaluation and assessment of occupational exposures to hand-transmitted vibration established in ISO 5349-1. Since the response of the human hand and arm to vibration is frequency dependent, the ISO standard recommends to weigh the root-mean-square (r.m.s.) acceleration magnitude of vibratory tools by means of a frequency weighting (called W_h) which assumes that the sensitivity of the finger-hand-arm system to vibration is approximately proportional to vibration acceleration below 16 Hz, and decreases in inverse proportion to frequency from 16 to 1250 Hz. This means that low frequency vibration is believed more important for the adverse health effects than intermediate and high frequency vibration. Upon consideration of recent findings of biodynamic studies, psychophysical and physiological investigations in humans and experimental animals, and epidemiological surveys of VWF occurrence in vibration exposed workers, an ISO Technical Report (ISO/TR 18570:2017) has been prepared in which a new form of frequency weighting for hand-transmitted vibration (called W_p) and a supplementary method for improving the assessment of the risk of vibration-induced vascular disorders are proposed [3]. Compared to the ISO frequency weighting W_h, the hand-arm vascular weighting W_p gives more weight to intermediate and high frequency vibration (Figure 1). The aims of this study were: (i) to investigate if there is epidemiological evidence which can support the supplementary metrics of daily vibration exposure for vascular disorders as defined in ISO/TR 18570:2017; (ii) to compare the relative performance of the vibration metrics constructed with the frequency weighting W_h or the frequency weighting W_p to predict the risk of VWF in a cohort of vibration exposed forestry and stone workers recruited in the Italian arm of the EU research project VIBRISKS [2].

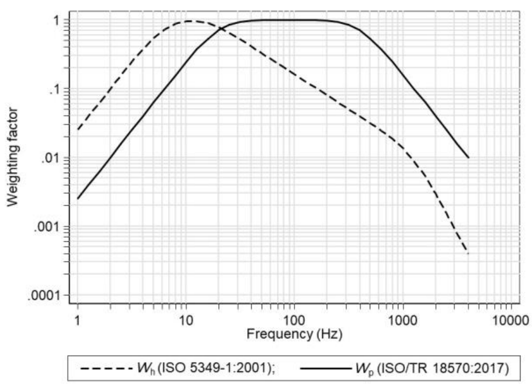

Figure 1: Comparison of frequency weighting functions for hand-transmitted vibration.

Methods

The study design and the description of the cohort have been reported in a previous paper [2]. The study population included 249 vibration exposed workers (215 forestry operators and 34 stone workers). They were investigated at the cross-sectional survey and annually over a 4-yr follow-up period. The diagnosis of VWF was based on a reliable history of symptoms of white finger according to the minimal requisites established at the Stockholm Worshop '94, assisted by colour photographs and supported by abnormal findings at a cold test with measurement of finger systolic blood pressure ($\%FSBP_{10°} < 70\%$). Daily vibration exposure was expressed in terms of r.m.s. acceleration magnitude normalised to an 8-hour day ($A(8)$), frequency weighted according to W_h or W_p (W_f):

$$A(8)_{(W_f)} = \sqrt{\sum_{i=1}^{n} a_{vi(W_f)}^2 \frac{T_i}{T_0}} \qquad (ms^{-2}\ r.m.s.)$$

where a_v is the vibration total value of the r.m.s. acceleration of tool i, T_i is the duration of the i^{th} operation with tool i in hours, and T_0 is the reference period of 8 hours.

To estimate a threshold value for vascular hand-arm vibration risk, ISO/TR 18570 recommends to calculate the W_p weighted vibration exposure value over a working day ($E_{p,d}$ in $ms^{-1.5}$):

$$E_{p,d} = \sqrt{\sum_{i=1}^{n} (a_{pvi})^2\, T_i} \qquad (ms^{-1.5})$$

where a_{pvi} is the r.m.s. vibration total value of the hand-transmitted vibration for the i^{th} operation with tool i, frequency-weighted according to the hand-arm vascular weighting W_p, and T_i is the duration of the i^{th} operation expressed in seconds.

The relation of VWF to alternative measures of daily vibration exposure, adjusted by confounders, was estimated by means of the GEE method using a logit link function. The fit of the models including either $A_h(8)$ or $A_p(8)$ was assessed by the Quasi-likelihood Information Criterion (QIC) statistic: the lower the QIC value, the better the goodness-of-fit of the model.

Results

The prevalences of VWF over the study period were 7.4 and 47.1% in the forestry operators and the stone workers, respectively. Both $A_h(8)$ and $A_p(8)$ were significantly associated with the occurrence of VWF (Table 1). The QIC statistic suggested a better fit when $A_p(8)$ rather than $A_h(8)$ was included in the models as a predictor of VWF (ΔQIC: 23). As a result, models including $A_p(8)$ performed better than those with $A_h(8)$ for the prediction of VWF, mainly in the stone workers (Table 2).

Table 1: Odds ratios (OR) and robust 95% CI for the association between VWF and alternative measures of daily vibration exposure expressed as either $A_h(8)$ or $A_p(8)$. The Quasi-likelihood Information Criterion (QIC) for the comparison between models is also shown.

Factors	$A_h(8)$ (×1 ms^{-2})	$A_p(8)$ (×10 ms^{-2})
	OR (95% CI)	OR (95% CI)
$A_f(8)$ (ms^{-2})	1.38 (1.26-1.52)	1.41 (1.26-1.58)
Exp duration (y)	1.04 (0.99-1.10)	1.04 (0.99-1.11)
Age (×10 y)	1.59 (0.90-2.81)	1.79 (0.96-3.34)
Smoking (n/y)	1.90 (0.81-4.47)	2.10 (0.87-5.08)
QIC	558	535
ΔQIC	23	

In an informative annex to ISO/TR 18570 [3], it is said that the daily exposure threshold at which symptoms of VWF may be expected to occur may be estimated around an $E_{p,d}$ value of 1750 $ms^{-1.5}$. In this study, 32 out of 249 vibration exposed workers (12.9%) were exposed to $E_{p,d} \leq 1750$ $ms^{-1.5}$; among these workers, only one reported VWF with excessive vasoconstrictor response to cold (3.1%). After adjusting for duration of exposure, age and smoking, the predicted overall prevalence of VWF for $E_{p,d}$=1750 $ms^{-1.5}$ was 5.4%.

Table 2: Observed and predicted prevalences of VWF in the vibration exposed workers by job title and measures of daily vibration exposure expressed as either $A_h(8)$ or $A_p(8)$. The predicted prevalences of VWF are estimated by means of the models reported in Table 1.

Job title	Prevalence of VWF (%)		
	Observed	Predicted	
		$A_h(8)$	$A_p(8)$
Forestry workers (n=215)	7.4	9.5	8.1
Stone workers (n=34)	47.1	35.6	43.3

Discussion

In the Italian VIBRISKS cohort, a measure of daily vibration exposure constructed with the vascular weighting W_p according to ISO/TR 18570 [3] performed better for the prediction of VWF than that obtained with the frequency weighting W_h recommended in ISO 5349-1 [1]. The findings of this study seem to provide some epidemiological evidence for the $E_{p,d}$ threshold value for the onset of VWF suggested by ISO/TR 18570.

Conclusion

The measurement and evaluation of vibration exposure by means of the frequency weighting W_p may have some implications for the implementation and management of preventative measures at the workplace, e.g. the choice of gloves with effective antivibration properties. In our previous studies of the VIBRISKS cohort, we found no differences in the prediction of either neurosensory or musculoskeletal disorders between measures of vibration exposure calculated with either alternative frequency weightings similar to W_p or the ISO frequency weighting W_h. These findings suggest that it is unlikely that a single frequency weighting is appropriate to predict the occurrence of all components of the HAVS because different aetiological factors and different underlying pathophysiological mechanisms may be associated with the several upper limb disorders caused by hand-arm vibration.

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The vibration-induced arterial wall shear stress: a potential groundwork for a new vascular filter?

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Keywords:
Wall shear stress; pulsatile flow; ultrasound; hemodynamics

Introduction

Many physiological, histological and epidemiological studies [1] have highlighted that the vibration dose assessed according to the current ISO 5349 standard may overestimate (e.g. breakers) or underestimate (e.g. riveting tools) the onset predictions of vibration white finger (VWF) disorders. The ISO 5349 weighting is likely to be responsible of these discrepancies and therefore a new vascular filter was proposed in ISO/TR 18570 [1]. In order to get a better inclusion of vascular pathophysiological matters due to vibration, an original strategy is set up [2]. It combines the measurements of acute vibration-induced wall shear stress (WSS) and chronic stenosis related to these recurring hemodynamic disturbances. This paper is dedicated to the first stage of our mechanobiological approach: analyzing and understanding how the vibration-induced wall shear stress between the blood and endothelium is altered by the vibration parameters.

Methods

An experimental device was set up to assess the vibration-induced WSS of the left proper volar forefinger artery at the level of the distal interphalangeal joint. The apparatus (figure 1) consists of an ultra-high frequency (centre frequency: 50 MHz, bandwidth 29-71 MHz) ultrasound transducer (UHF70 from Fujifilm VisualSonics) with a 30 µm spatial resolution connected to an ultrasound imaging system (Vevo MD from Fujifilm VisualSonics). Vibration was transmitted to the entire right hand through a 40 mm-diameter handle (no mode until 1300 Hz) fixed to an electrodynamic shaker (B&K 4809) driven in acceleration by Matlab and two National Instrument cards (9263 output voltage and 9234 acquisition cards). Acceleration was measured with an accelerometer (PCB model 356A43) inserted in the handle.

The subject was laid on a stretcher and held the handle without gripping it. Vibration was a pure harmonic acceleration at 40 $m.s^{-2}$ unweigthed root mean square for the following 8 frequencies:

- 31, 63, 125, 160, 200, 250, 315 and 400 Hz

Two configurations of vibration exposure were measured (table1).

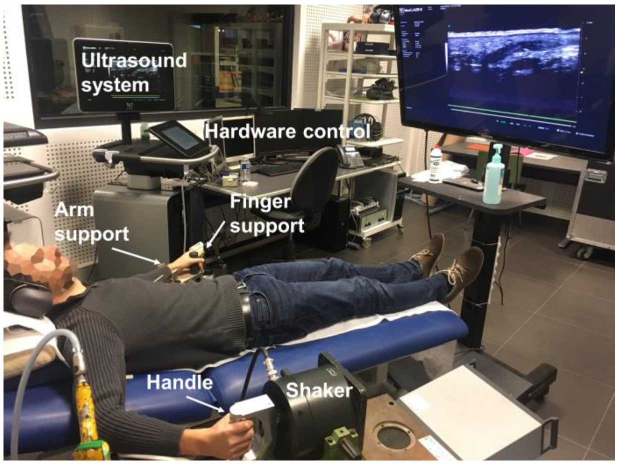

Figure 1: test setup

Table 1: configurations of vibration exposure

Exposure	Rest: No vibration	Vibration	Back to rest: No vibration
Short	10 s	10 s	10 s
Long	1 min	1 min	1 min

The WSS $\tau(t)$, t being the time, was computed from the Womersley pulsatile blood flow mathematical model which needs to know the blood velocity and artery diameter [3]. The blood flow velocity was directly measured from the Pulse-Wave Doppler mode of the ultrasound device. A robust despeckling filter was applied to B-mode images. They were post processed for extracting the diameter with the Otsu's segmentation method tuned for the digital arteries calibers and implemented to run rapidly in Matlab.

The 10 s exposure measurements were analyzed through the time-average wall shear stress $\text{WSSTA} = \frac{1}{T}\int_0^T |\tau(t)|\, dt$ computed over the period T of the cardiac cycle, whereas the 1 min configuration was studied by using a more complex time-frequency decomposition based on the Morlet wavelets.

The study protocol was reviewed and approved by the French state agency that oversees biomedical research on human subjects: the French ethical research committee (n° ID-RCB: 2018-A00614-651).

Results

The WSS was computed for one subject at rest and for a 31 and 200 Hz vibration (figure 2) for the 10 s exposure condition. The effect of the vibration frequency on the WSS was highly significant. For instance at 200 Hz it is roughly three times lower than at rest.

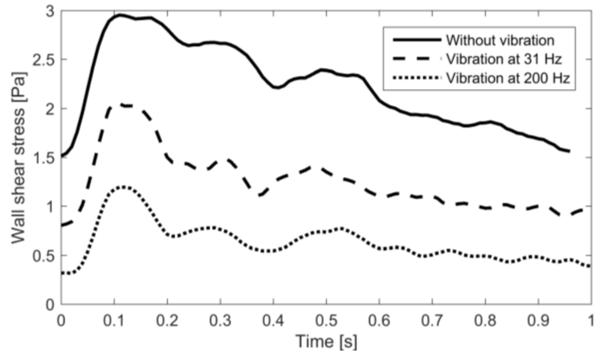

Figure 2: WSS at rest and with vibration

The frequency effect on the vascular hemodynamic factors was investigated through the ratio between WSS time-average (WSSTA) computed with and without vibration (figure 3). The WSS decreased dramatically until 160 Hz and then rose up to 315 Hz where it remained roughly at the same level.

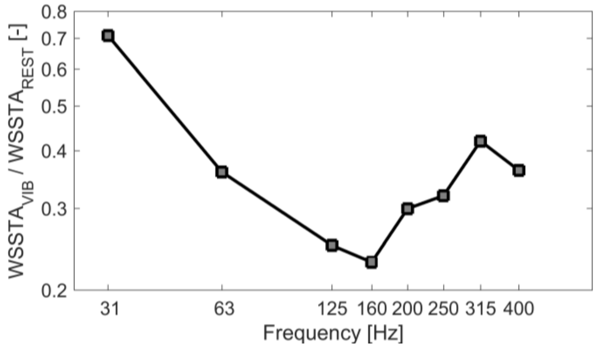

Figure 3: frequency effect on the normalized WSSTA

The wavelet power spectral density of the WSS (figure 4) was processed for the 1 min vibration exposure condition with and without vibration.

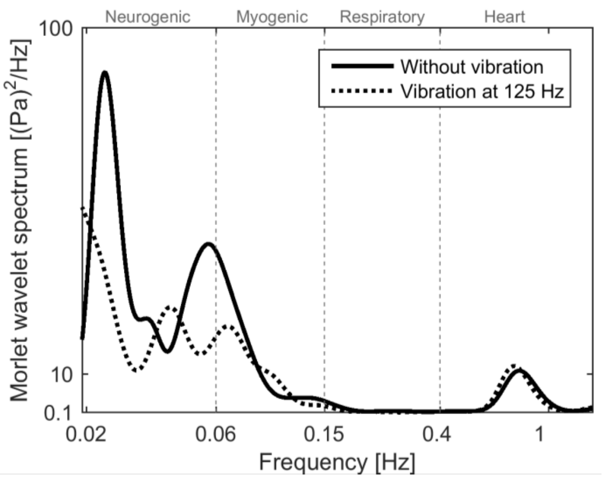

Figure 4: Morlet wavelet spectrum of the WSS

This wavelet spectrum unveiled that the higher WSS drop due to vibration occurred mostly in the frequency band [0.02 Hz-0.06 Hz]. The WSS remained nearly steady above 0.15 Hz.

Discussion

Our test bench was able to assess the WSS with suitable accuracy (figure 2):

- to highlight the pulsatile behavior due to the diasto-lo-systolic cycle generated by the heart beats
- to discriminate the vibration frequency effects on the WSS

The WSS time-average (figure 3) outlined a meaningful effect of the vibration frequency on the peripheral vascular network. The greater effects occurred between 125 Hz and 250 Hz, which matches with the spectral band where the Pacinian corpuscles get their higher sensitivity to vibration. Indeed, these corpuscles are likely to be directly involved in the sympathetic neural response leading to the vibration-induced vasoregulation imbalance.

Moreover, the wavelet power spectral density (figure 4) of the WSS emphasized that vibration altered the proper volar artery vasoregulation by involving neurogenic mechanisms. Actually, this neural response was linked to physiological cycles whose frequency ranges between 0.02 Hz and 0.06 Hz [4]. The myogenic response was also disturbed but to a lesser extent. The respiratory or heart cycles were not modified by vibration.

Conclusion

These first findings showed the potential insights to use the vibration-induced WSS as a physiological indicator of the vibration effects on the vascular network. This study will be statistically extended to a group of at least 20 subjects to confirm, detail and stabilize these primary results.

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Tools of the Trade and Associated Health Risks – Railway Maintenance-of-Way Workers

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Keywords:
Railway Trackworkers; Handarm-vibration epidemiology

Introduction

Railway maintenance-of-way (MoW) workers (trackworkers) in the USA are a sub-set of construction workers with special tasks and unique tools which have not been adequately studied [1]. We collected comprehensive information about type and use of tools that are unique to this trade and industry and studied ergonomic health hazards based on a comprehensive survey of BMWED members[1]. Vibration exposure from hand-tools is a common occurrence. The health study of ergonomic, physical, and work organization hazards systematically analyzed responses of BMWED members to questions from international standardized questionnaires and, in some cases, compared them to results from surveys of specific occupations or of all employees which had asked the same questions.

Methods

In a cross-sectional survey, ergonomic factors and musculoskeletal disorders of the upper extremeties were assessed for their association. Approximately 39,000 current and retired BMWED members were surveyed and 4,816 members responded, coming from all 48 continental states and major US railroads (response rate 12 %).The questionnaire was compiled using standardized questions from the ‘Risks of Occupational Vibration Exposures‘ questionnaire (VIBRISKS), NHIS-OHS and others [2]. MoW workers were compared to national surveys of U.S. workers and to other studies of the general population or studies of workers in physically demanding jobs that used the same questions. We adjusted for potential confounders. Poisson regression (GENLIN in SPSS v. 24) analysis was used to assess the adjusted prevalence ratio (PR) of having each of 11 selected health problems. The measures of working conditions, job titles, equipment and tools were entered into separate regression models to determine their associations with each of the 11 health outcomes. All regression analyses adjusted for age, region of the country, race/ethnicity, second job, second job potential vehicle vibration exposure and spare time potential vehicle vibration exposure.The study was approved by the SUNY Downstate Medical Center IRB

Results

MoW workers typically use a combination of hand-tools, powered-hand-tools and heavy machinery and vehicles. The most commonly used hand tools with shock exposure were: sledgehammer (n=3,999, 97.7%), spike maul (n=3,841, 94.0%), claw bar (n=3,937, 96.5%), lining bar (n=3,748, 92.0%), track wrench (n=3,574, 87.9%), spike puller (n=3,521, 87.9%). The most commonly used powered tools with vibration exposure were: rail saw (n=3,395, 84.7%), rail drill (n=3,344, 83.3%), impact wrench (n=3,190, 80.6%), tamping gun (n=3,031, 76.5%), spike driver (n=3,019, 76.9%), and impact tool (n=3,005, 77.2%). Surveyed workers reported always (8-10 hours/day) or often (4-6 hours/day) ‘standing’ (n=3,008, 77.4%),‘bothered by vehicle/equipment vibration’ (n=961, 26.7%), ‘bothered by hand tool vibration’ (n=1,022, 27.8%) and bothered by ‘noise’ (n=1,480, 39.9%). Nearly 1 in 10 members and retirees reported having been physician diagnosed with ‘carpal tunnel syndrome’ (n=370, 9.7%) and 473 (12.4%) reported having been diagnosed with ‘arthritis’. 21.6% of active BMWED members reported cold-induced blanching (whitening) attacks of their fingers in the past year. 12.5% of active BMWED members reported blanching attacks associated with a clear edge in the past year.

Average years using power tools and average years using hand-tools were both statistically significantly associated with increased risk of hand symptoms or carpal tunnel syndrome, even after taking age into account. Every 10 years use of power tools increased risk for diagnosis of carpal tunnel syndrome by 2.85 times. Significant associations between 10 years use of power tools and hand symptoms/diagnoses ranged from PR=2.31 to PR=3.59. Significant associations between 10 years use of hand-tools and hand symptoms/diagnoses ranged from PR=1.33 to PR=2.02.

Discussion & Conclusion

Years using power tools and years using hand-tools were both statistically significantly associated with increased risk of all 11 health problems we examined, after taking age and other potential confounders into account. As we hypothesized, and consistent with past research on vibration-related health effects, the increase in risk of hand symptoms/diagnoses tended to be greater for power tools than for hand-tools. Associations between specific power tools and symptoms/diagnoses tended to be larger than associations between specific hand-tools and symptoms/diagnoses. Listed vibration emissions of powered hand tools range from 6.3 m/s^2 (rail-saws) to 37-49 m/s^2

(impact wrench). Study limitations include the cross-sectional design, self-reports of both exposures and outcomes, and potential selection bias. Prevention efforts should focus on hand-tools and vibration reduction in power-tools.

Tables and Figure

Table 1: Associations of "Hand tool vibration bothers me" with Reported Diagnosis of Carpal Tunnel Syndrome among Active BMWED Men (n=2,748)

17. Hand tool vibration bothers me	Symptom %[a]	Prevalence Ratio[a]
8-10 hours/day	15.0%	**8.96** ***
4-6 hours/day	11.0%	**6.44** ***
1-2 hours/day	7.0%	**4.22** ***
<1 hour/day	3.0%	2.01
0 hours (ref.)	2.0%	1.00

[a] Prevalence ratio (PR) and symptom % adjusted for age, region, race/ethnicity, second job, second job vehicle vibration, spare time vehicle vibration using Poisson regression. Significant PRs >2 in boldface. **p<.01, ***p<.001

Table 2: Associations of "Hand tool vibration bothers me" with White Fingers from Cold or Clear Boundary Daily or Weekly among Active BMWED Men (n=2,748)

17. Hand tool vibration bothers me	Symptom %[a]	Prevalence Ratio[a]
8-10 hours/day	17.0%	**15.25** ***
4-6 hours/day	10.0%	**8.96** ***
1-2 hours/day	4.0%	**3.95** **
<1 hour/day	2.0%	1.62
0 hours (ref.)	1.0%	1.00

[a] Prevalence ratio (PR) and symptom % adjusted for age, region, race/ethnicity, second job, second job vehicle vibration, spare time vehicle vibration using Poisson regression. Significant PRs >2 in boldface. **p<.01, ***p<.001

Table 3. Comparison of musculoskeletal symptom prevalence among BMWED members to other studies

Symptom	BMWED active members, 2016-17	British male workers, 1997-8 [Palmer, 1999]
	Past year	Ever
Blanching attacks		13.0%
Cold-induced blanching attacks	21.6%	10.6%
Blanching attacks assoc. w/ clear edge	12.5%	4.1%
	Past week	Past week (lasting 3+ min)
Tingling/numbness in hand	25.0%	17.3%
Tingling/numbness in hand disturbing sleep	17.6% (incl. pain)	7.4%

Figure 1: Typical maintenance-of-way tool set (selected) of worker with Carpal Tunnel Syndrome (CTS).

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1) Study funded and supported by the Brotherhood of Maintenance of Way Employes Division (BMWED) of the International Brotherhood of Teamsters. The union represents 35,000 men and women who build, inspect, maintain and repair tracks, bridges and related railroad infrastructure throughout the United States. Any conclusions and opinions are of the authors only and do not necessarily reflect the conclusions or opinions of the BMWED.

Association between Myosin Light Chain 2 (MLC_2) and Vascular Injury Induced from Hand-Transmitted Vibration Exposure

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Introduction

The typical clinical manifestation of Hand Arm Vibration synthesis(HAVS) is vibration white finger(VWF), which is the main basis for the diagnosis and classification of HAVs. But VWF is difficult to induce, and the presence of VWF indicates that the damage of peripheral vessel has been serious. At present, there is a lack of indicators to determine the early damage of HAVs. With the occurrence and development of the peripheral vessel damage, relevant proteins or factors in blood would change. Tthe early specific related proteins as biomarkers are significant for the early detection of HAVs damage. MLC_2 is the light chain of myosin, which is found in vascular smooth muscle cells, which are also part of the cytoskeleton of some non-muscle cells[1-2]. The results of a research we did before showed the concentration of MLC in the plasma of the workers with HAVS was 1.87 times more than that in control group by iTRAQ.This study is dedicated to find whether there is any correlation between myosin light chain 2 (MLC2) and vascular injury induced from hand-transmitted vibration exposure through an epidemiological study and an laboratory investigation using an animal model.

Methods

Laboratory investigation using animal model: 32 male SD(Sprague Dawley) rats, aged 7-8 weeks old with mean mass of 211.3±11.1 g, were randomly divided into three groups: ①control group: 14 rats without vibration exposure; ②7 days vibration exposure group: 9 rats exposed to vibration continuously for 7 days; ③14d vibration exposure group: 9 rats exposed to vibration continuously for 14 days. The head and body of each rat were constrained within a retainer, and their tails were fixed on the vibration table separately with 3M breathable adhesive tape during the vibration exposure. The rats in the two exposure groups were submitted to vibration at frequency of 125Hz, amplitude of $49 m/s^2$ and one-way vertical vibration for 4 hours each day. When the exposure was finished, the rats were anesthetized. Then, the blood of each rat was collected from the abdominal aorta, and the rat's ventral mid-mural artery was dissected to make tail pathological sections and ultrathin sections for examining the pathological morphology and subcellular structures under optical and transmission electron microscopes. The Enzyme-linked immunosorbent assay (ELISA) was used to measure the expression levels of MLC_2 in the plasma of those three groups.

Occupational Epidemiology study: Three groups of workers in a large sport equipment factory in China participated in the study, where many workers daily exposed to hand-transmitted vibration in their grinding of handheld workpieces for several years. The first group included 61 grinding workers who had the symptoms of VWF, which was termed as vibration exposure group with WVF. The second group included 61 workers who also performed the grinding of handheld workpieces but they had no symptom of VWF, which was termed as vibration exposure group without VWF. The third group was control group and it included 64 workers who were not exposed to hand-transmitted vibration. ELISA was used to measure the expression levels of MLC_2 in plasma. Logistic regression analysis was performed to identify the factors affected the presence or absence of VWF. The receiver operating characteristic curve (ROC) was used to analyze the clinical significance of MLC_2 as a biomarker in the determination of vascular injury caused from hand-transmitted vibration exposure.

Results

The results of the animal experiment showed that the longer the vibration exposure duration was, the more serious were the damages of the vascular endothelium. In the control group, the rat tail artery blood vessels were found to be normal under optical microscope. Their elastic intimal membranes (IEM) showed a continuous wavy and smooth pattern in that group. Furthermore, their vascular smooth muscle cells (VSMC) were arranged neatly and closely, and no vacuoles were observed. In the 7d vibration exposure group, the discontinuous phenomenon of IEM, the vacuolation of the VSMC layer and the swelling of the vascular endothelial cells (VEC) were observed. In the 14d vibration exposure group, parts of the IEM were observed to have disappeared, while vacuolization was seen in the VSMC and IEM layers, and rupture appeared in the VEC. The ELISA assay results showed that the mean expression level of MLC_2 in the three groups was significantly different in the rat plasma ($\chi^2=3.80$, $P< 0.05$). As shown in Figure 1, the level of MLC_2 in the 7d vibration group was significantly higher than that in the control group, while no significant difference was found between the 14d vibration group and the control group.

The results of the epidemiology study showed that the expression levels of MLC_2 in the three groups were significantly different (χ^2=74.920, $p < 0.05$). As shown in figure 2, the MLC_2 level in the vibration exposure group without VWF (Group 2) was significantly higher than that in the control group (Group 1). The MLC_2 level in the vibration exposure group with VWF (Group 3) was significantly higher than that in the first and second groups. After converting the independent variable to the counting data and excluding the related confounding factors such as age, seniority, smoking and alcohol consumption, through the Logistic regression analysis, we found that there was a correlation between MLC and VWF (OR = 11.974). The area under the ROC curve of MLC2 was 0.826($p < 0.05$), the sensitivity was 82.5%, and the specificity determined from the ROC curve analysis was 73.1%.

Discussion

Myosin is found in vascular smooth muscle cells, which are also part of the cytoskeleton of some non-muscle cells. MLC_2 is the light chain of myosin, which is involved in cell contraction or gap expansion through phosphorylation[1-2].In the experiment with the rat tail vibration model, the plasma expression level of MLC_2 of the rats was significantly increased in the 7d vibration group, but it did not increase in the 14d vibration group. The results suggest that local vibration exposure may lead to damages to vascular endothelium and vascular smooth muscle, which may make MLC_2 released into the blood. However, with the destruction of vascular endothelium and smooth muscle structure which may have resulted from prolonged vibration exposure in the 14d vibration exposure group, the number of MLC_2 that can be released into the blood perhapas decreased, which would explain why no difference was observed with the control group.

The results of the occupational epidemiology study showed that the expression levels of MLC_2 were increased significantly in the two exposure groups, compared with that in the contro group, which were not fully consistent with the results of the laboratory investigation using the animal model. The possible reason could be that the daily doses of the human vibration exposure were much lower than those of the rats used in the experiment that would not cause the severe destruction of vascular endothelium and smooth muscle structure like the rats in 14d vibration exposure group. Their expression levels of MLC_2 could increased with the increase of the endothelial and smooth muscle damage. The high correlation between MLC_2 level and VWF in the population exposed to hand-transmitted vibration suggests that the level of MLC_2 may be used to help diagnose VWF with high sensitivity and specificity. It may have a great value in the detection of vascular damage, especially early damage resulting from hand-transmitted vibration exposure.

Figure

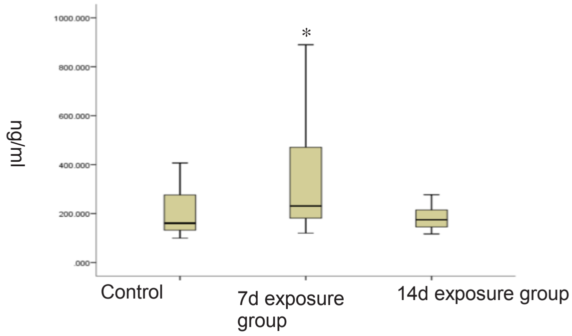

Figure 1: Comparison of MLC_2 expression in plasma of three groups of rats
*compared with control group, P<0.05.

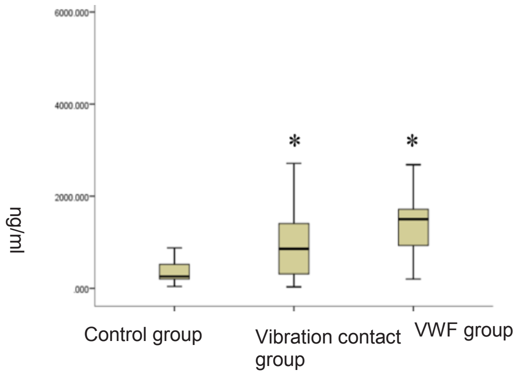

Figure 2. Comparison of MLC2 expression levels in plasma of three groups of workers
*compared with control group, P<0.05.

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Symtoms and clinical signs among carpenters compared to painters

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Keywords:

Carpenters; painters, hand-arm vibration, Raynauds´s phenomenon, neurosensory, carpaltunnel syndrome.

Introduction

Prolonged exposure to vibrating tools can cause *Hand Arm Vibration Syndrome (HAVS),* a condition with finger blanching (Raynaud's phenomenon) and diffuse neuropathy of Aα-, Aβ-, Aδ- and/or unmyelinated C-fibers. The handling of vibrating tools is ergonomically demanding. Musculoskeletal involvement from the upper extremity is often co-reported. Vibration exposure in combination with forceful grips in non neutral wrist positions makes the median nerve especially prone to entrampent in the carpal tunnel [1]. HAVS is one of the most frequent diagnosis for workers´ compensation among Swedish men [2].

Our aim of the study was to compare HAVS-prevalence among carpenters, a highly exposed group, with that of painters, who have lower exposure.

Methods

196 carpenters (195 males), and 39 painters (34 males) answered a questionnaire on symptoms related to HAVS and went through a clinical examination to evaluate neurosensory perception of touch, cold, vibration, heat and pain in the hands [3-7]. Results are reported for males only. The mean age for carpenters was 40 years (range 17 – 65), for painters 45 (25 – 64), 45% of the carpenters were tobacco users, 53% of the painters.

Individuals that reported symptoms of finger blanching when exposed to dampness or cold, were asked to fill in a hand diagram for the worst attack. Finger blanching was graded based on number of affected phalanges [8]. Hands were graded separately and the scoring for the hand with the highest grade was given.

0V: No attacks of blanching
1V: Digit blanching score 1-4
2V: Digit blanching score 5-12
3V: Digit blanching score >12.

Neuropathy was graded into:

0N: No symptoms.

1N: "Some" or "rather much" numbness in fingers.

1.5N: 1N and at least *one* of the following
- Decreased sensory perception (Semmes Weinstein Monofilament >3.61)
- Decreased temperature perception (Temp Rolls 25°C/40 °C)
- Increased vibrotactile threshold (125/250 Hz)

2N: 1N and at least *two* of the above

3N: 2N and reporting "some" or "rather much" symptoms of impaired dexterity ("easily dropping things" and/or "difficulties buttoning") and decrease two-point discrimination (>5 mm)

Hands were graded separately and the scoring for the hand with the highest grade was given.

We defined carpal tunnel (CTS) as symptoms of numbness/tingling in finger I-III and a positive nerve entrapment test in the same hand (Phalen´s test and/or Tinel´s sign), or previous operation due to carpal tunnel syndrome.

Results

8% of carpenters and 9% of painters reported finger blanching but the carpenters had a higher grading score.

27% of carpenter and 18% of painters fulfilled the criteria for neuropathy, and the carpenters showed more clinical findings.

Carpenters reported more cold intolerance (35% vs. 21%; not in table). Further, 12% of carpenters and 3% painters reported that they easily drop objects, and 7% vs. 3% had difficulty buttoning.

Reduced vibration thresholds was more common among carpenters (22%) compared to painters (15%).

The prevalence of CTS was similar between the groups.

Table 1. Symptoms and neurosensory findings among 195 carpenters and 34 painters.

	Carpenters N (%)	Painters N (%)
Digital blanching		
0V	179 (92)	31 (91)
1V	6 (3)	3 (9)
2V	6 (3)	0
3V	4 (2)	0
Neuropathy		
0N	144 (74)	28 (82)
1N	27 (14)	4 (12)
1.5N	16 (8)	2 (6)
2N	10 (5)	0 (0)
3N	0 (0)	0 (0)
CTS	22 (11)	3 (9)

Discussion

We used the recently suggested International Consensus Criteria (ICC) for grading the severity of vascular symptoms [8]. By not using the Stockholm workshop scale, we thus omitted to involve the frequency of attacks, since this is closely related to outer temperature [9].

For neuropathy we tried to get as close as possible to the ICC grading, but we added a stage 1.5. This was to include individuals that only had one clinical sign of neurosensory loss (instead of two out of three in stage 2). For clinical sign of decreased manipulative dexterity we used 2PD. The validity of 2PD has been questioned [10]. In fact the ICC grading system, recommends to measure impaired manipulative dexterity with Purgue Pegboard instead [8], but that was not included in our study. Further, we used 125 and 250 Hz, instead of 31.5 and 125 Hz, which is the ICC suggestion.

The prevalence of CTS is high in both groups compared to the general population [11]. Both groups have highly hand-intensive work tasks. CTS is claimed difficult to distinguish from vibration induced diffuse neuropathy. A combination of nocturnal symptoms and positive median nerve provocation over the wrist (Phalen´s test, Tinel´s sign) can strengthen the diagnosis. We didn’t grade CTS according to severity of symptoms as in CTS Boston symptom questionnaire, and we did not ask for nocturnal symptoms. Still, as we used both symptoms and findings, we find our results valuable.

The results are preliminary as we are still collection data for painters.

Conclusion

Carpenters showed higher scores concerning digital blanching and neuropathy. Both groups have hand intense work and we hypothesize that the difference is due to a higher exposure to hand held vibrating tools among carpenters. The prevalence of CTS was higher than in the general population for both groups.

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Risk assessment of musculoskeletal disorders among workers exposed to hand-arm-vibration: design, exposure assessment methods and first results of an epidemiological case-control study

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Abstract

In this paper, we presented the first findings of the German Hand-Arm-Vibration Study. In a industry based case-control study, 200 cases of musculoskeletal disorders and 600 controls were recruited. Frequency specific hand-arm-vibration were quantified by using a machine-vibraton exposure-matrix, which was established based on industrial hygiene measurements. Our first findings demonstrated that, 67% of workers exposed to Hand-arm-vibration in the past 5 years in Germany have exposure values over the permissible Eurppean exposure limit of $A_{hv(8)}$=5 m/s^2. This indicates an ugent need of improvement of current working conditions for workers exposed to hand-arm-vibration in Germany.

Keywords:

Hand-arm-vibration; Musculoskeletal disorders; Epidemiology

Introduction

Mechanical vibration arises from a wide variety of processes and operations performed in industry, such as mining, construction and forestry. Studies from different countries indicate an elevated risk of musculoskeletal disorders among vibration-exposed workers in compare to non-exposed workers. In Germany, there are approximately 1.5 to 2 million employees are currently exposed to hand-arm vibration which may represents a threat to their health. Although the human responses to vibration depend both on the magnitude and frequency of the vibration signal, their impacts on human health are poorly investigated. In order to quantitatively evaluate the effects of frequency dependent hand-arm-vibration on the risk of musculoskeletal disorders of the hand-arm-shoulder system, an epidemiological case-control-study was conducted among workers in the construction, mining and metal industries in Germany.

Methods

In total, about 200 clinical confirmed cases and 600 controls are recruited by the German Social Accident Insurance Institutions. The individual work history, its related working activities and the use of hand-transmitted vibration equipment were collected in a standardized personal interview by trained and experiences work safety inspectors of the German Social Accident Insurance Institutions. In addition, a database on the magnitude and frequency spectrum of mechanical vibrations of commonly used hand-transmitted vibration equipment was established based on standardized industrial hygiene measurements. Information on relevant confounding factors such as sports, leisure activities and co-morbidities are also collected in the standardized personal interview.

Quantification of hand-arm-vibration

- Vibration values assessed [1]
  $a_{hv} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2}$ and $a_{hw(x,y,z)}$
- Daily vibration exposure [2]
  $A(8) = \sqrt{\frac{1}{T_0}\sum_{i=1}^{n}(a_{hvi}^2 \cdot T_i)}$ T_i: working hours with ith machine
- Long-term cumulative vibration dose [3]
  $D_{hv} = \sum_{i,j=1}^{n,k} A(8)^2 \cdot d_i \cdot a_j$ d_i: working days per year
  a_j: total working years

Results

Currently there are 207 cases and 397 controls available in the analysis database. 76% of the study population are between 40 and 60 years of age. About 30% of them are heavy overweight. Generalized form of osteoarthritis and inflamatory joint disorders are more common among the cases than that among the controls. Hand-arm-vibration and frequency specific hand-arm-vibration values were complete assessed currently for 89% and 77% of study population, respectively. Our analysis demonstrated that, 80% of the study population with up to 28 equipments used by each worker have hand-arm-vibration values over the current permissible European exposure limit of A(8)=5 m/s^2**.**

Table 1. Description of study population

		Cases (n=207)	Controls (n=397)
Age (year):	20 – 30	3%	3%
	30 – 40	2%	3%
	40 – 50	29%	20%
	50 – 60	47%	56%
	60 – 70	15%	16%
	>70	3%	3%
Overweight:	no (BMI<=25)	17%	21%
	slightly (25<BMI<=30)	51%	52%
	heavily (BMI>30)	32%	27%
Nationalities:	German	90%	92%
	Turkey	6%	7%
	Others	4%	1%

Table 2. Comorbidity of study population

Comorbidity	Cases (n=207)	Controls (n=397)
Gout	15%	12%
Pseudogout	0,5%	0,3%
Hand injuries	40%	32%
Elbow injuries	12%	8%
Shoulder injuries	14%	11%
Arm fracture	10%	8%
Inflammatory disorders of wrists	26%	8%
Inflammatory disorders of Elbow	24%	7%
Inflammatory disorders of shoulder	18%	12%
Osteoporosis	2%	2%
Gonarthrosis	29%	20%
Coxarthrosis	10%	5%
Spinal OA	19%	9%
Rheumatism	6%	4%

Table 3. Proportions of study population with A(8) values over 2.5 or 5 m/s²

Hand-arm-vibration values	Proportions of study population				
	Last 5 year	Last 10 year	Last1 5 year	Last 20 year	Total
N	269	441	476	507	578
A(8) ≥ 5 m/s²	67%	69%	71%	75%	80%
$a_{hw(8)}$ ≥ 5 m/s²	29%	34%	37%	39%	50%
A(8) ≥ 2.5 m/s²	85%	85%	86%	88%	92%
$a_{hw(8)}$ ≥ 2.5 m/s²	71%	75%	77%	81%	86%

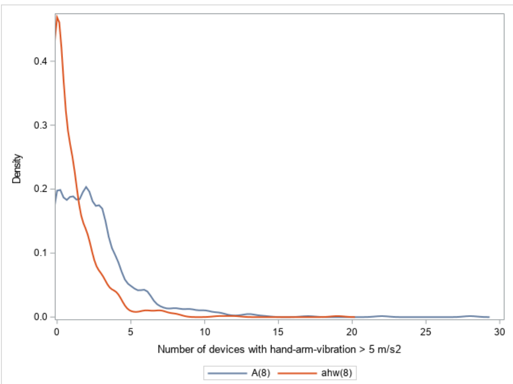

Figure 1: Number of Equipments used by each indivuduals with A(8) or $a_{hw(8)}$ value > 5 m/s²

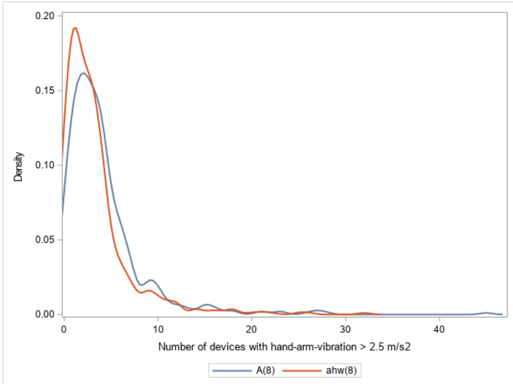

Figure 2: Number of Equipments used by each individuals with A(8) or $a_{hw(8)}$ value > 2.5 m/s²

Conclusion

The mojarity of German workers exposed to hand-arm-vibration in the past 5 years still have higher vibration values over the current permissible Eurppean exposure limit, which underlines the need of improvent of current working conditions.

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Identification of low molecular organic compounds in serum of vibration exposed workers

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Keywords:
White fingers; Metabolites

Introduction

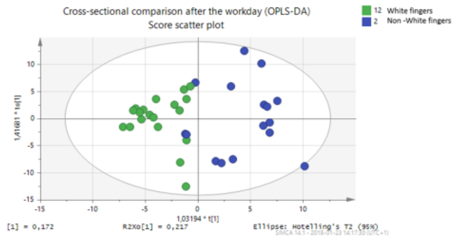
Vibration induced white fingers has been recognised for several decades, but still, it is not fully understood if hand transmitted vibrations initiates an injury to the nerves, the blood vessels or an induced change in rheostatic properties of the blood vessels in the exposed fingers. By the time the syndrome has manifested it is often too late to perform preventive actions at the workplace. It would thus be a great advantage to develop a clinical method, which could be used to, at an early stage, evaluate if a vibration-exposed worker is at risk to develop white fingers.

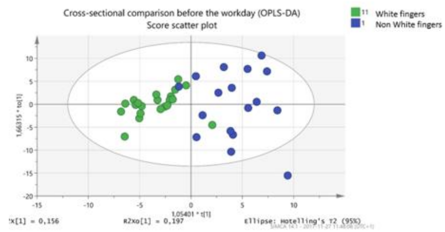
Methods

The study population consisted of 38 metalworkers. The main task was grinding and quality control of the finished products.
All participants answered a validated questionnaire about hand symptoms was used to detect symptoms of white finger and neurological symptoms (tingling, numbness in hands). A medical examination was carried out done according to a standardized procedure. It contained an examination on the hands, used to diagnose Carpal tunnel syndrome and identify signs of vascular damage at the wrist, using Phalen-, Tinells- and Allen tests. All of the participants were classified according to the Stockholm Workshop scale for vascular disorders and neurological disorders.
The vibration exposure was estimated by measuring the vibration level at a point close to where the operator had their hand while working with the grinders.
Blood samples were collected before and after the work shift and analyzed with GC-TOFMS techniques. OPLS-DA models were used to identify a different profile of low molecular organic compounds.

Results

23 of 38 persons reported vascular symptoms that was judge as vibrations related. 9 persons describe white finger, 7 in stage 1 and 2 in stage 2. 14 persons described increased cold intolerance that had appeared after start of exposure.
The mean (AM) daily vibration exposure for each worker was found to wary between 0.9 – 3.1 m/s^2 depending on work tasks





There was a difference both before and after workshift between white fingers vs non-whitefingers in the metabolic profile.

Conclusion

By using GC-TOFMS techniques and OPLS-DA models we have identified a different profile of low molecular organic compounds in serum for workers with white fingers vs workers whiteout white fingers, as well as found differences in the profile of low molecular organic compounds after exposure to vibrations during work. Some of these low molecular organic compounds might be potential indicators of a health effects from occupational exposure to vibrations from hand held equipment. This is the first time to our knowledge that an identification of low molecular organic compounds have been done in workers exposed to hand- arm vibrations.

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Blood biomarkers for vibration induced white fingers

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Introduction

Vibration induced white fingers (VWF) is one form of secondary Raynaud's phenomenon (sRP) in this case suspected to being caused by hand transmitted vibrations from hand held equipment. Vibration induced white fingers has been recognised for several decades, but still, it is not fully understood how hand transmitted vibrations influences the mechanisms contributing to altered vasoconstrictive activity or initiate injury of the nerves in the fingers. Etiopathologic hypothesis include injury to the blood vessels in the fingers.. A use of biomarkers for diagnostics of VWFis a sicentific challenge.

Methods

Sixteen individuals (cases) occupationally exposed to vibrations from hand held equipment and diagnosed as suffering from vibration induced sRP participated. To each case we selected a control person matched for age and occupational vibration exposure)
From each individual a blood sample was collected 60 or 5 minutes before and at 5, 30, 60 or 120 minutes after a cold challenge test (Critical Opening Pressure – COP). The concentration of six potential biomarkers in blood; was determined using commercial validated ELISA techniques.

The COP test measured the systolic finger blood pressure of digits (dig) 2–5 on the right hand continuously. The % FSBP10 was calculated

A % FSBP10 value <100% indicates an increased vasospastic reaction to local finger cooling.

Diagnostic test

The potential biomarkers were, in combination with a cold challenge test (COP) evaluated in a diagnostic test. Likelihood ratio^{+} (LH^{+}), (LH^{-}), sensitivy or specificity was determined using an EBM calculator.

Results

COP

Compared with the controls, the selected cases showed a significantly lower % FSBP10. Cases as well as controls had a %FSBP10 < 100%.

Biomarkers

The concentration of one of the biomarkers was significantly lower among the cases in blood samples collected before or after COP. Following cold exposure (COP) the concentration of an additional biomarker decreased among the cases resulting in a significantly lower concentartion compared with the controls. In addition a third biomarker increased following cold challenge among cases.

Diagnostic test

The diagnostic test indicatetd strongly that two of the biomarkers, in combination with COP, can be used in diagnostic testing

Discussion

Our results provide evidence that at least three endogenos substances can be used as potential biomarkers for vibration induced sRP. A COP test is often used when diagnosing sRP. The cases as well as the controls showed an increased vasospastic reaction to local finger cooling, Our results strongly indicates that at least two of the biomarkers identified can, in combination with COP, provide important additional information during the diagnosis of sRP.

Conclusion

We have identified three endogenous potential biomarkers in blood for vibration induced sRP.

The biomarkers can, either separately or in combination with cold challange, be used during diagnosis of sRP.

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Role of 5-HT1B-receptor in activation of ERK pathway on vascular smooth muscle cells

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Introduction

Hand arm vibration syndrome(HAVS) is induced by hand-transmitted vibration, a vasospastic and neurodegenerative occupational disease. Vascular smooth muscle cell (VSMC) hypertrophy was found in finger skin biopsies from patients with HAVS[1]. By previous study, we have found that 5-hydroxytryptamine (5-HT1B) receptor gene variants was associate with HAVS in workers exposed hand-arm vibration[2]. Considering the mediation of 5-HT1B-receptor in vasoconstriction[3], and the critical role of extracellular signal-regulated kinase (ERK) in the mitogenic, which belong to mitogen-activated protein kinase(MAPK) family, we aim to study the role of 5-HT1B-receptor in activation of ERK pathway on VSMC in the present study.

Methods

Cell culture and treatment: human VSMCs were purchased from Amerian type culture collection(ATCC). Cells were cultured in Dulbecco's modified Eagle's medium(DMEM) supplemented with 10% bovine serum, streptomycin at 37°C and 5% CO_2 cells. Cells used in the experiments were between the third and fifth passage. All experiments were conducted in duplicate.
Cell treatment and transduction: 5-HT1B plasmids were established in Guangzhou Ryder Liankang Biotechnology Co., Ltd.. and HTR1B gene were cloned into the expression vector pcDNA3.1. and 5-HT1B plasmids were transconducted into VSMCs according the procedures[4].human VSMCs were treated with restructure 5-HT1B plasmids(5-HT1B group), and 10% bovine serum(control group), separately.
Cell identification: SM-α-actin was detected by immunocytochemical staining for identification of VSMCs coverslides bearing the 3rd and 5th passage.
Western blotting: the expression level of p42/44 MAPK were determined by western blotting[5]. VSMC cultures were washed three times with PBS wash buffer and lysed with lysis buffer. Protein concentration was measured by the BCA protein assay. Proteins were separated by SDS-PAGE and blotted onto poly(vinylidene fluoride) (PVDF) membranes and dyed with ponceau. Blots were incubated with rabbit anti-rat p42/44 MAPK (Santa Cruz Biotechnology Inc.). Bound antibody was detected using the appropriate horseradish peroxidase-conjugated antibody. Chemiluminescent detection system were used to detect the signals.

Statistical analysis: Results are presented as $\bar{x} \pm s$ from at least 3 independent experiments. Statistical signi fi cance was assessed using either *t* test or analysis of variance, followed by Least Significant Difference(LSD) test. Differences are considered significant at $p < 0.05$.

Results

Cell identification: Results of culturing vascular smooth muscle cells (VSMCs) and transfecting 5-HT1B restructuring plasmids into vascular smooth muscle cells (VSMCs)(Fig 1): green fluorescence protein(GFP) was observed in cytoplasm under fluorescent microscope(× 400),after restructuring 5-HT1B plasmids transfect into vascular smooth muscle cells(VSMCs) for 48 hours, proving that the recombinant plasmid transfect into VSMCs successfully.
p42/44 MAPK protein expression: as the result s of Fig 2 and Fig 3, significant difference of p42/44 MAPK protein expression among the control group, liposome group and 5-HT1B group were found. Compared with control group,the expression level of p42/44 MAPK protein in liposome group and 5-HT1B group were significanctly decreased(p<0.05); Compared with liposome group, the expression level of p42/44 MAPK protein in 5-HT1B group were significanctly decreased(p<0.05).

Discussion

Although the effects of hand transmitted vibration on peripheral vascular were demonstrated and related with injured VSMC, the mechanism of vibration-induced VSMC injury remained unclearly understood. In the present study, the potential mechanism of VSMC injury were explored by 5-HT1B receptor via MAPK signalling pathway.

In the present study, we found that protein expression level of p42/44 MAPK were significantly decreased by the 5-HT1B receptor receptor, and regarded that 5-Hydroxytryptamine receptor 1 B gene expression may influence the activation of the MAPK pathway on vascular smooth muscle cells. And the result of the present study were supported by the Hinton's research[6].

Lots of studies suggests that MAPK signalling pathways, classically associated with cell growth and mitogenesis, and regulated the smooth muscle contractility. And the activation by MAPK is mediated by 5-HT 1B receptors[6]. So the vasospasticcould mediate by the 5-HT 1B receptors through the MAPK signalling pathway.

Conclusion

The data revealed that the MAPK p42/44 protein (EKR1/2)expression and the level of phosphorylation in restructuring 5-HT1B plasmids group were significantly much lower than those in other groups, suggesting that 5-Hydroxytryptamine receptor 1 B gene expression may influence the activation of the MAPK pathway on vascular smooth muscle cells.

Figure

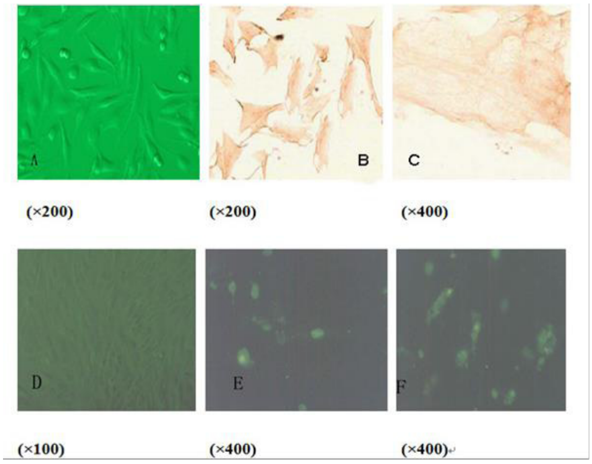

Figure 1. Results of Cell identification. A: normal VSMC(3rd cell passage);B: VSMC marked by SM α-actin at 200×; C: VSMC marked by SM α-actin at 400×; D: normal VSMC(5th cell passage);E: VSMC were transducted by 5-HT1B plasmids 2 hours; F:VSMC were transducted by 5-HT1B plasmids 4 hours.

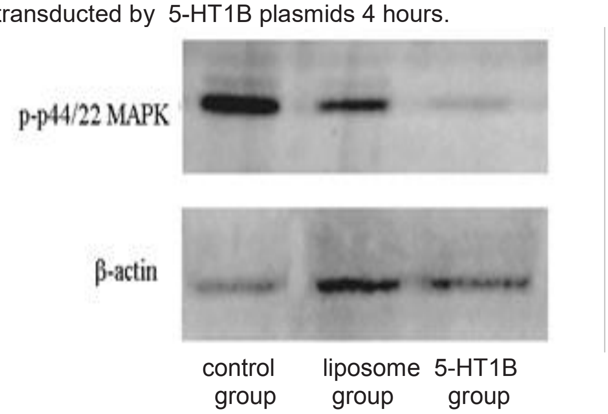

Figure 2: p42/44 MAPK protein expression of three groups of rats

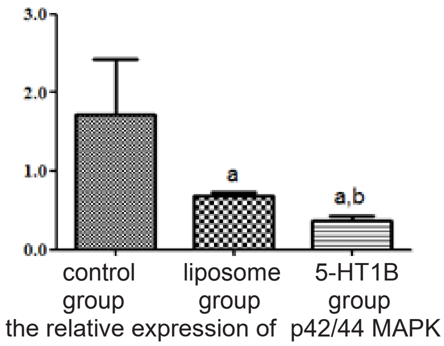

Figure 3. Comparison of p42/44 MAPK relative expression levels in three groups

[a] compared with control group, *P*<0.05.

[b] compared with liposome group, *P*<0.05.

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Penile Raynaud's phenomenon in workers exposed to hand-arm vibration: case report and literature review

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Abstract

Workers exposed to hand-arm vibrations (HAV) can present with Raynaud's phenomenon to their hands and feet. We present the case of a young worker that suffered from penile Raynaud's phenomenon associated with erectile dysfunction. No other causes for this disorder has been found. Rare studies relate this association with vibration exposure. We hypothezised a central sympathetic hyperactivity and/or circulating vasoconstrictor substances induced by exposition to vibrations.

Keywords:

Penile Raynaud's phenomenon; hand-arm vibration exposure; sympathetic hyperactivity

Introduction

Workers exposed to hand-arm vibration (HAV) can present with Raynaud's phenomenon both to their hands and feet [1-4]. Raynaud's phenomenon of the ears [5], tongue [6] and nipples in breastfeeding mothers [7] has also been reported in the general population but few workers report blanching in other parts of their body than the hands and feet. We present a case of a worker suffering from hand, feet and penile Raynaud's phenomenon, accompanied by erectile dysfunction.

Methods

We searched the literature in Medline and Embase medical databases for articles in French or English from 1946 to november 2018. A search strategy (figure 1) was developed with an experienced librairian with the following concepts : sexual dysfunction or impotence, autonomic vegetative disorders, vibration exposure and vibrating tools.

Case history

A 30-year old man consulted for episodes of patchy discoloration of his hands and feet, without frank demarcation, associated with pain and paraesthesia. As a millwright for the past 10 years, he reported important vibration exposure from hand-held vibrating tools such as grinder, zip gun, and various manual tools. Whole body vibration from nearby machinery were also reported.

The symptoms in the hands appeared about 5 years after he started to use the vibration tools, followed by the same symptoms in his feet. After a couple of years, he noticed blanching of his penis, accompanied by local pain, provoked by exposure to cold temperature of less than 10^{o} C and the presence of humidity. The penile blanching also occurred at night while getting in a cold bed and during leisure activity such as hunting.

He further reported erectile dysfunction, for which his family doctor attributed a diagnosis of "performance stress". This disorder was associated with great disability and relationship problems.

The patient does not smoke, take medication or use drugs of any kind. Cold provocation tests were positive for hands and feet. He was evaluated by multiple specialists, including specialists in internal medicine and urology, to search for a cause for his penile blanching. Blood tests were normal for connective tissue diseases, diabetes and other common causes of secondary Raynaud's phenomenon. No other cause than vibration exposure could be identified and a diagnosis of hand-arm vibration syndrome was made. The Workers' Compensation Board accepted his claim as an occupational disease.

After ceasing exposure to HAV for about 8 months, he noted improvement from his hands and feet discoloration. Without medication, he recovered from his erectile dysfunction but still presented penile Raynaud's phenomenon.

Results

From the 213 articles identified in our literature search, only 2 articles met our inclusion criteria. Penile Raynaud's phenomenon is rare [8]. Literature review could identify two articles on Raynaud's phenomenon and/or erectile dysfunction among workers exposed to HAV [9-10].

According to Andreeva-Galanina classification, central nervous system complaints such as, headaches, severe sleepiness, depressive mood, memory losses, impotence and palmar sweating were reported as part of vibration disease. Matoba reported that 55% of 300 chain-saw operators reported impotence [9]. The association between erectile dysfunction and Raynaud's phenomenon is also reported in autoimmune diseases [11] .

Discussion

Workers exposed to hand-arm vibration can present with Raynaud's phenomenon in different parts of their body such as hands and feet. Penile blanching represents a unsuspected problem which could be the cause of important distress. This impariment is probably frequently overlooked and forgotten by clinitians during their anamnesis.

The pathophysiology of Raynaud's phenomenon in patients suffering from HAVS (hand arm vibration syndrome) is complex and the current hypothesis is that of both a central and peripheral sympathetic overstimulation [12]. Cumulative exposure to vibration could over-stimulate Pacinian corpuscules, initiating the cascade of events leading to an increase in sympathetic activity and a decrease in parasympathetic tone. In addition, there is a local acral dysregulation of blood vessel tone in the hands. Locally released or systemically circulating vasoconstrictors such as endothelin, 5-hydroxytryptamine and thromboxane may participate to this phenomenon. A deficience or increased degradation of nitic oxide, possibly due to increased oxidative stress, could also be involved [4,12-15].

No organic causes have been identified to explain the patient's erectile dysfunction or Raynaud's phenomenon. In young and healthy subjects, various etiologies for erectile dysfunction, different from those of older subjects, have been suspected. These etiologies involved increased sympathetic tone as the cause of "psychogenic" erectile dysfunction. [16,17]. It is thought that inhibition of the spinal erection center attributable to exaggerated normal inhibition or increased sympathetic outflow results in increased penile smooth muscle tone and poor vasodilation [18].

We suspect that the patient's condition is related to an increased sympathetic tone also demonstrated by the shortening of systolic time interval in workers exposed to vibration [4,19] and neurosensorial hearing loss among workers with white finger disease [20]. The combination of Raynaud's phenomenon to the penis, hands and feet strongly suggest central sympathetic reflex activity plays an important role in the pathogenesis of HAVS. As local factors (such as circulating vasoconstrictors) are also likely to have a direct effect on penile Raynaud's phenomenon, we believe that combined central and peripheral mecanisms play an important vasoconstricting effect on the penis.

Conclusion

To our knowledge, Raynaud's phenomenon of the penis, with or without erectile dysfunction, has rarely been described in the literature. In workers exposed to hand-arm vibration, we suspect that hyperactivity of the sympathetic nervous system combined with the effect of circulating vasoconstrictor substances could lead to Raynaud's phenomenon of the penis and/or erectile dysfunction.

Figure 1. Research strategy

Enregistré dans compte Ovid : « 20181120-vibration-erectile »

Database: **Embase** <1974 to 2018 Week 47>, Ovid **MEDLINE(R)** and Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Daily and Versions(R) <1946 to November 19, 2018> Search Strategy:

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1 ((sexual adj2 (dysfunction* or function*)) or penis or penile or erectile or impotence).ti,ab. (147904)
2 ((autonomic or vegetative) adj "nervous system*").ti. (7644)
3 "erectile dysfunction"/ or *"autonomic nervous system"/ (72148)
4 1 or 2 or 3 (187639)
5 (HAVS or "hand-arm vibration*" or ((Raynaud* or vibration) adj (syndrome* or phenomenon* or disorder* or disease*))).ti,ab. (17700)
6 "hand-arm vibration syndrome"/ or "Raynaud disease"/ (12743)
7 vibration disease/ or Raynaud phenomenon/ (18898)
8 (((vibrating or vibration* or vibratory or percussive or percussion* or impact* or nonimpact* or non-impact* or powered-hand or hand-held or handheld or power or pneumatic or grinding or chipping or handle-powered) adj1 (tool* or gun* or wrench* or hammer*)) or jackhammer* or jack-hammer* or chainsaw* or chain-saw* or riveter* or grinder* or ((grinding or chipping) adj operation*)).ti,ab. (4903)
9 5 or 6 or 7 or 8 (29101)
10 4 and 9 (273)
11 remove duplicates from 10 (**213**)

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Shock and Vibration Issues in Professional Sports

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Introduction

While shock and vibration has long been recognized as a workplace hazard, ergonomic intervention over the years has made significant strides in ameliorating this issues in many jobs. However more recently, the effects of shock and vibration has become to be appreciated as a significant risk factor in various professional and amateur sports and including soccer, football, baseball as well as other sports activities. This is led to the appreciation of resulting pathology to the head, whole body and extremities depending on the insult. The implication of this has included significant disability, impairment of function and careers, financial cost and post career disease including even death. While the major attention has been focused on professional sports, similar injury and impairment has also been identified in the amateur arena of the same sports. It is recommended, that in a like fashion of the endeavors to control whole body and hand-arm vibration in the workplace by the scientific community, that a similar multidisciplinary endeavor be instituted to address and resolve this risk in sports.

Issues

Sports is becoming industry, an avocation and entertainment. While professional sports are billion-dollar industries involving a few highly skilled professionals the participation in the same sports at the amateur level considerably dwarfs the number of participants at professional of the sport. Overall participants no matter what level of expertise, training or participation are almost always subject to the same risk that is inherent in that sport. Over time, some type of shock or vibration, has been identified in many of the commercial sports activities with the potential effects of causing increase cost to the game, participant morbidity and mortality, decrease participation in this potential risk and possible alteration of the game itself.

Each sport can be analyzed for specific risk of all shock and vibration trauma. Classically, the first sport to be recognized as having significant deleterious effects on the participants was noted to be boxing. The effects of this has been characterized as significant head and brain trauma that has been documented brain imaging and scanning with clinical findings of significant diminishment of brain function from the repetitive shocks to the to the head over time. This is led to decreased public interest, public dismay at the effects on the participants, limited amateur participation that often leads to fewer venues for the remaining participants.

In a similar fashion, American football is the subject to similar scrutiny over identified traumatic brain injuries. This is led to multimillion dollar lawsuits against the league by affected players, changes in rules, decrease participation at the amateur level the level of schools where parents have expressed concerns over the potential damage to their children resulting in the threat of significant changes to the game itself including question of sufficient players needed for survival. While ultimately the game itself may survive but with some modifications, the appreciation of the risk will not go away unless solutions are found to ameliorate the trauma sustained in participation at all levels of expertise in the sport. Although football has many other injuries due to the physical nature of the sport itself, it is a brain trauma that is captured the attention of the players, lawyers, the public and the league itself. While there has been made improvement in helmet protection, there is no lasting proof that the risk to chronic brain trauma has been eliminated. While international soccer may even have more participants and be more popular on an international level than American football. It also suffers the risk of head trauma from collisions " headers" without the advantage of having helmets. The fact at a major motion picture has been made about this issue confirms the importance of this issue.

Baseball, another popular international sport, also suffers from the risk of brain trauma. What direct shock to the head is less frequent than in football, there are significant parts of the game that have high risk. Pitching the baseball, hard line drives back to the pitcher's head and collisions both in from base running including attempts to get past the catcher at home plate as well as collisions with walls and other players in the field as significant risk of head trauma. To make matters worse, helmet protection albeit inferior and inadequate for full protection is only provided to the batter. This is led to some rule changes in terms of collisions at home plate and efforts to provide additional helmet protection for the pitcher. The helmet is rarely used by the pitcher due to cosmetic reasons and comfort reasons. Baseball also has issues of the upper extremity from the shock and vibration from batting and even catching. Some the common injuries that occur from batting include wrist fractures such as trauma to the hook of the hamate bone, degenerative changes in the wrist and elbow and acute fractures. In addition, there is significant risk factors to catchers and umpires from the trauma of the pitch ball in the head itself. As an example of the significance of this risk and impact on the team, at one point in time there was one baseball team with players with a combined salary over $25 million were sidelined to the bench for most of the season from concussions. In another case, trauma and resulting surgery that were a result from batting shock and vibration resulted in decisions that led to trading a player that ultimately want up to be an all-star player on another team. The ability to keep players in the game has a significant impact on the sports franchises outcome at the professional level and continued participation at the amateur level. As with medical issues of any type, prevention is almost always more effective over remedial therapies after the trauma or insult has occurred.

While warm weather sports are more prominent to the publicly more recognized for these issues of shock and vibration, winter sports such as ice hockey and skiing also have the risk in a similar fashion. The high speeds and lack of often control from these issues can lead to trauma the body and in particularly the head with a high risk for brain pathology and brain injuries that is no different from baseball or football venues.

A hand and arm intensive sport such as tennis, racquetball and handball have significant risk to the upper extremity in pathologies have been noted from the sports at all levels of participation. Even golf can result in hand related problems from the vibration transmitted through the shaft of the golf club. There have even been complaints and sports car racing such as NASCAR of vibration to the hands causing pathology, fatigue and sometimes control issues.

Recreational sports that are popular with the public such as mountain biking are subject to hand issues due to the significant vibration, over the course of either competition or pleasure ridding. This can lead to the short-term fatigue, control issues and potential long-term issues such as carpal tunnel syndrome and other wrist and hand pathology.

Methods

Analysis of injuries in contact sports such as football, baseball and hockey indicate significant incident of head trauma leading to concussions, brain trauma and long-term brain damage. Analysis of hand intensive supports such as baseball and other ball related sports leads to shock damage to hands and as well as causing other upper extremity pathology. Sports that require prolonged gripping vibration such as mountain biking can lead the same pathological medical conditions seen in industries that have vibration exposure. Exploration of these sports indicate that the incidence and severity of these conditions may be increasing. Attempts to remedy these issues have often been hindered by sport rules, technological limitations and reluctance of players to accept uncomfortable or unfashionable solutions.

The intervention method that often been used have include various shock absorbing materials as well as hard indestructible helmets. For the most part this at protection is designed to reach the level of preventing skull fractures but do not necessarily achieve the level of dissipating enough force to prevent traumatic brain injury and concussions. Attempts to find solutions for the prevention of brain trauma included technological problems in terms of designing, materials of proper quality, shape and configuration as well as allowing for continued cosmetically acceptable design. As an example, major league baseball has come up with a few different alliterations for protective headgear for pitchers. But to date, there a few pictures and use them because of the awkwardness of the design, lack of comfortable fit and the cosmetic appears that they perceive is not be acceptable to the public.

To this point in time other than numbers of studies to define these problems which are relatively easy identified through modern medical technology examination, is not clear that any of the technological innovations have medically sufficient preventive criteria to solve and prevent the trauma in question. Many of the current solutions that have been offered are primarily products of individual entrepreneurial research and development. There's been little recent redress of the specific standards that need to be established or revised that apply specifically to sports that offer preventative advantage in solution. While there have been many studies and patents obtain to address some of these issues, it is yet unclear that any of these sports risk has been solved and retired from the sport.

Results and Recommendations

While there have been considerable investigations to define the level of pathology as result of these shock and vibration hazards in sports, no definitive solution has been found for all or individual supports. Efforts from a combination of engineering, medical and ergonomic resources need to be marshalled to find acceptable solutions. Advancements in medical technology including imaging as well as biological monitoring are now available to help in the assessment of various interventions in these areas of trauma. Well-controlled human studies ,ay be difficult due to ethical issue but ongoing retrospective studies the effect on sports that may document changes over time with the level intervention provided certainly will be helpful. Redressing and establishing sufficient standards based on defined scientific assessment that is confirmed with studies will be helpful to provide guidance for players, teams and the public to make decisions about acceptable levels of protection. If these solutions are not found, one can only expect an ongoing list of injured athletes, legal and financial challenges and possible threat to the nature of the sport themselves. For over 100 years scientific expertise has been addressing the effects of shock and vibration in general industry as well as to the public. It is only appropriate that the same efforts, expertise and endeavor be applied to sports both at the professional and amateur level. It is recommended that the expertise that applied to dealing to shock and vibration in the industrial setting now be also directed to the sports venue.

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Vibration induced injuries in hands in long-term vibration exposed workers

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Introduction

Long-term vibration exposure may cause neurophysiological disturbances such as dampness and tingling, reduced grip strength and difficulties in handling small objects. Most workers are right-handed and thus, the right hand will usually have a higher vibration exposure than the left hand. In Sweden about 400 000 workers will have a daily exposure exceeding two hours to different types of vibrating tools. Vibration injuries is at present the dominant reason for an approved occupational injury in our country.

It is often difficult for a worker to make a correct estimate of the vibration exposure time. Mostly, there is an overestimate that can vary with a factor from 2 to and up to 8 times. This uncertainty makes it more difficult to make a correct calculation of the individual vibration dose. Another complicating factor is the large difference in sensitivity to hand-arm vibration. Some workers can develop quite severe symptoms within a few years while others can work for decades with only minor symptoms.

Aims

In this study, we are comparing neurophysiological test results in the right and left hand in long-term vibration exposed workers. The underlying hypothesis is that signs of adverse health effects will be more pronounced in the dominant hand of the workers.

Methods

The study is based on 47 (36 males and 11 females; mean-age 50 ± 12 y; mean exposure time 16 y) vibration exposed workers, all former patients from the department of occupational and environmental medicine, Gothenburg university. Of these workers, 36 were right handed (mean-age 51 ± 12 y; mean exposure time 19 y). The comparison group consisted of 18 randomly selected subjects (mean-age 38 ± 16 y) from the general population of Gothenburg. All participants completed several questionnaires about e.g. work and medical history, use of tobacco, alcohol and of vibrating tools (years), and symptoms related to vibration exposure. Thereafter, an experienced physician performed a careful physical examination. The neurological tests included Baseline hand grip strength, the Pinch-grip, the 3-Chuck grip, the Purdue Pegboard test and determination of thermal (TPT) and vibration (VPT) perception thresholds.

Measurements of vibrotactile thresholds were evaluated by delivering sinusoidal vibrations to the pulps of digits 2 and 5 in both hands (the ascending-descending method of limits) and registering the subject´s response, using the VibroSense Meter® system (VibroSense Dynamics, Malmö, Sweden) testing seven frequencies from 8 to 512 Hz. The vibration probe had a diameter of 4 mm. The test didn´t start until the skin temperature of the subjetct´s forefinger exceeded + 28 oC. The rate of change of the vibration amplitude was 3 dB/s and for each frequency there were six reversals.

The test of thermal sensibility was performed with an unidirectional stimulation technique using a commercially available test instrument with a Peltier element-based thermode of 25 x 50 mm (Termotest®; Somedic Sales AB, Sweden). The starting temperature was 32 oC for both cold and warmth. The perception thresholds to nonpainful cold and warmth, respectively, were obtained by delivering six cold stimuli, followed by six warm stimuli in random order, at a rate of 1 oC/s. The average of the last four assessments for cold and warmth on the finger pulps of digits 2 and 5, was calculated as the cold or warmth perception thresholds.

Results

The temperature perception thresholds (TPTs) did not differ significantly between the right vs left hand in neither all workers, nor right-handed workers or referents. All TPTs in digits 2 and 5, however, were significantly increased by the long-term vibration exposure among the workers as compared with the referents ($p \leq 0.05$). The same pattern was shown for the vibration perception thresholds (VPTs), which did not differ between RH and LH among the workers. The VPTs in digits 2 and 5, however, were significantly higher in the workers compared to the referents ($p \leq 0.034$). The latter group showed significantly higher thresholds in the right hand compared to the left hand ($p \leq 0.01$).

The Purdue Pegboard test showed a significantly better performance in the right vs left hand among all workers and right-handed workers ($p \leq 0.018$), but that was not found among the referents. The referents, however, performed significantly better ($p<0.001$) than all workers on the Purdue Pegboard test in both the right and left hand. The hand grip strength and the finger muscle strength tests did not differ significantly between the right and left hand in any of the three study groups, and there was no significant difference between workers and referents. The strongest correlation coefficients between the right and left hand with correlation coefficients (rs) around 0.8 or higher, were observed for VPTs in digits 2 and 5 and for the three muscle strength tests among both workers and referents.

Conclusions

Differences as regards symptoms and neurophysiological test results in the right vs left hand of exposed workers have been reported in several studies. In this study, similar minor differences were noted for the determination of VPT and the Purdue Pegboard test, which should be considered in future studies of vibration exposed workers. The exposed workers showed significantly higher VPTs and TPTs compared to the referents. The muscle strength tests, however, were of the same magnitude in the right vs left hand comparison within all three study groups.

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Assessing the sensorineural component of the hand-arm vibration syndrome (HAVS): Sensitivity and specificity of standardized tests

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Abstract

In 60 males reporting symptoms of the hand-arm vibration syndrome, this study investigated the sensitivity and specificity of standardized tests for detecting sensorineural symptoms (numbness or tingling). Thermotactile thresholds for detecting hot and cold and vibrotactile thresholds at 31.5 and 125 Hz were measured on the index and little fingers of both hands. The thermotactile and vibrotactile thresholds had sensitivities >80% and specificities >90%. The findings suggest thermotactile and vibrotactile thresholds provide useful indications of sensorineural function in patients with symptoms of the sensorineural component of the HAVS and indicate the extent of sensorineural disorder.

Keywords:

Sensorineural dysfunction; Hand-transmitted vibration

Introduction

Vibration-induced neuropathy can be manifested as reduced sensitivity, numbness, tingling, pain, or clumsiness in the fingers that reduces work ability and the quality of life. For the assessment of changes in sensorineural function associated with hand-transmitted vibration, the measurement of thermal thresholds and vibrotactile thresholds have been recommended in the UK[1]. From a comparison of any changes in four different thresholds (i.e., hot, cold, Meissner's, and Pacinian), it can be identified whether deterioration in tactile perception is concentrated in one or more sensory unit or neural pathway.

This paper reports an investigation of the sensitivity and specificity of standardised tests for thermal and vibrotactile thresholds on fingers with sensorineural symptoms. It also investigated whether the tests distinguish between fingers with a differing extent of sensorineural symptoms.

Methods

Sixty male patients referred for HAVS assessment at the Institute of Sound and Vibration Research (University of Southampton) agreed to participate in the study. The study was approved by the Ethics Committee of the Faculty of Engineering and the Environment (10704).

An *HVLab* thermal aesthesiometer was used to measure thermotactile thresholds (hot and cold thresholds) via the method of limits[1]. The temperature of the applicator increased or decreased from 32.5°C at a rate of 1°C.s^{-1}.

An *HVLab* vibrotactile perception meter was used to measure vibrotactile thresholds (thresholds at 31.5 and 125 Hz) via the von Békésy method in a manner compliant with the methods in ISO 13901-1[2]. A 6-mm diameter vibrating probe was separated by 2-mm from a fixed surround to which fingers applied a downward force of 2 N.

Thresholds were measured on the distal phalanges of the index and little fingers of the right and left hands.

Data analysis was performed using the software package SPSS (version 22.0). Non-parametric tests were employed with a significance criterion of p=0.05.

The diagnostic criteria used in the study were: (i) hot thresholds greater than 45°C, (ii) cold thresholds lower than 22°C, (iii) 31.5-Hz thresholds greater than 0.3 ms^{-2} r.m.s., 125-Hz thresholds, greater than 0.7 ms^{-2} r.m.s. [1]. Receiver operating characteristic (ROC) analysis showed the effects of varying these criteria.

Results

The ROCs are shown for thermal thresholds in Figure 1 and vibrotactile thresholds in Figure 2.

On fingers with sensorineural symptoms, thresholds for detecting hot and cold changed more on fingers with a sensorineural score of 6 than on fingers with sensorineural scores of 1 or 3 (p<0.01), where 1 indicates numbness or tingling on the distal phalanx, 3 on distal and middle phalanges, and 6 on all phalanges. There were no significant differences in hot or cold thresholds between fingers with sensorineural scores of 1 and 3 (p=0.217-0.829).

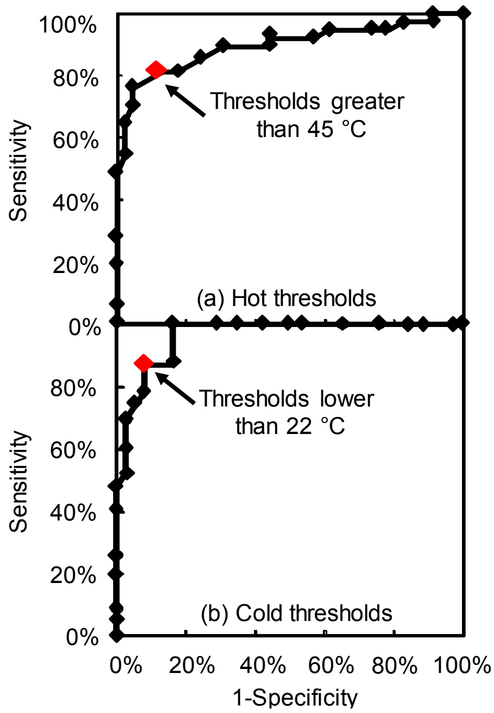

Figure 1: Receiver operating characteristic (ROC) curves for hot thresholds and cold thresholds (red markers indicate the diagnostic criteria[1]).

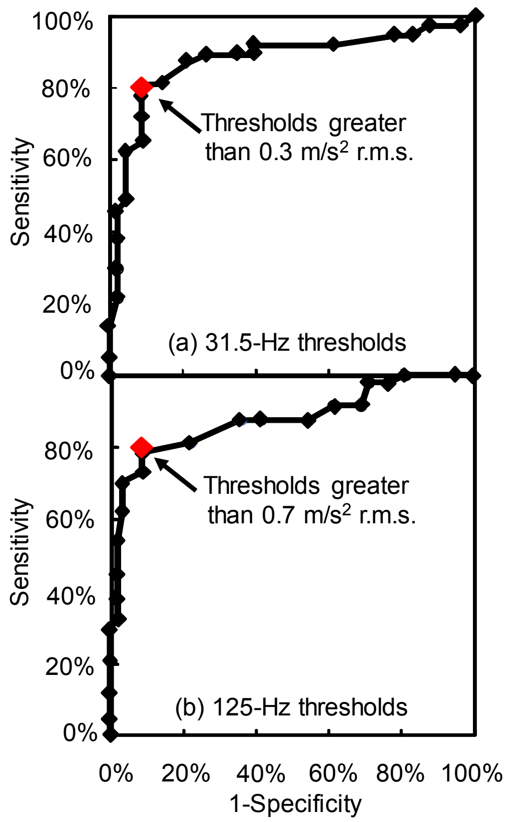

Figure 2: Receiver operating characteristic (ROC) curves for vibrotactile thresholds at 31.5 and 125 Hz (red markers indicate the diagnostic criteria[1]).

The sensitivities and specificities for thermotactile thresholds to distinguish between fingers with and without sensorineural symptoms were, respectively, 81% and 92% for hot thresholds and 87% and 94% for cold thresholds. The areas under the ROC (AUC) and 95% confidence intervals (CI) were 0.89 (CI: 0.81 to 0.97) for hot thresholds and 0.96 (CI: 0.92 to1.00) for cold thresholds (Figure 1).

On fingers with sensorineural symptoms, vibrotactile thresholds at 31.5 and 125 Hz were greater on fingers with sensorineural scores of 3 and 6 than on fingers with a sensorineural score of 1 (p<0.05). There were no significant differences at 31.5 or 125 Hz between fingers with sensorineural scores of 3 and 6 (p=0.092-0.418).

The sensitivities and specificities for vibrotactile thresholds to distinguish between fingers with and without sensorineural symptoms were, respectively, 80% and 91% for thresholds at 31.5 Hz and 82% and 91% for thresholds at 125 Hz. The AUC and 95% confidence intervals were 0.90 (CI: 0.84 to 0.96) for 31.5-Hz thresholds and 0.91 (CI: 0.85 to 0.97) for 125-Hz thresholds (Figure 2).

Discussion

The study found impaired thermal perception on fingers with sensorineural symptoms that are innervated by both the median nerve (index finger) and the ulnar nerve (little finger). The findings appear consistent with other studies showing thermal dysfunction in the fingers of various groups of vibration-exposed workers[3,4,5].

Vibrotactile thresholds at 31.5 and 125 Hz reflect the responses of two different mechanoreceptors in the skin, and their afferent fibres[2]. The impaired vibrotactile thresholds in this study are consistent with other studies suggesting vibration perception thresholds can be used to assess sensory loss in the fingers of vibration-exposed workers with sensorineural symptoms[3,4,5].

The study also found that both thermotactile thresholds and vibrotactile thresholds were more impaired in patients with a greater extent to their sensorineural symptoms, suggesting that thermotactile and vibrotactile thresholds can reflect the severity of nerve damage[6,7].

A deterioration in thermotactile or vibrotactile thresholds in a finger of a vibration-exposed worker is not sufficient to diagnose the sensorineural component of the hand-arm vibration syndrome. Symptoms in the same finger, the absence of alternative explanations for the signs and symptoms, and the extent of exposure to hand-transmitted vibration also need consideration.

Conclusion

Both thermotactile thresholds and vibrotactile thresholds appear to provide useful indications of whether a finger has sensorineural symptoms. Impaired thermotactile and vibrotactile thresholds on fingers with greater sensorineural scores suggest these thresholds also provide useful indications on the severity of sensorineural disorder[8].

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Diagnostic value of high-frequency ultrasonography in testing carpal canal structure in patients with occupational hand-arm vibration disease

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High-frequency ultrasonagraphy; Hand-arm vibration disease; Median nerve; Cross-sectional area; Carpal canal.

Introduction

Hand-arm vibration disease (HAVD) is one of legal occupational diseases in China, it’s induced by long-term use of vibration tools and stationary tools that transmit vibration through a work-piece[1]. At present, the criterion of diagnosis of occupational hand-arm vibration disease is based on occupational history and clinical manifestations, combined with EMG test and field occupational health survey, in contrast, image examination is rarely used. However, with the development of ultrasound technology, high-frequency ultrasound examination can clearly show the structure of carpal canal, so it can be used as a diagnostic imaging basis. In this paper, we aimed to evaluate the clinical value of high-frequency ultrasound in testing carpal canal structure in the diagnosis of patients with occupational hand-arm vibration disease.

Methods

Eighteen patients with occupational mild HAVD (36 wrists) were selected as the case group and 20 healthy volunteers (40 wrists) were enrolled as the control group by using convenience sampling method. The color doppler ultrasound was used to measure the cross sectional areas (CSA) of median nerve at the level of pisiform bone，the thickness of transverse carpal ligament，and the internal diameter of median nerve and the CSA of median nerve at the level of hamate hook of the 2 groups. Fisher discriminant analysis and receiver operating characteristic (ROC) curve were performed to assess the effect of diagnosing HAVD with the CSA of median nerve at the level of pisiform bone in patients with HAVD [2].

Results

The CSA of median nerve at the level of pisiform bone in both hands was smaller than that of the control group (P＜0. 01). However，there was no statistical significance in the thickness of transverse carpal ligament of both hands，the internal diameter of median nerve and the CSA of median nerve at the level of hamate hook in the case and control groups (P＞0. 05). It’s shown in table 1.

Through the Fisher discriminant analysis which was carried on and the distinction equation which was established meanwhile by using the CSA of median nerve at the level of pisiform bone in both hands as HAVD diagnostic criterion，the HAVD predictive accuracy rate was 78.9%. The ROC curve was underway with the discriminant score as an indicator for distinguishing HAVD, and the result showed that the area under the curve was 0.842，with sensitivity of 75.00% and specificity of 88. 90%.

Table 1

Groups	CSA of median nerve at the level of pisiform bone (mm2)		Thickness of transverse carpal ligament at the level of hamate hook (mm)		Internal diameter of median nerve at the level of hamate hook (mm)		CSA of median nerve at the level of hamate hook (mm2)	
	Left hand	Right hand	Left hand	Right hand	Left hand	Right hand	Left hand	Right hand
Control group（20）	10.15±0.02	9.65±0.02	3.06±0.02	3.05±0.04	2.15±0.02	2.22±0.02	9.55±0.02	9.35±0.02
Case group（18）	8.44±0.01	8.22±0.01	3.14±0.03	3.04±0.04	2.11±0.02	2.24±0.02	8.78±0.02	8.89±0.01
F	7.70		0.46		1.83		1.26	
P	＜**0.01**		0.64		0.18		0.30	

Comparison of high-frequency ultrasound examination between two groups (x ± s)

Discussion

Previous diagnostic method of HAVD could evaluate the neurological function, but it could not show the anatomic structure of peripheral nerves and the relationship with the adjacent structures directly, nor provide morphological changes caused by nerve compression. X-ray and MRI can make up for these defects, but they are time-consuming and expensive. In recent years, High-frequency ultrasound is widely used in diagnosis of Carpal tunnel syndrome CTS, for it can clearly show the structure of carpal tunnel and compressed position of median nerve[3].

Although our target disease is HAVD, the study results of CTS have some referential significance for us. The result about CSA of median nerve at the level of pisiform bone is consistent with various CTS studies[4]. The reduction of CSA may be associated with weakness of anterior wall of median nerve, the oppressed nervechanged the nerve medial diameter. In contract, there was no significant change in the thickness of transverse carpal ligament of both hands and the CSA of median nerve at the level of hamate hook. We think this is because transverse carpal ligament is relatively thin (m＜3.5 mm), and the median nerve is relatively narrow (m＜2.5 mm), and the hamate hook bone in horizontal position is deep, so it’s difficult to be measured by ultrasound. Therefore, the accuracy of the data is reduced. CTS studies in this respect have not arrived at a unified conclusion either.

In related studies, median nerve CSA were used to diagnose CTS, and the results show sensitivity ranges from 67.00% to 94.00%, specificity ranges from 57.00% to 97.00% [5], these are consistent with the results of our study. But our specificity and sensitivity are at low levels, which may be related with severity of our patient’s disease, they are all mild cases. HAVD is a progressive disease that first affects the distal end of the finger and then spreads to the proximal end of the finger, palm, wrist, and arm. Besides, HAVD injuries of nerves involving both hands, CTS affects only one hand and only median nerve. The characteristics of the disease are different, so lead to different results.

Conclusion

High-frequency ultrasonography can be used to observe and quantify the imaging changes of carpal canal structure in patients with HAVD，which can provide objective and scientific diagnostic basis for the diagnosis of HAVD．

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Raynaud's phenomenon and cold sensitivity in Northern Sweden – the impact of hand-arm vibration

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Raynaud's phenomenon; Occupational exposure

Introduction

Raynaud's phenomenon (RP) is a common occupational injury among subjects exposed to hand-arm vibration (HAV) [1]. Cold sensitivity (CS) has been defined as a collection of acquired symptoms resulting in an abnormal aversion to cold with pain, sensory alterations, stiffness and/or color changes, which may occur after an injury such traumatic amputation of digits or the HAV syndrome [2]. CS is often distinguished from RP by the fact that there is no clinically observable vasospasm present in CS, which is mandatory for a firm diagnosis of RP.

The objective of this project [3-5] was to determine the prevalence of CS and RP in Northern Sweden and the association to occupational HAV exposure. We also wanted to distinguish between RP cases who concomitantly reported CS from those who did not.

Methods

A first questionnaire was sent out to a sample of men and women (N=35 144), aged 18–70, living in the four northernmost counties in Sweden: Norrbotten, Västerbotten, Västernorrland and Jämtland. Subjects with RP and CS were identified, and a subset invited to participate in a second data collection effort for a nested case–control study.

In this study, cases with RP (N = 578), and matched controls (N = 1 156), were asked to respond to a questionnaire focusing on different risk factors. Univariate and manual stepwise forward multiple conditional logistic regression were performed. For the multiple model, in each step, the factor with the lowest *p* value when added was included, and the procedure stopped when no variable with a *p* value <0.25 when added remained. All analyses were stratified according to whether the RP cases reported concomittant CS or not.

Results

In the first data collection, 12 627 out of 35 144 subjects responsed (response rate 35.9%) and the prevalence of RP and CS was 12.4% and 4.0%, respectively. In the subsequent nested case–control study, 1400 out of 1734 study subjects answered the questionnaire (response rate 80.7%).

In the univariate logistic regression analyses, occupational HAV exposure of any type was significantly related to being a case reporting CS and RP (OR 1.98; 95% CI 1.23–3.19) but not with reporting only RP (OR 1.19; 95% 1.0.76–1.86).

Table 1: Univariate logistic regression showing odds ratios for reporting Raynaud's phenomenon (RP) and cold sensitivity (CS) in relation to a variety of occupational hand-arm vibration (HAV) exposures.

	Cases (N=228)		**Controls (N=379)**		
Exposure	**N**	**%**	**N**	**%**	**OR (95% CI)**
Impact tools	39	17.4	28	7.5	**2.6 (1.5–4.5) ***
Rotating tools	7	3.2	5	1.3	2.0 (0.6–6.4)
Forestry tools	35	15.8	50	13.5	1.4 (0.8–2.5)
Vibrating tools [a]	44	19.6	40	10.8	**2.2 (1.3–3.8) ***
Heavily vibrating tools [b]	39	17.5	32	8.6	**2.8 (1.5–5.2) ***
Vehicles with vibrating controls	34	15.2	36	9.7	**1.9 (1.1–3.4) ***
Any HAV	67	31.0	79	21.5	**2.0 (1.2–3.2) ***

(Table adopted from reference [5])

** Bold values indicate odds ratios (OR) vid significant 95% confidence intervals (95% CI).*

[a] *E.g. screwdrivers, drilling machines and belt sanders.*

[b] *E.g. reciprocating saws, oscillating sanders and soil compactors.*

In the final multiple model for cases reporting RP and CS, the following factors remained, reported in the same sequence as added to the model: frostbite affecting the hands (OR 12.4; 95% CI 5.8–26.5); heredity for RP (OR 4.0; 95% CI 2.2–7.5); BMI ≥ 25 kg/m^2 (OR 0.3; 95% CI 0.2–0.5); upper extremity nerve injury (OR 2.2; 95% CI 1.3–3.9); and work with cold objects (OR 1.7; 95% CI 0.9–3.3).

For cases reporting only RP, the final multiple model included the following factors: frostbite affecting the hands (OR 4.0; 95% CI 1.8–9.0); heredity for RP (OR 5.1; 95% CI 2.8–9.2); BMI ≥ 25 kg/m^2 (OR 0.5; 95% CI 0.4–0.8); daily tobacco use (OR 1.6; 95% CI 1.0–2.6); heavily vibrating tools (OR 1.5; 95% CI 0.7–2.9); high leisure-time cold exposure (OR 1.3; 95% CI 0.9–2.1); migraines (OR 0.6; 95% CI 0.3–1.2); and heredity for migraines (OR 1.4; 95% CI 0.8–2.2).

Discussion

The proportion of reported RP in the first data collection was higher than anticipated, especially since the setting entailed the general population of Northern Sweden and not a specific HAV-exposed worksite or similar. One concern is that the low response rate might have limited the generalizability of the results and increased the uncertainty in the prevalence estimates. However, a non-responder analysis revealed no major differences in demographical factors compared to responders. To compare with other studies, in a recent review, the prevalence of primary Raynaud's phenomenon was estimated to be 0.8–6.5% in men and 2.1–5.8% in women, with the exact figure depending on the region in which the study was conducted and how a case was defined [6]. In a Finnish study [7], performed in similar climate, the prevalence of Raynaud's phenomenon was 11.9% for men and 12.4% for women, which compares well with our results. High occurrences might indicate secondary etiologies, such as HAV injury or auto-immune diseases, but the cold climate in Sweden and Finland might also trigger Raynaud's phenomenon more easily than in a warmer climate. For cold sensitivity, one previous study [8] have reported a prevalence in the general population of 4.9%, which is well in line with the results of the present study.

In the univariate analyses, cases with RP and simultaneous CS showed an association to occupational HAV exposure that was not present among cases only reporting RP. It is plausible that the latter group to a higher extent consisted of subjecs with primary RP, where occupational factors are not causal. An alternative explanation would be that the group with only RP had less severe disease, where long-standing vibration exposure had not yet been obtained. Also, when sex-specific subanalyses were made, HAV exposure was only significant for men (data not shown). This indicates that there are sex differences in exposure that have not been accounted for in the study design.

In the multiple model, HAV was not a strong predictor of the outcome. Instead, frostbite, heredity for RP and high BMI (protective) remained in both case groups. Upper extremity nerve injury only remained in the group reporting RP and CS. When comparing effect sizes in the multiple model, the odds ratio for frostbite was much higher among those reporting RP and CS compared to the other group. Previous studies have shown cold injury to be a risk factor for the development of both RP [9] and CS [10]. The fact that upper extremity nerve injury was the only remaining factor that differed between case groups in our multiple model, offers additional support to the neural basis for CS [11].

Conclusion

Both Raynaud's phenomenon and cold sensitivity are common among the working population in Northern Sweden. Hand-arm vibration exposure is also prevalent, but not a major predictor of reporting Raynaud's phenomenon or cold sensitivity in this population sample. Instead, previous cold injury affecting the hands seems to be the strongest risk factor, with a larger effect size among those who report both Raynaud's phenomenon and cold sensitivity simultaneously. Our reults implies that previous cold injury should be taken into account when performing studies on the HAV syndrome.

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Dose–response relationships and factors influencing the occurrence of the hand-arm vibration syndrome associated with the grinding of handheld workpieces in a subtropical environment

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Introduction

The hand-arm vibration syndrome (HAVS) has been studied extensively in temperate climate countries; however, there has been only a limited number of studies aimed at populations within subtropical and tropical areas. The results of several researches performed in tropical environments showed that the HAVS tends to be characterized predominantly by the neurological component without the occurrence of vibration white finger (VWF)[1,2]. In recent years, the occurrence of HAVS within workers grinding handheld workpieces has been reported in a subtropical area in the south of China and most cases have been diagnosed with VWF[3]. The exposures resulting from vibration being transmitted to the hands and fingers through handheld workpieces have not been sufficiently studied. It is observed that with the grinding of handheld workpieces, the fingers have a more direct contact with the vibration source, the high frequency vibration is predominant and the use of anti-vibration gloves is generally excluded[4]. This study aims to provide an understanding of the risks of developping the HAVS for a population exposed to vibration resulting from the grinding of handheld workpieces in a subtropical environment.

Methods

A total of 803 grinding workers forming the exposure group were recruited by cluster sampling within a large sport equipment factory of golf club heads in the Guangdong province of China characterized by a subtropical climate. A group of 464 workers not exposed to hand-transmitted vibration were recruited as the control group within the same factory. The age of the participants involved in this study ranged from 20 to 50 years old and those with any of the following medical conditions were excluded: history of current hypertension, diabetes, hepatitis, nephritis, immunological diseases or trauma (muscular, neural and osseous). The main information was obtained by a questionnaire which included four parts: basic personal information, employment status, habits, medical history and clinical characteristics. The section on the clinical characteristics included recording evidence of finger blanching, finger numbness, tingling, coldness, dullness, deformity and the time of occurrence and severity of the disorder for each participant reporting symptoms associated with the HAVS. Identification of the fingers and phalanges affected was also made when the participants reported episodes of finger blanching.

Results

The results presented in Table1 show that 15.4 percent of the workers within the exposure group reported having had finger blanching, while no people in the control group reported any such occurrence. Finger blanching occurred in the winter, mostly in the morning. The results presented in Table 2 show that only 1 case (1.2%) was reported for an exposure duration of less than 2 years; 21 cases (10.6%) for a duration ranging from 2 to 5 years, 32 cases (15%) for a duration ranging from 5 to 10 years and 70 cases (22.7%) for an exposure duration of more than 10 years. Applying Pearson's correlation analysis to those results, the incidence rate of finger blanching was found to be positively correlated with the duration of exposure or work duration. In the 124 people reporting finger blanching episodes, 31 people (25.0%) reported that blanching only involved the distal phalange, 67 people (54.0%) reported blanching in at least one finger and two phalanges, 26 people (21.0%) reported blanching in at least one finger and three phalanges.

Among the effects associated with peripheral nerve disorder, the results shown in Table 1 indicate that the most frequent symptom that was reported by the workers exposed to vibration was hand numbness. In total, 27.5% of the workers in the exposure group reported occasional or frequent hand numbness, which was significantly higher than the 6.3% reporting such symptom in the control group. The other self-reported symptoms in the exposure group, namely hand coldness and hand tingling was 5.9% and 4.5% respectively, which was significantly higher than the rates in the control group, 2.6% and 0.2% （$P<0.05$）. Symptoms of finger numbness first appeared after an exposure duration of 12 month. According to the results presented in Table 2, the rate of hand numbness in the exposure group was reported to be 12.2% after an exposure duration of less than 2 years, 23.2% after 2 to 5 years of exposure, 26.3% after 5 to 10 years and 35% after more than 10 years. On the basis of Spearman's correlation, the incidence of finger numbness was positively correlated with the exposure duration to vibration.

The results presented in Table 3 show that the work exposure duration, ethnicity and means of transportation are positively identified as risk factors with regard to the occurrence of finger blanching. Taking the subgroup exposed to vibration for less than 2 years as a reference, the values presented in Table 3 showed that the OR value for an exposure duration from 2 to 5 years is 9.13, that from 5 to 10 years is 12.67, while it reaches 20.42 for more than 10 years of exposure. The effects of vibration on peripheral nerve were found to be related to the work exposure duration and ethnicity. The longer the exposure was, the higher the risk was found to be. Furthermore, Han people were found to be at higher risk for hand numbness and finger blanching than other ethnic minorities and motorcycle riding led to a higher risk for finger blanching.

Table

Table 1: Self-reported symptoms in both the exposure and control groups.

symp-toms	control group N=464(%)	exposure group N=803(%)	Total	χ^2	*P*
Finger blanching	0	124 (15.4%)	124 (9.8%)	79.43	0.00
Finger numbness	29（6.3%）	221（27.5%）	250（19.7%）	84.02	0.00
Finger tin-gling	1（0.2%）	36（4.5%）	37（2.9%）	18.89	0.00
Hand cold-ness	12（2.6%）	47（5.9%）	59（4.7%）	7.07	0.008
Deformity of finger(s)	0	3（0.4%）	3（0.2%）	1.74	0.19

Table 2 Self-reported symptoms for different exposure durations in months in the exposure group.

symp-toms	~23 months N=82（%）	24~59 months N=198（%）	60~119 months N=213（%）	120 months~ N=309（%）	Total N=803（%）	χ^2	*P*
Finger blanching	1 (1.2%)	21 (10.6%)	32 (15.0%)	70 (22.7%)	124 (15.5%)	28.56	0.000
Finger numb-ness	10（12.2%）	46（23.2%）	56 (26.3%)	108 (35%)	220 (27.4%)	20.23	0.008
Hand coldness	2 (2.4%)	8 (4.0%)	12 (5.6%)	25 (8.1%)	47 (5.9%)	5.73	0.125
Finger tin-gling	1 (1.2%)	10 (5.1%)	7 (3.3%)	18 (5.8%)	36 (4.5%)	4.20	0.24

Table 3 Logistic regression analysis of the factors identified as influencing the occurrence of finger blanching and numbness

Affecting factors		*OR* (95%CI) Finger blanching	Finger numb-ness
Exposure duration	~23months	1	1
	24~59 months	9.13(1.20, 69.25)	3.82(2.44, 6.15)
	60~119 months	12.67(1.69, 94.81)	4.45(2.85, 6.96)
	120 months ~	20.42(2.78,150.09)	6.60(4.42, 9.84)
Ethnic group	Ethnic minori-ties	1	1
	Han people	5.0(1.19, 21.00)	2.02(1.01, 4.03)
Means of transpor-tation	Walking or au-tomobile	1	—
	electric bicycle	1.30(0.71, 2.40)	—
	Motorcycle	1.76(1.13, 2.75)	—

Discussion

Most results of studies reported in the literature have shown that the workers exposed to hand transmitted vibrations in subtropical and tropical regions did not show evidence of finger blanching, while some studies have shown different rates of self-reported hand coldness (1.5%~42.4%)[1,2,5]. In comparison, this study revealed self-reported symptoms of finger blanching occurring in 15.4% of a population of handheld workpiece grinding workers in subtropical area. In this study, the average vibration exposure level of grinding workers was about 5m/s^2. On the basis of the dose-response relationship proposed in the ISO 5349-1 standard, for an exposure dose value equivalent to A(8)= 5 m/s^2 , it would take about 6 years (72 months) for 10% of the workers to show symptoms of finger blanching. This study suggests rather that finger blanching for 10.6% of the workers could occur as early as 24 to 59 months following the beginning of the exposure, thus with a latency period considerably lower than that predicted by the ISO model. Three reasons could explain these results: 1) vibration transmitted through hand-held workpieces as opposed to hand-held tools could introduce additional stress to the hands and fingers due to increased contact with the vibration source; 2) the intensity of the vibration exposure characterized by the high levels of vibration and long exposure periods; and 3) the high frequency content of the vibration which would not be sufficiently taken into account in the current Wh frequency weighting applied by ISO [5].

Researches have shown that in temperate and tropical regions, the common symptoms of peripheral nerve damage related to HAVS are finger tingling and numbness. However, the dose-response relationship between hand transmitted vibration exposure and injury of peripheral nerve is still unclear at present. The results of this study showed that 12.2% of exposed workers reported numbness within two years of exposure. The results also indicated that the onset of neurological symptoms is earlier than that of white fingers. This suggests that the current occupational exposure limit which is based on the occurrence of white fingers would not adequately protect against the occurence of nerve injury.

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Shoulder disorders among workers exposed to hand-arm vibration : A review of literature

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Introduction

Workers using vibrating handtools are often simultaneously exposed to various biomechanical and organisational risk factors kown to be of etiological importance in the developement of shoulder disorders. Accordingly, data describing the specific effect of hand-arm vibration exposure on the shoulder is currently lacking. However, hand-arm vibration often appears to be an important co-factor in the developement of shoulder pain/disorders.

Shoulder disorders are frequent in the working population with a prevalence rate for non-specific shoulder pain of up to 31%[1] and as high as 6% to 11% under the age of 50 years old.[2] Shoulder pain ranks third among musculoskeletal disorders as the reason for clinical consultation, behind low back pain and cervical pain.[3]

Shoulder disorders affect the shoulder's functional status and the quality of life of the individuals who suffer from them. In the case of workers, it can lead to absenteeism and loss of productivity. In 2005-2007, the costs generated annually by shoulder injuries that were covered by the Workers compensation board (CNESST), including human costs and costs associated with loss of productivity, totaled $393,204,738.

In 1981, Bjelle et al. reported that both individual factors such as constitution, age or disease, and external factors such as trauma from occupation or other activities are of etiological importance.[2] A number of epidemiological studies reporting on potential risk factors for shoulder pain have also been done in the past decade.

A recent systematic review and meta-analysis has shown moderate evidence that arm-hand elevation and shoulder load double the risk of specific shoulder disorders. Low to very-low-quality evidence was found for an association between hand force exertion, hand-arm vibration, psychosocial job demands and working together with temporary workers and the incidence of specific shoulder disorders.[5]

Conflicting results for the role of hand-arm vibration associated with the onset of shoulder disorders are reported.[6-7-8] In fact, repetitive use of a handheld vibrating tool such as a grinder is often associated with flexion of the shoulder, shoulder load and hand-force exertion among the biomechanical factor described as an important risk factor of RCS.

The purpose of this study is to examine the risk factors associated with shoulder disorders, to isolate the exposition to vibration as a risk factor for shoulder disorders for a working population, to report the number of tendinitis claims by the CNESST in association with handheld vibrating tools, to isolate the exposition to "vibration" as a risk factor in shoulder disorders for a working population and to evaluate potential solutions for workplaces.

Methods

Our research strategy aimed for articles published in French and English on Medline and Embase from 1974 to 2018 relating the association between risk factors and specific shoulder disease will be completed using key-words/Mesh descriptors centered around three major concepts: shoulder diseases, work and vibrations. Data collection included study design, assessment of outcome, subject age, occupation, years of exposure, tool type, tool acceleration, diagnosis, biomechanical risk factors, organisational risk factors and psychosocial risk factors. Ergonomic evaluation of three worplaces will be presented as examples during the presentation (i.e. Figure 1).

Results

As of the literature review, 592 articles were retained during the initial research and 24 were added from a previous one (Turcot, A. 2018). After a first selection, 66 full text articles were retained for analysis. Our preliminary results show that there are very few epidemiologic studies on shoulder disorders among workers exposed to handheld vibrating tools. Preliminary results show that there are very few publications on shoulder disorders among workers exposed to HAV. Also, there are very few data isolating the vibrations and/or demonstrating a dose-response relation between vibration exposure and shoulder disorder.

Discussion

Incriminating a specific tool, vibration frequency or vibration acceleration cannot be ascertained as there are too few data relating this issue. Other biomechanical, organisational or psychosocial risk factors can be related to the onset of the shoulder disorder. Consequently, the complete risk assessement is not complete as shown on figure 2.

Conclusion

Prevention of occupational shoulder diseases is a challenge as many risk factors must be assessed and the contribution of concommitant vibration needs to be fully understood to identify adequate preventive mesures. The relation between vibrations and shoulder disease remains to be properly documented. Our results show that there are insufficient data to identify the contribution of a specific tool and to distinguish the contribution of low and high frequency tools.

Figure

Figure 1: Foundry worker and shoulder abduction

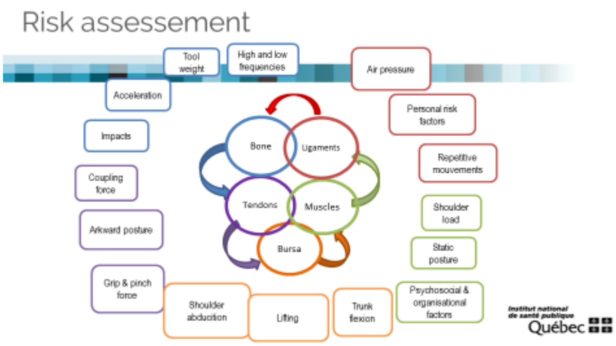

Figure 2 : Risk assessement

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A Sentinel Health Investigation of Carpal Tunnel Syndrome (CTS) in a Railway Maintenance-of-way worker – International Comparison of HAV Emission Information for Hand-tools

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Keywords:
Sentinel Health Investigation 1; Occupational HAV Exposure 2; HAV emission information comparison 3

Introduction

As part of a sentinel health investigation for a railway maintenance-of-way worker (MoW) with bilateral carpal tunnel syndrome (CTS) the information of vibration emission of tools used in the specialized railway construction trade was researched. A further goal of this study was to review and compare published manufacturer information for users of hand-tools used in the rail-maintenance and construction industries in North America (NA) and the European Union (EU).The EU Machinery Directive mandates that manufacturers inform the EU user of hand-held tools about the vibration values emitting acceleration exceeding a=2.5 m/s^2[1]. Emission assessment and declaration guidelines exist (ISO 20643 and EN 60745) [2].

Methods

In a medical case evaluation following a differential diagnostic methodology established in occupational medicine, a) the clinical diagnosis, b) an exposure assessment and c) a causal relationship was assessed for a MoW-worker with bilateral hand symptoms typical for CTS and an hydraulic impact wrench in question. In addition to the case-specific occupational history, the exposure-time history and work practices were inquired. The specific tool manufacturer vibration information for the impact wrench was compared with actual field measurements to investigate the magnitude of exposure using a Svantek SV106 and sensor SV105A devices compliant with ISO 8041 (2005) following professional guidelines. Furthermore, a product information internet search of typical hand-operated tools of MoWs was performed utilizing online resources provided for the specific EU and North American market. To filter manufacturer vibration emission information for users of different geographical regions (regional internet registries: ARIN and RIPE NCC) a search browser VPN extension (ZenMate) was utilized using the same search terms. In addition, vibration data from independent or governmental sources was compared with manufacturer information, i.e., Network Rail [3].

Results

The clinical diagnosis of the sentinel case (59-year-old male MoW track worker; with a 40 y work history) was established based on the occupational history, clinical and neurological findings (i.e., positive Tinel and Phalen test) and a nerve conduction study (EMG/NCS) showing bilateral distal motor and sensory latencies of the median nerve, consistent with severe CTS. Patient underwent a bilateral endoscopic carpal tunnel release surgery with volar forearm fasciotomy complicated by a post-op wound infection and subsequently filed a claim for permanent total disability. Based on the occupational history among other typical MoW hand-tools primarily a hydraulically powered impact wrench was used over the period of 24+ months to check and fasten rail/track bolts several times for several minutes per day, with regular work gloves and during all seasonal outdoor temperature extremes. Field measurements of the impact wrench (weight 26 lbs.) emission showed a vector sum result range of $a_h v_{1-3}$ = 13 to 37 m/sec^2. A commercially available similar impact wrench with a weight of 12 kg was listed by the manufacturer in the online available user manual with an emission of a=49 m/sec^2 and uncertainty (K) 5.2 m/sec^2 according to ISO 8662-7 [4].

A general comparison of leading EU and NA manufacturers' (n=18) hand-powered tools shown in the respective web sites, on-line available sales catalogues and product manuals showed either no, partial or inconsistent listings of vibration emissions data for users of MoW-specific tools such as breakers, tamping guns, spiking guns, rail drills, grinders, spike pullers/drivers, tampers and saws. Vibration emission ranges of commonly used MoW hand-tools listed by manufacturer and independent sources are shown in table 1. Only one international manufacturer listed in both EU and NA markets vibration emission information following the ISO recommendation. The majority of manufacturers in both markets (n=17) did not follow the ISO recommendations to list the vibration levels (a_h,) uncertainty factor (K), and the utilized measurement standard. In the EU, one third of the listings showed the required emission information and the measurement standard was mentioned in 40%. In the NA market only about 20% of the hand-tool user information by manufacturers provided some vibration information and more than half had no emission listing at all. Furthermore, manufacturer used different measurement standards for their laboratory vibration measurements of hand-tools, limiting a comparison of similar tools from different manufacturers.

Discussion and Conclusion

Upper extremity and hand injuries associated with hand-tools, such as CTS may lead to irreversible painful and disabling conditions that can result in cessation of work and employment. In a recent epidemiological study of active MoW union members and retirees in the USA, nearly 10% reported having been physician diagnosed with 'carpal tunnel syndrome' (n=370, 9.7%) [5]. Principally, HAV injuries are avoidable with proper engineering controls, exposure time management and medical monitoring. Early recognition of health hazards and intervention are important to prevent such adverse health outcomes. It is known, that as a general principle HAV emission should be kept as low as possible or below the current EU action limit of 2.5 m/s^2, keeping in mind that a definite threshold level for CTS or Raynaud' s disease has not been established and exposure should be controlled and limited. This sentinel health investigation and emission study shows that users in construction or rail industries often face practical difficulties in obtaining important safety and health information for tools with HAV risk to educate workers and monitor health outcomes. In the North-American market compared to the EU only very limited information and specific data of HAV emissions of hand tools is provided by national and international manufacturers in the NA market. Vibration measurements and performance of hand-tools may differ considerably under laboratory and field applications. Field measurements of rail-tools would be important to further assess and quantify workers' exposures.

Table

No	Tool	Manufacturer & Reference generic (***)	Emission $m/s^{2*/**/***}$
1	Tamper/ Breaker	Atlas-Copco, Bosch, Wacker Neuson, et al	4.2- 12,.8
2	Breaker	Makita, Chicago, et al	8-30
3	Impact wrench	Bance, Stanley , GT, Hilti, Makita, Cembre, Maxin, et al, IFA & NIOSH Power Tools Database (PTD)	4-49
4	Rotary hammer drill	Bosch, Hilti, Hitachi, IFA generic range	12-31
5	Hammer drill	Makita, IFA generic	7-16
6	Drill cordless	Hilti, DeWalt, Milwaukee	15-21
7	Tamper (vertical)	Robel	5.7
8	Rail head scrubber	Geismar	7.1
9	Rail / chain saws	Husqvarna	6.3 - 10.2
10	Angle grinder	Makita, IFA generic range	4 -13.5
11	Jack hammer	Chicago, Atlas Copco	15.3 - 29
12	Rock Drill	Atlas Copco	21.2

*Sources: Mfr., NetworkRail [NetworkRail, 2017] , IFA*** [Christ, 2010], NIOSH Power Tools Database (PTD) [NIOSH, 2018], own data (**)*

Table 1: Maintenance-of-way powered handtools vibration emissions > 5 m/sec^2 listed by manufacturers and from independent/governmental data bases.

Figure

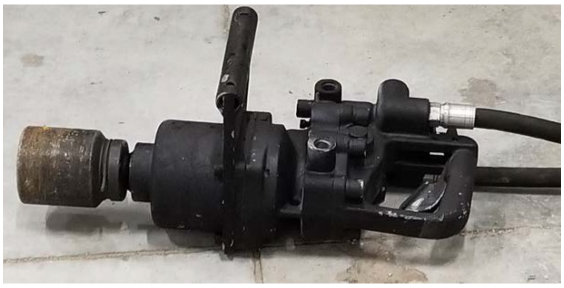

Figure 1: Impact wrench used for track/rail bolts in the railway maintenance-of-way industry

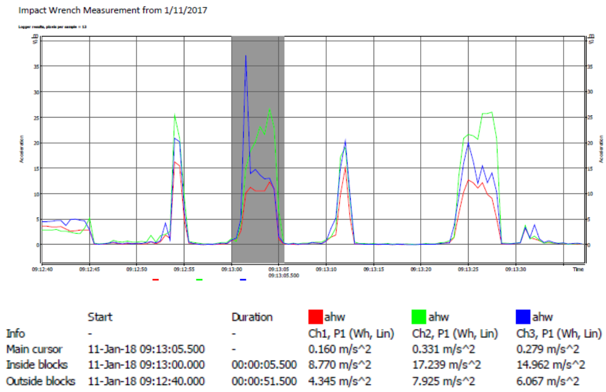

Figure 2: Vibration time signal of impact wrench shown in Fig 1 used in the railway maintenance-of-way industry

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Assessing the vascular component of the hand-arm vibration syndrome (HAVS): Sensitivity and specificity of standardized tests

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Abstract

In 60 males reporting symptoms of the hand-arm vibration syndrome, this study investigated the sensitivity and specificity of two standardized tests for detecting fingers with attacks of cold-induced blanching. Times for fingers to rewarm by 4°C (after immersion in 15°C water for 5 minutes) and finger systolic blood pressures (FSBPs) at 30, 15, and 10°C were measured on all four fingers of the right hand. The finger rewarming test had a sensitivity of 77% and a specificity of 79%, whereas the FSBPs had sensitivities and specificities >90%. Although both tests may be considered to have 'good' discriminability, the FSBPs had greater sensitivity and greater specificity and reflected the extent of reported finger blanching.

Keywords:

Vibration-induced white finger; Hand-transmitted vibration

Introduction

Vibration-induced white finger (VWF) is the vascular component of the hand-arm vibration syndrome (HAVS). The diagnosis of VWF often relies on a report of cold-induced finger blanching and an appropriate exposure to hand-transmitted vibration. The occurrence of cold-induced finger blanching suggests patients suffering from VWF have digital blood vessels that over-respond to cold. In Parts 1 and 2 of ISO 14835:2016, two cold provocation tests are recommended: the measurement of finger rewarming times after cold provocation[1] and the measurement of finger systolic blood pressures during cold provocation[2].

This paper reports an investigation of the sensitivity and specificity of the finger-rewarming test and the finger systolic blood pressure test in detecting which fingers are reported to experience blanching, and whether the tests distinguish between fingers with differing extent of reported cold-induced whiteness. The tests were compared in a group of males who reported symptoms of HAVS.

Methods

Sixty male patients referred for HAVS assessment at the Institute of Sound and Vibration Research (University of Southampton) agreed to participate in the study. The study was approved by the Ethics Committee of the Faculty of Engineering and the Environment at the University of Southampton (10704).

An *HVLab* 8-channel temperature monitor measured finger skin temperature (FST) rewarming times following cold provocation. After a settling period of 2 minutes with both hands at heart level, the lightly gloved right hand was immersed in stirred water at 15°C for 5 minutes. The hand was then removed from the water, the glove removed, and the hand kept at heart level to rewarm for 11 minutes.

An *HVLab* plethysmograph measured finger systolic blood pressures (FSBPs) following cold provocation of the digits. Water-perfusable cuffs were placed around the middle phalanx of each finger, with a separate air cuff around the thumb as a reference. Strain gauges were placed at the base of the finger nails of cuffed fingers. The FSBPs were measured on the right hand after cooling by water circulating at 30, 15, and 10°C. The FSBP was the cuff inflation pressure at which arterial inflow returned to the finger. Percentage changes in finger systolic blood pressures (%FSBPs) were calculated.

Data analysis was performed using the software package SPSS (version 22.0). Non-parametric statistical tests were employed with a significance criterion of p=0.05.

The diagnostic criteria used in the study were: (i) longer than 300 s for FST to rewarm by 4°C, (ii) %FSBP less than 80%[3]. Receiver operating characteristic (ROC) analysis showed the effects of varying these criteria.

Results

The ROCs are shown for finger rewarming times in Figure 1 and for %FSBPs at 15°C and 10°C in Figure 2.

On fingers with whiteness, there were no significant differences in rewarming times between different whiteness scores: 1, 3, 6 (p=0.07-0.47), where 1 indicates whiteness on the distal phalanx, 3 on distal and middle phalanges, and 6 on all phalanges.

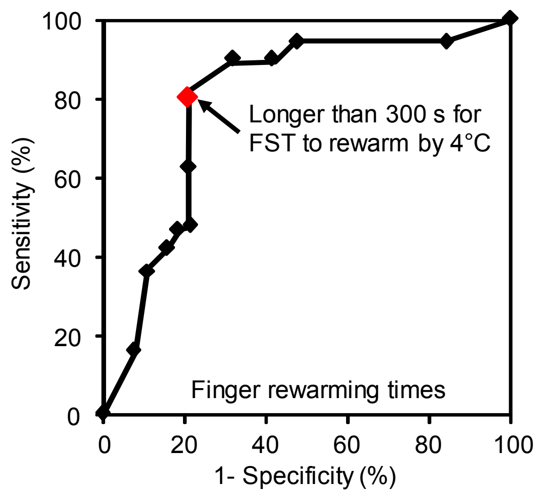

Figure 1: Receiver operating characteristic (ROC) for finger rewarming times (red marker indicates the diagnostic criterion: time to rewarm by 4°C[3]).

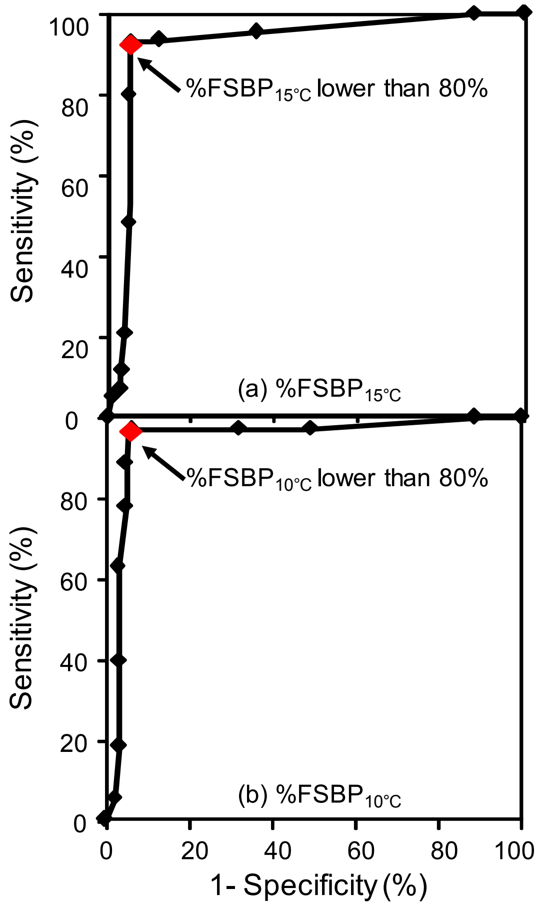

Figure 2: Receiver operating characteristic (ROC) for %FSBPs at 15°C and 10°C (red markers indicate the diagnostic criteria: %FSBP less than 80%[3]).

The sensitivity and specificity of the finger rewarming test were 77% and 79%, respectively, with an AUC of 0.80 (confidence interval 0.74-0.85) (Figure 1).

On fingers with whiteness, %FSBPs (at both 15 and 10°C) were lower on fingers with a blanching score of 6 than on fingers with blanching scores of 1 or 3 (p<0.01). There were no significant differences in %FSBP at either 15 or 10°C between blanching scores of 1 and 3 (p=0.07-0.29).

The sensitivities and specificities of the %FSBP test were, respectively, 93% and 95% for $\%FSBP_{15°C}$ and 97% and 95% for $\%FSBP_{10°C}$. The AUC was 0.93 (confidence interval 0.89-0.96) for $\%FSBP_{15°C}$ and 0.95 (confidence interval of 0.91-0.98) for $\%FSBP_{10°C}$ (Figure 2).

Discussion

The previously determined diagnostic criterion for finger rewarming (longer than 300 s for FST to rewarm by 4°C) provided a useful indication of fingers with and without symptoms of VWF[3]. This is consistent with studies concluding finger rewarming can distinguish between groups of patients with and without VWF[4,5]. However, rewarming durations did not depend on the finger whiteness scores (1, 3, or 6), suggesting finger rewarming times may not indicate the extent of the vascular disorder. The sensitivity and specificity of the rewarming test can be influenced by test conditions and assessment protocols and can be lower than found in this study [4,5].

The %FSBPs were more powerful indicators of whether a finger experienced blanching, with sensitivities and specificities greater than 90% and an AUC greater than 0.9. Using the same conditions and criteria, previous studies have reported a sensitivity 84-99% and specificity 94-100% when comparing groups of patients with and without VWF[6,7]. The reduced %FSBPs on fingers with greater whiteness scores, suggests the test may also be used to indicate the severity of symptoms, which can influence decisions on the removal of symptomatic workers from exposure to vibration and compensation for injury.

Conclusion

Using the conditions applied in this study, both the finger rewarming test and the finger systolic blood pressure test found differences between fingers with and without vascular symptoms of VWF. The sensitivity and specificity for detecting blanching in a finger are greater for finger systolic blood pressures than finger rewarming times. Moreover, finger systolic blood pressures were lower in fingers reported to have greater areas of whiteness (i.e., greater blanching scores), suggesting %FSBPs also reflect the severity of vibration-induced white finger[8].

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Cold water immersion test (10℃,10 min) for diagnosing vibration-induced white finger among a group of polishers in a subtropical environment

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Keywords:

Cold water immersion;Hand arm vibration syndrome;Diagnose

Introduction

In many previous publications, only four studies[1-4] carried out in warm environments utilized a cold provocation test in investigating the hand functions of vibration-exposed workers without VWF. However, none of these studies reported the detailed characteristics of FST following cold water immersion. This study aimed to investigate whether the finger skin temperature (FST) after cold provocation (10°C, 10 min) could provide useful indication to assist the diagnosis of vibration-induced white finger (VWF) in a group of polishers in a subtropical environment.

Methods

A total of 90 male vibration-exposed metal polishers (30 patients and 60 controls) from the Guangdong Province in southern China were recruited. Cold water immersion test was performed on all subjects during the winter season(December to February). The FST of 3 fingers (index, middle, ring) of both hands were measured. The FST at 30, 20, 10, 0 min before cold water immersion (FST_{pre-30}, FST_{pre-20}, FST_{pre-10},$FST_{baseline}$) and 0, 5, 10, 15,20,25 and 30 min after cold water immersion (FST_0, FST_5, FST_{10}, FST_{15},FST_{20},FST_{25} and FST_{30}) was determined. The relative recovery rates of FST at 5 and 10 min (R_5 and R_{10}) and the absolute recovery rates at 5 and 10 min (FST_{5-0} and FST_{10-0}) after immersion were calculated. The Mann-Whitney test was used to analyze differences between groups. The sensitivity and specificity of statistically different results were analyzed between patients and control subjects using ROC curves.

Results and Discussions

For both patient and control groups, the median values of the FST measured on the index finger of the left hand before and after cold water immersion are presented graphically in Figure .During the first 20-min adaptation period, there was a significant increase in FST in 3 fingers ($p<0.05$) on both hands in the two groups. In contrast, there were no significant differences between FST_{pre-10} and $FST_{baseline}$($p>0.05$). Furthermore, FST_{pre-30}, FST_{pre-20}, FST_{pre-10} and $FST_{base line}$ of the 3 fingers in both hands did not differ significantly between the patients and controls ($p>0.05$). During recovery, the indicators FST_{5-0},FST_{10-0},R_5,R_{10} for the index finger of the left hand in patients were lower than for the controls ($p<0.05$). Among the various indicators, the absolute recovery rate, FST_{5-0}, at 5 minutes after immersion was identified as the best diagnosis indicator with a sensitivity of 76.7 % and specificity of 70.0% when applied to the index finger of the left hand(Table).

Conclusion

The study has shown that the cold water immersion test (10℃, 10 min) in controlled conditions can have fair discriminative ability for diagnosing VWF in a population of vibration exposed workers living in a subtropical environment. The results obtained in this study suggest using FST_{5-0} as the evaluation indicator and setting the adaptation time to 20 min. With the population considered in this study, best results were obtained when applying the approach to the most severely affected finger, namely the index finger of the left hand.

Table

Table : Sensitivity and specificity of the FST test as applied to the index finger of the left hand for various indicators

	Cut-off value	Se (%)	Sp (%)	AUC (95%CI)
FST_5 ,°C	14.6	66.7	70.0	0.672(0.543-0.802)
FST_{10},°C	17.5	60.0	68.3	0.658(0.525-0.790)
FST_{30},°C	26.2	53.3	63.3	0.572(0.434-0.709)
R_5,%	22.9	73.3	63.3	0.702(0.573-0.832)
R_{10},%	38.9	60.0	68.3	0.682(0.550-0.813)
FST_{5-0},°C	3.3	76.7	70.0	0.706(0.579-0.835)
FST_{10-0},°C	4.8	60.0	76.7	0.679 0.551-0.808)

Figure

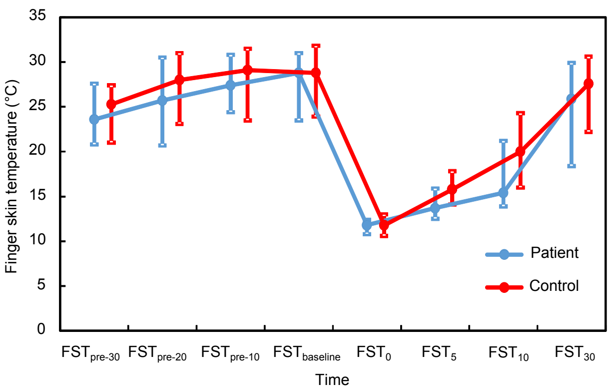

Fig. Median FST of the index finger of the left hand before and after immersion of the left hand in cold water at 10°C for 10 min for both control and patient groups.

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Sensory Perception Testing using Monofilaments in Workers with HAVS and Controls

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Keywords:
monofilaments; hand-arm vibration syndrome; HAVS; neuropathy

Introduction

The effect of heavy manual work on sensory perception in the digits is unknown. Monofilaments are used by physicians to determine sensory perception, but there is no standardised method for their application and their reliability is unknown. They are used on the principle that a fibre will buckle when compressed according to its length, diameter and the type of material used to make it. Once buckled, the force imparted by the fibre should be constant. The effectiveness of monofilaments as a screening tool for sensorineural hand-arm vibration syndrome (HAVS) is unknown.

Methods

Sensory perception was determined on the pulps of the digits of both hands in a) office workers; b) heavy manual workers not exposed to hand-transmitted vibration (HTV) and c) in workers with HAVS. The office workers were all employees of the Health & Safety Executive (HSE); the heavy manual workers were bricklayers, roofers and scaffolders; the workers with HAVS had all been referred to the HSE's Laboratory in Buxton, UK for high level health surveillance testing.

Sensory perception was determined using a full set of Semmes-Weinstein (SW) nylon monofilaments with soft tips in hand sets supplied by Connecticut Bioinstruments, New York, USA. The smallest fibre to be felt twice out of a maximum of three applications with the eyes closed was taken as the sensory threshold for the digit being tested. To determine intra-subject variability, 20 office workers and 10 heavy manual workers were re-tested in the same way and by the same operator two to four weeks later.

95th percentiles for sensory thresholds were estimated by sex, age, hand, digit and study population for office workers and heavy manual workers. Agreement between repeated testing was assessed using linear weighted kappa. For the workers with HAVS, the relationship between the SW monofilament bend force threshold and the number of abnormal thermal (hot and cold) perception thresholds and abnormal vibration (31.5 and 125Hz) perception thresholds was examined using mixed effects Poisson regression. Thermal aesthesiometry was undertaken according to the method described by Lindsell and Griffin [1] and vibration perception according to ISO 13091-2:200. The work was reviewed and approved by the HSE research ethics function operating under delegated authority from the University of Sheffield Research Ethics Committee.

Results

There were 300 office workers, mean age of 42 (19-68); 115 heavy manual workers, mean age 40 (18-66) and 62 HAVS cases, mean age 51 (23-69) years. The HAVS cases were significantly older than the office and heavy manual workers ($p<0.001$).

The median sensory perception threshold of the office workers was 0.07 g-f with a 95th percentile of 0.16 g-f, which did not vary by sex, hand dominance or digit. Women < 30 had a significantly lower 95th percentile than women > 30 years. The median sensory perception threshold of the heavy manual workers was 0.16 g-f with a 95th percentile of 1.0 g-f, which was significantly greater than the office workers ($P<0.05$). Heavy manual workers >50 years had the highest 95th percentile of 1.4g-f, but there was no consistent trend with age. The HAVS cases had a 95th percentile of 4.0 g-f, which was significantly higher than the heavy manual workers.

Of the 30 subjects that underwent repeat testing there was perfect agreement for 198/300 (66%) of digits; 92/300 (31%) of digits differed by one filament. No digit differed by more than two filaments. The weighted kappa statistic of reliability was 0.63 (95% CI 0.53-0.70).

For the HAVS cases, the number of abnormal thermal and vibration thresholds by hand increased with the SW monofilament threshold, approximately doubling with each 1g increase in force. The fitted curve flattened at about 2 g-f (Figure). Similar curves were obtained when the SW monofilaments were compared separately with the number of abnormal thermal and vibration perception results.

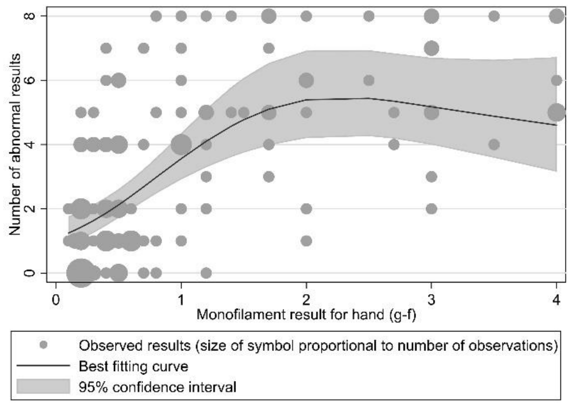

Figure: Best fit regression line between SW monofilament thresholds and the number of abnormal thermal and vibration perception thresholds in workers with HAVS

Discussion

Heavy manual work which is undertaken without gloves is known to thicken the epidermis of the skin, so the finding of raised sensory perception thresholds as measured by SW monofilaments in the digits of heavy manual workers is not surprising. The reliability of SW monofilament testing when undertaken by the same operator is good, but it is a skilled technique that needs to be practised using a standardised method and a range of fibres with reproducible bend forces. SW monofilaments have utility as a screening tool for HAVS in the community where a bend force threshold >1.0 g-f in two or more digits of a heavy manual worker exposed to HTV is likely to indicate thermal and vibration perception abnormalities in the digits.

Conclusion

The sensory perception thresholds of the digits of heavy manual workers was higher than office workers. SW monofilaments are a useful screening tool for detecting sensory neuropathy in the digits of workers exposed to HTV.

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Vibration risk assessment - evaluation of exposures to vibration, control and measurement strategies

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Abstract

Long-term exposure to hand-arm vibration from powered machinery is known to present a risk of damage to the hand and arm.

In Great Britain, the actions required of employers controlling vibration exposure and providing health surveillance are defined in Regulations based on European Directive 2002/44/EC. Assessment of hand-arm vibration risk is an important part of the process of controlling risk. However, assessment does not need to be onerous, or complicated; it needs to be suitable and sufficient so that it leads to the appropriate control of exposure.

This paper discusses the requirements for evaluation of risk and how the appropriate level of assessment will produce timely, suitable and effective control actions.

Keywords:

hand-arm vibration, risk assessment, measurement, monitoring, control, exposure.

Assessment of hand-arm vibration risk

What is a risk assessment?

Health and Safety Executive (HSE) guidance says:

> *"A risk assessment is not about creating huge amounts of paperwork, but rather about identifying sensible measures to control the risks in your workplace."* [1]

and goes on to say:

> *"What you must do is make sure you know about the main risks and the things you need to do to manage them responsibly."*

The purpose of a risk assessment is therefore to identify whether control is required and identify which control measures are appropriate. A key part of the assessment is an exposure evaluation. The format and precision required of that evaluation will depend on where an employer is in the process of determining and controlling risks.

Initial evaluation of risk

A risk evaluation can be relatively simple; ask some basic questions:

- Do we use hand-held or hand guided power tools, or holding other vibrating surfaces?
- Are they used for a significant amount of time?

We now know who is at risk and an indication of those at greater risk (due to the longer handling times). This is sufficient information to allow us to consider some initial controls.

Initial Controls

Ideas and advice on controlling risks can come from review work processes with workers, supervisors and other managers, experiences reported by similar industry groups, trade-associations and equipment suppliers.

Use the hierarchy of control for considering how to control vibration risks:

- ELIMINATION: Why do we use these machines – can we do the job in a different way to avoid risk?
- SUBSTITUTION: Are these machines the best machines to do the work – can we find suitable lower-vibration machines?
- ENGINEERING CONTROL: Can we modify the work or the task to reduce the risks?
- ADMINISTRATON: Are the machines in good condition, well maintained, using the right accessories? Are the machines being used correctly – do the workers need additional training? Can we limit the time spent using the machines?
- PERSONAL PROTECTION: Are machine operators keeping their hands and body warm and dry?

Initial assessment review

The initial assessment may identify simple changes that reduce vibration risks. In some cases, these changes may be sufficient such that all the likely vibration risks have been removed or reduced to a point where further control is not necessary.

If there is a remaining risk, this will need to be addressed, and the next stage of risk assessment is likely to require more detailed information and perhaps a numerical evaluation of exposure.

Evaluation of hand-arm vibration exposure

For workplace risks, EU Directive 2002/44/EC[2] does not require measurement of vibration. It says:

> *"the employer shall assess and, if necessary, measure the levels of mechanical vibration to which workers are exposed"*

and:

> *"The level of exposure to mechanical vibration may be assessed by means of observation of specific working practices and reference to relevant information on the probable magnitude of the vibration corresponding to the equipment or the types of equipment used in the particular conditions of use, including such information provided by the manufacturer of the equipment."*

Information from a variety of (non-measurement) sources, including manufacturer's data, can therefore be used to estimate likely vibration levels in the workplace.

HSE recognises that manufacturer data does not always reflect the vibration experienced during real use[3] and recommends comparing values from multiple sources; in this way vibration values are confirmed by a second source. HSE publishes its own list of likely in-use vibration values[4] to assist this process.

Measurement of vibration

Where the existing data is insufficient or inconsistent, it may be appropriate to perform measurements. ISO 5349-1[5] defines how vibration exposure should be evaluated. This standard provides the basis for both the daily exposure action and limit values in regulations[6], and the requirements for declaration of vibration emission values for manufacturers or suppliers of machinery. Guidance on practical measurement is provided in ISO 5349-2[7].

Instrumentation should satisfy the requirements of the appropriate instrumentation standard i.e. ISO 8041-1[8]. This general standard for vibration instrumentation provides a good basis for ensuring the errors of measurement are minimised, and that the instrument is capable handling vibrations from a wide range of rotary and percussive machines.

Since ISO 5349-1 and ISO 5349-2 were published in 2001, there have been substantial changes in measurement instrumentation. It has become more accessible, easier to use, lower cost and smaller in size. However, the challenges of hand-arm vibration measurement in the workplace have not necessarily become easier. It remains important that a measurement is carefully planned, to account for variations of vibration levels which may be introduced by changes in:

- machine and machine operator,
- workpiece and work materials,
- inserted tools (drill bits/ abrasives etc),
- postures and applied forces,
- fatigue and engagement of the operator,
- environment (e.g. noise, temperature), etc.

Devices are now available that enable a form of personal vibration exposure monitoring which offer new opportunities and challenges. For HSE it is important to understand the strengths and weaknesses of new and novel measurement systems. For users, it is important to understand how such systems can properly contribute to their measurement objectives.

Measurement planning

There is a risk of measurements being made for no clear purpose – it becomes an exercise in collecting data. Measurements should not be made without a clear plan of how to assess and act on the information those measurements provide. Remember, the purpose of risk assessment is to identify those individuals at risk and to consider how those risks might be managed.

The employer should have a clear plan for their measurements. The plan will show how the results will feed into an improved understanding of vibration risks and then into decisions on controlling those risks.

Continual personal exposure monitoring is not required by Regulations in Great Britain[9] (or Directive 2002/44/EC). Monitoring may be useful for a limited period. If monitoring is used, it should be planned, with clear objectives and instructions, for example, specifying the actions expected of individuals using the monitor, particularly when exposure alerts are raised.

Summary and conclusions

The risk assessment process is a critical component of the control of vibration risks. Assessment does not need to be onerous, or complicated; it needs to be suitable and sufficient so that it leads to the appropriate control of exposure.

Measurement is not always required for a risk assessment. Sufficient information can be obtained from other sources.

Where measurements are undertaken it is important to understand the limitations of measurement and to have a clear plan for how the results from those measurements will feed in to the risk assessment process.

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Vibration reduction on reciprocating tools

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Abstract

Power tools with reciprocating action often expose workers to high levels of vibration. A combination of auto tuning vibration absorber and vibration isolation is used to reduce the vibrations significantly on three prototype tools.

Keywords:

Vibration reduction; Tuned vibration absorber, Rock drill, Hand held impact machine, Tamper, Rammer

Introduction

Hand held power tools with reciprocating action, such as needle scalers, tampers(rammer), rock drills and breakers expose workers to high levels of vibration. These machines usually have a piston that is driven back and forth creating a periodic force on the rest of the machine. This periodic force is the dominating source of vibration on these tools.

Different approaches can be taken to reduce the vibration exposure on the operator. One common approach is to isolate the handles from the rest of the machine. The vibration exposure can be reduced with isolation but in order to maximize the degree of isolation the coupling between the handles and the rest of the tool must be soft. If the stiffness of the coupling is reduced too much the tool can become uncontrollable. The stiffness is therefore a compromise between controllability and vibration isolation.

Another option is to use a Tuned Vibration Absorber (TVA) to counter the excitation force. The linear tuned vibration absorber is an old invention. It was first patented in 1909 by Frahm[1] and later described by Den Hartog[2]. Linear TVAs are useful for suppressing unwanted resonances in buildings, but their effectiveness often is limited in tools with reciprocating action because of the narrow suppression band. If the TVA is tuned to frequency above the excitation frequency the effect of the suppression is very limited and if the TVA is tuned to a frequency slightly below the excitation frequency, the TVA will phase shift and amplify the vibrations instead. Tuning the absorber is therefore difficult and if the operating frequency of the tool varies the use of a linear TVA is impossible.

The effective frequency range can however be broadened significantly by introducing nonlinear spring characteristics[3]. This has been implemented on three pneumatic machine types. First on a hand-held impact machine[4] (HHIM) and later on a rock drill and a tamper.

Methods

The internal mechanism of all three machines is similar. All three have a piston that is driven back and forth in a cylinder. The key difference is that in the rock drill and the HHIM the piston hits the drill/chisel but in the tamper the piston is connected to the butt with a rod.

The Non-Linear Tuned Vibration Absorber, NLTVA, consists of a counter mass that slides on the outside of the mechanism and the movement is restricted by linear springs. The nonlinearity is introduced by preloading the springs and by having a small gap between the spring and the counter mass. This non-linearity makes the resonant frequency of the absorber to follow the operating frequency resulting in an automatically tuned vibration absorber (ATVA).

The vibration of the handles on the tools is further reduced by attaching the housing with handles to the internal mechanism via vibration isolators. The engineering model of the HHIM, rock drill and tamper can be seen in Figure 1.

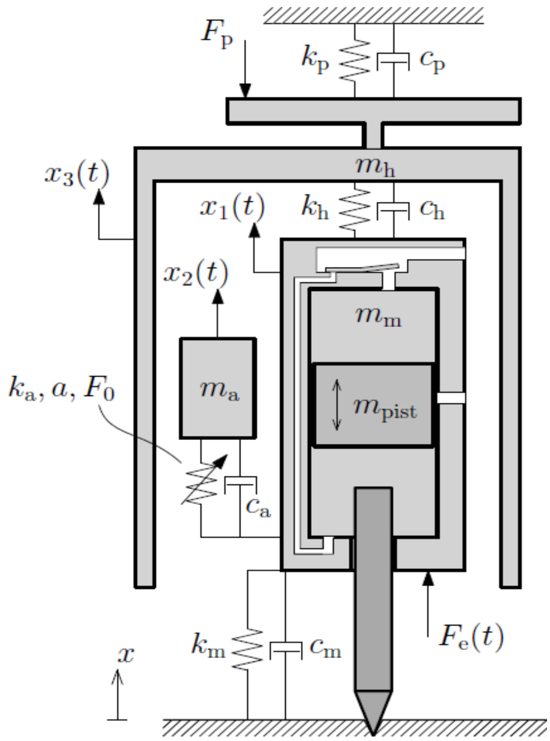

Figure 1: Engineering model of the tools. The piston and the tool are connected in the tamper.

The equations of motion are set up based on the engineering model and transformed to a computational

MATLAB model. The model has been validated in a special test rig, where all parameters can be controlled. The parameters of the ATVA are optimized for each machine to minimize the vibration amplitude of the handles around the operating frequency. The stiffness of the vibration isolation is chosen as soft as possible without compromising the controllability. The simulated displacement of the handles on the HHIM with vibration isolation and NLTVA can be seen in Figure 2. The displacement of: a single mass machine, machine with vibration isolation and a machine vibration isolation and LTVA is shown for comparison.

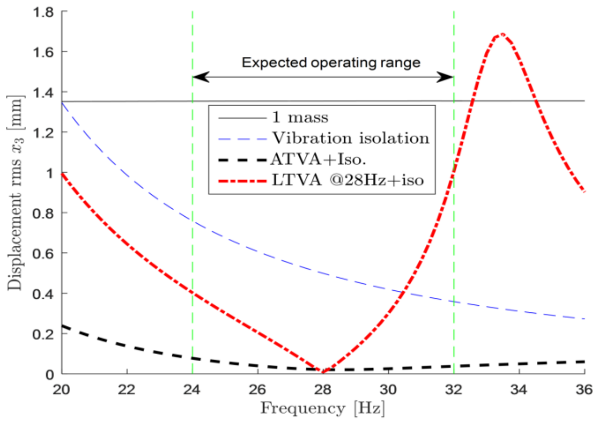

Figure 2: Vibration level on the HHIM handle

Results

Figure 2 shows how the effective frequency range of the TVA is significantly widened by introducing nonlinearities. The ATVA can therefore be used on machines with varying operating frequency. The combined vibration isolation and ATVA reduces the acceleration of the handles on the HHIM from 20 m/s^2_{haw} to 2.7 m/s^2_{haw}. The same approach lowers the vibration level of a pneumatic drill from 18 m/s^2_{haw} to 3 m/s^2_{haw} and from 32 m/s^2_{haw} to 7 m/s^2_{haw} on the tamper

Discussion

The ATVA has been successfully implemented on three tool types. When the ATVA is combined with vibration isolation, the acceleration of handles can be reduced significantly. A small pre-series of the HHIM machines has been built and the machines are being tested in a granite quarry. The prototype rock drill has been also been tested in the quarry and with will be upgraded to the next generation. The tamper is being tested in a steel atomization plant.

The work is part of the project ‘Zero vibration injuries’ which is funded through Vinnova's Challenge-Driven Innovation program. The goal of the project is to reduce vibration injuries by demonstrating how vibration exposure and injuries can be reduced by redesigning the tools.

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A Comparison of Three Bucking Bar Handles: Vibration Measured at the Tool Interface and Transmitted to the Hand, Forearm and Shoulder

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Introduction

Aircraft production is central to meeting transportation, governmental and military needs; however, manufacturing airplanes does not come without consequences because each airplane requires an intensive amount of manual labor. Some of the manufacturing processes require riveting and bucking bar work, which produces impulsive vibration exposures, which are transmitted into the hands, forearms and shoulders. Performing bucking and riveting tasks every day may expose workers to potentially harmful levels of vibration, therefore both administrative and engineering controls are needed to reduce the risks for vibration-related injuries to the upper extremities.

The objective of this study was to instrument a bucking bar with three different handles and measure the vibrations transmitted from the handle of the bucking bar to the operators' hands, forearms and shoulders. The goal was to determine whether there were differences in vibration exposures across the three different bucking bar handles, and whether there were handle-related differences in the amount of acceleration transmitted through the operators' upper extremities. In addition, a wrist-worn device was used to characterize vibration exposures. This wrist-mounted device was designed to capture and estimate the tool-born exposures occurring at the hand.

Methods

Testing was conducted using the automated test bench located in the Boeing Advanced Research Center (BARC) located on the University of Washington campus in Seattle, Washington. Using two experienced mechanics, who were both right handed, three bucking bar handles were evaluated: 1) a typical 0.14 Kg plastic bucking bar handle (P), 2) similarly designed 0.66 Kg handle with a steel core and a built-in spring (SS), and 3) a similarly designed 0.29 Kg handle with an aluminum core and the same built-in spring as the steel-core handle (AS). These handles were affixed to a 4140-steel bucking bar with a 5 x 5 cm square face, that was 17.8 cm long and weighed 2.8 kg. This was a representative bucking bar used in plane fuselage riveting.

The BARC automated test bench was used to hold the rivet gun (Model AC-10P; Atlas Copco, Stockholm, Sweden) and controlled factors such as rivet gun position, trigger pull duration, and push force. On the other side of the test bench, the mechanics used the bucking bars to form a series of rivets with each of the three bucking bar handles. To replicate riveting, a 15.2 x 28.1 x 5 cm thick rectangular sheet of 2325-T-39 fuselage aluminum, with twelve evenly spaced 0.55 cm holes, was used to receive the 12 rivets.

To measure the bucking bar handle vibrations, a ±5000 g, 2 - 4000 Hz, triaxial accelerometer (Model SEN040, Larson Davis; Depew, NY) was rigidly affixed to the bucking bar handle and collected the vibration at 20K Hz. To measure the vibrations transmitted through the operators' right arms, 3.4 x 2.2 x 0.9 cm triaxial inertial measurement units (IMUs) were mounted to the back of the hand, middle of the forearm and middle of the upper arm with a double-sided medical tape. The battery powered IMUs (Model AX-3; Axivity Ltd; Newcastle upon Tyne, UK), had 512 Mb of internal memory, a ±16 g's measurement range, a bandwidth of 0 – 1000 Hz and collected the vibration data at 3200 Hz. Finally, a wrist-worn accelerometer device (HavWear, Reactec, Edinburgh, UK) was secured to the right wrist of the subjects. This wrist-mounted device, through the use of a transfer function, was designed to capture and estimate the ISO 5349-1 [1] tool-born exposures occurring at the hand.

With the exception of the HavWear device, all the acceleration data were analyzed employing the *Wh* filter as outlined un the ISO 5349-1 standard [1]. For the rivets formed with each bucking bar and handle, the twelve, short 0.6 to 1 second riveting episodes were analyzed, subject averages were calculated from the twelve riveting episodes and the group averages were calculated for each handle condition. The HavWear device, using its proprietary transfer function, calculated the vibration exposure based on the vibration data collected between the start and end of each riveting task. The operators would scan an RFID chip HavWear device to indicate the beginning and end of using each bucking bar handle. With all the devices, the tool averages were based on the mean of the two subjects. Due to the small sample size, no inferential statistical analyses were performed and general trends were compared across the bucking bars and measurement locations.

Results

As shown in Table 1 there were differences in the vibration magnitudes measured across the three bucking bar handles. In addition, the differences in the vibration magnitudes measured across the bucking bar handles were consistent and present across the three locations measured from the right arm. The plastic bucking bar handle (P) had the highest vibration magnitudes, the aluminum-core bucking bar handle with the spring (AS) had intermediate vibration magnitudes, and the steel-core bucking bar handle with the spring (SS) had the lowest vibration magnitudes.

Table 1 also shows that there was a relatively good correspondence between the vibration magnitudes measured at the bucking bar handle and the tool-measured vibration magnitudes estimated by the wrist mounted HavWear device.

Table 1: Mean (standard error) vector sum accelerations in m/s² measured at the various locations using the three different bucking bar handles. (n = 2)

Handle Type	Bucking Bar	Hav Wear	Hand	Fore-Arm	Upper Arm
P	23.6 (1.0)	26.6 (5.6)	17.9 (1.1)	16.5 (3.2)	11.3 (0.5)
AS	19.1 (3.2)	21.7 (4.8)	13.8 (2.9)	12.0 (2.2)	7.2 (1.8)
SS	14.5 (2.4)	14.8 (4.8)	10.5 (2.0)	8.8 (0.7)	4.8 (0.3)

Table 2 shows the percentage of the vibration exposure measured at the bucking bar handle transmitted through the upper extremities. As shown in Table 2, the bucking bar with the plastic handle (P) transmitted a greater percentage of vibration through the upper extremities when compared to the spring-loaded bucking bar handles (AS and SS). In addition, a fair amount of vibration energy from the bucking bar handle was transmitted through the right arm. Ranging from 72 - 77% transmitted through the hand to 34 – 49% transmitted to the upper arm.

Table 2: Mean (standard error) percentage of bucking bar measured vibration transmitted through the upper extremities. (n = 2)

Handle	Bucking Bar	Hand	Fore-Arm	Upper Arm
P	1.00	0.77 (0.01)	0.71 (0.11)	0.49 (0.00)
AS	1.00	0.72 (0.03)	0.63 (0.01)	0.37 (0.03)
SS	1.00	0.72 (0.02)	0.62 (0.05)	0.34 (0.03)

Discussion

Based on the initial results from this small pilot study, the preliminary results demonstrated that different bucking bar handle designs may affect the amount of vibration transmitted into the hand and through the arm of the bucking bar operator. Relative to the bucking bar with the plastic handle (P), on average, the aluminum-core bucking bar handle with the spring (AS) reduced the amount of vibration reaching in the handle of the tool by 19%, and the spring-loaded bucking bar handle made out of steel reduced the vibration measured in the handle by 39%. These handle-related reductions in vibration transmissibility were relatively consistent across the other locations measured from the operators' right arms.

The results also demonstrated that a fair amount of the tool-measured vibration was transmitted through the right arm. On average, 74% of the tool-measure vibration energy reached the back of the hand, 65% of the energy was reached the middle of the forearm and 40% of the energy reached the mid upper arm. Finally, the vibration exposure estimates from the wrist-mounted HavWear device corresponded relatively well with the magnitudes and exposure trends measured from the bucking bars; however, the between subject variability measurements (standard errors) were larger with the HavWear device.

Altering the bucking bar handles to contain a spring to absorb vibration appears to be an effective engineering control to reduce the vibration exposures the tool operators experience in the right hand, arm and shoulder. The vibration exposure levels measured were high and an overestimate of the true exposures. This was due to the analysis focusing on the riveting episodes only, and not accounting for the idle time between rivets. During actual manufacturing, there would be a greater amount of idle time between riveting episodes and the calculated vibration exposures would be lower. A limitation was all devices were evaluated with only two subjects, and studying a larger group of subjects would be merited to have greater confidence in the measurements and trends observed in this pilot study

Besides engineering controls, administrative controls are likely to be of utility for reducing and/or balancing out hand-arm vibration exposures across workers. In addition, vibration is not the only physical agent that may be contributing to these vibration-related disorders. There are high forces with bucking bar and riveting activities and characterizing these forces with load cells on the tools and/or using electromyography to measure muscle activity in the upper extremities may be merited.

Finally, based on this preliminary analysis of bucking bar activity, the HavWear device seemed to be relatively accurate in estimating characterizing the bucking bar-born exposures. This fairly non-invasive tool can be used to estimate full day and multi-day, longitudinal exposures across groups of workers. With the relatively inexpensive and minimally invasive capture of full day, longitudinal vibration exposures across large groups of workers, this device may have the potential to better estimate and/or determine the causality of tool-related vibration-induced injuries, and potentially be used as an administrative tool to measure and distribute exposures across a group of workers.

Conclusions

Different bucking bar handle designs may affect the amount of vibration transmitted to the hands and through the upper extremities of bucking bar operators. Both engineering and administrative controls should be pursued to reduce and more efficiently distribute vibration exposures across groups of workers

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Testing, On-site Pilot Trial and Assessment of the Bio-Inspired Anti-Vibration Exoskeleton (BIAVE)

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Abstract (optional)

A novel anti-vibration structure is designed for suppressing hand-held jackhammers. With the testing and trail data collected, the performance of the anti-vibration exoskeleton is systematically assessed using vibration transmissivities and ISO hard-arm-vibration standard. The testing results indicate that the vibration transmitted to operator handles can be significantly suppressed up to 90% in vibration energy and up to 70% in ISO HAV standard, while the handles can still be pushed down to increase demolition force. The overall cost of the BIAVE is only about 10% or even less of the commonly used jackhammers with active vibration suppression.

Keywords:

Anti-vibration structure; Nonlinear vibration;

Introduction

Construction workers manipulating heavy-duty jackhammers or road breakers receive excessive vibration to hand and arms, eventually leading to serious vibration-related syndrome. It is known that the most harmful vibration is in the frequency range between 5 Hz and 50 Hz [1]. However, the traditional springs or dampers applied in a traditional way cannot solve the problem due to that (1) the worker needs to press down to hold the machine tightly in order for high demolition efficiency and (2) more compression in traditional springs or materials leads to dramatically increasing stiffness and consequently serious downgrade of vibration suppression. Therefore, market products with different active vibration control appear but extremely increase the cost in manufacturing and maintenance still with quite limited reduction of practical vibration level.

To solve this troublesome problem, an innovative passive anti-vibration exoskeleton is developed in this study based on the bio-inspired X-shaped structure [2-10], referred to bio-inspired anti-vibration exoskeleton (BIAVE) (Fig1). The BIAVE is light-weight, foldable and adjustable in size and stiffness and thus adaptive to be used for different jackhammers. Due to the beneficial nonlinear stiffness, the vibration in jackhammers would be significantly reduced. Moreover, when the operator pressed down the handles of the BIAVE, more downward forces would be added to the jackhammer which increase demolition efficiency, but the dynamic stiffness between the jackhammer and the BIAVE handles can be obviously decreased instead of increased due to the special nonlinear feature. These exactly solve the challenging issues mentioned above.

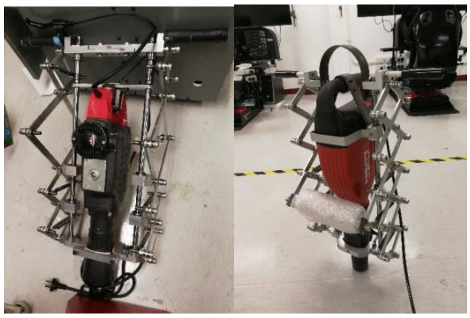

Figure 1. Prototypes for 2 different jackhammers (light-duty and heavy-duty electric ones)

Methods

Inspired by animal leg/limb skeleton (Fig 2), the bio-inspired X-shaped structure has been studied by the authors in [6-10]. The X-shaped structure is foldable and flexible in usage and easy to be manufactured and implemented in practice and thus potentially has a great promising future in various engineering vibration control issues. Most importantly, the nonlinear dynamics in the equivalent stiffness and damping of the X-shaped structure and its different variants (different asymmetric cases) are shown to be very beneficial to vibration control in a purely passive manner [6-10]. These facts motivate the application studies of this paper.

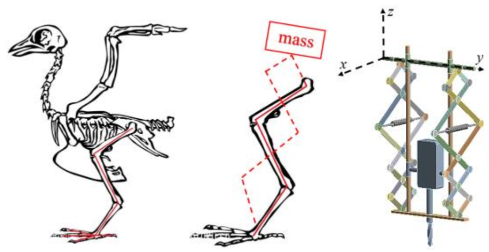

Figure 2. The X-shaped structure in biological systems: from bird limb skeleton to the X-shaped structure and the design of the BIAVE with a breaker

The bio-inspired structure is designed to be a flexible assistive tool via which different demolition tools such as jackhammers, road breakers or chisels etc can all be installed within such a tool. This functions like an exoskeleton and thus is named as Bio-Inspired Anti-Vibration Exoskeleton (BIAVE), as shown in Figure 2.

Results

To determine the design parameters, mathematical modelling can be conducted considering the vibration is exerted at the bottom and transmitted to the upper handle in this vertical direction. Moreover, the FEM can also be employed for overall dynamic analysis of the structure when there is a vibration excitation at the bottom.

The vibration transmissbility can be obtained both from the modelling and FEM analysis as shown in Fig 3 and Fig 4. It can be seen that with approprate parameter setting, the resonant frequency and resonant peak can both be suppressed significantly.

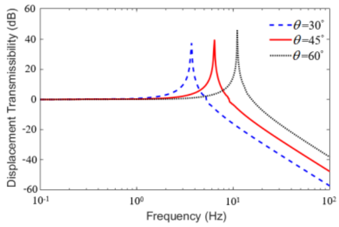

Figure 3. Vibration transmissibility of different angle

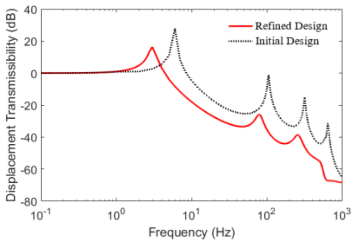

Figure 4. The refined design and initial design

Discussion

A series of laboratory and on-site testings are conducted to verify the practical effectivenss of the BIAVE technology as shown in Fig 5. To evaluate the vibration level, the ISO5349-2001 standard calculation for hands and arms vibration is adopted, which is a frequency-weighted acceleration energy. Some typical testing results are shown in Fig 6 (The black or green ones are vibration acceleration transmitted to operator's hands).

Conclusion

By employing nonlinear benefits, a novel bio-inspired vibration suppression system, referred to as Bio-Inspired Anti-Vibration Exoskeleton (BIAVE), is systematically developed with purely passive structure design. With mathematically modelling, FEM analysis and experimental validation, it is shown that the BIAVE is very effective for vibration suppression up to 70% or above and can significantly reduce the vibration transmitted from heavy-duty breakers to operator handles (the vibration weighted RMS is reduced to as low as 6 compared to 14 or above without the BIAVE), but also improve the demolition efficiency (up to 30% in terms of weighted vibration energy) with a very low development/maintenance cost (about 10% or less of active control systems). This presents an innovative technology which successfully solves the vibration issue during manually manipulating various construction tools everlasting for many years.

The BIAVE technology received the First Prize in Hong Kong CIC Construction Innovation Award 2017. An invention patent was filed both in China and USA.

Figure 5. On-site testing

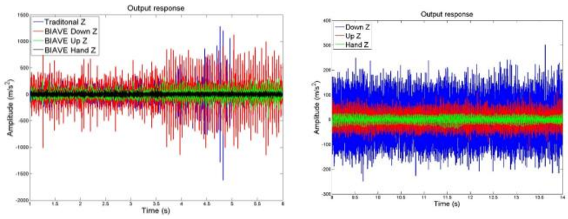

Figure 6. Acceleration signals from the BIAVE and Traditional Breaker

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The Effects of Exoskeleton Vests on Hand-Transmitted Vibration

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Introduction

Heavy hand-held power tools used in a range of occupational settings impose mechanical stresses on workers. Worksites with extensive use of power tools have begun to use passive (non-powered) exoskeleton vests to alleviate some of these stresses. The effects of these exoskeleton systems on hand-transmitted vibration (HTV) exposures are unknown. While results of research on the use of pneumatic grinders in conjunction with a counter-balanced mechanical arm indicated that the tool support system offered small to moderate reductions in HTV intensity, the reduced HTV levels can be offset by increases in work cycle times and may actually increase daily HTV exposures in some cases[1]. Exoskeletons are wearable technologies that give the worker more mobility and freedom of motion than stationary mechanical arm tool support systems, but exoskeleton use introduces some new safety and ergonomic challenges that have not been sufficiently examined. It is imperative that these technologies be evaluated prior to their widespread use; research is required to identify the best strategies for applying these ergonomic interventions for reducing occupational HTV exposures as well as other mechanical stressors. The objectives of this study were to evaluate the effects of passive occupational exoskeleton vests on the vibration transmissions to the arms and some other locations on the upper body of the vest wearer.

Methods

Three passive exoskeleton vest models were evaluated in this study (Fig. 1). Each exoskeleton has multiple spring settings that allow the exoskeleton to provide various levels of mechanical assistance to the worker. In this study, each exoskeleton model was evaluated with the springs set to their lowest settings and set to their maximum settings. Two of the three models can also be configured with the springs completely disengaged. For those two models, the disengaged condition was also evaluated. The human subject also completed a set of trials with no exoskeleton to establish baseline vibration transmissibility data. Thus, nine exoskeleton conditions were evaluated in this study. These nine exoskeleton conditions were independently randomized for each human subject. The subject completed three consecutive 20-s trials with each prescribed exoskeleton condition for a total of 27 data collection trials in a test session.

Fig. 1: Three exoskeleton vest models were evaluated in this study. The vests are adjustable to accommodate a wide variety of body shapes and sizes. Each exoskeleton model has multiple spring settings that allow the exoskeleton to provide various levels of mechanical assistance to the worker.

At the beginning of each test session, the human subject was custom-fitted with each vest. The subject stood on a force plate and grasped a shaker handle using a power grip. The force plate platform was adjusted to an appropriate height so that forearm was parallel with the floor with the elbow angled at 120° as shown in Fig. 2. The force plate was used to measure the subject's ground reaction force which is equal to the push force applied to the handle. The shaker handle was instrumented to measure and provide visual feedback of the subject's grip force. The grip and push forces were displayed on virtual dial gauges on a computer monitor placed in front of the human subject. The subject was instructed to try to maintain relatively steady grip and push forces near the prescribed targets of 30 N and 50 N, respectively.

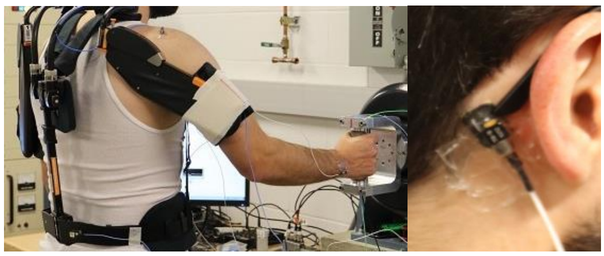

Fig. 2: Human subject grasping the shaker handle on a 1-D hand-arm vibration test system with the input vibration along the subject's forearm direction. Three triaxial accelerometers were installed on each exoskeleton (upper arm, shoulder, waist). Three more accelerometers were attached to the skin of the subject (wrist, shoulder, behind the ear).

The shaker excitation was that prescribed in the ISO glove testing standard[2] with the frequency range extended at the low-frequency end; the frequency ranged from 5 to 1,600 Hz. Triaxial acceleration data were collected at three locations on the exoskeleton frames: upper arm, shoulder, and waist. Three more triaxial accelerometers were attached with medical tape to the subject's skin at the wrist, the shoulder, and behind the ear (see Fig. 2). Acceleration data were expressed in the 1/3-octave bands with center frequencies from 6.3 to 1,250 Hz.

Results and Discussion

Note: The results presented in this abstract are preliminary results. Complete results will be presented at the conference.

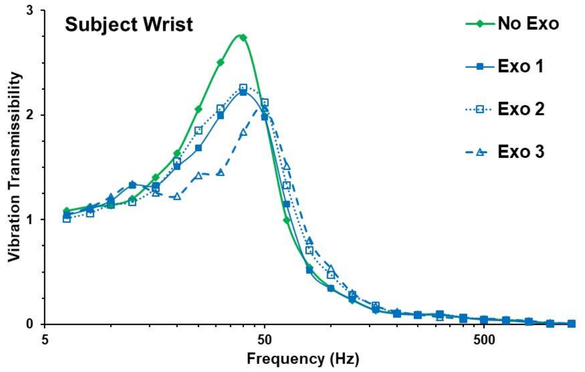

Fig. 3: Wrist vibration transmissibility curves for four exoskeleton conditions. Shown are transmissibility curves for the subject wearing each of the three exoskeleton models configured with their maximum spring-assist settings along with the no-exoskeleton condition.

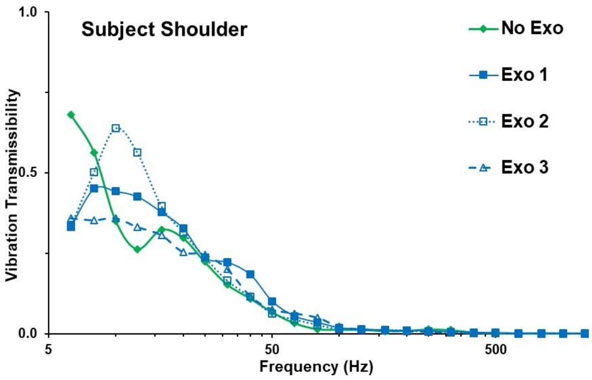

Fig. 4: Shoulder vibration transmissibility curves for four exoskeleton conditions. Shown are transmissibility curves for the subject wearing each of the three exoskeleton models configured with their maximum spring-assist settings along with the no-exoskeleton condition.

The vibration transmissibility curves at the wrist of the human subject for the exoskeletons configured to their maximum spring-assist settings compared with the no exoskeleton condition are shown in Fig. 3. As shown in the figure, each of the three vests reduced the wrist vibration in the frequency range of 20 to 50 Hz. The wrist acceleration was slightly increased by the vests in the frequency range of 60 to 125 Hz. The vests had little effect on vibration transmissibility outside of these two frequency ranges.

The vibration transmissibility curves at the shoulder of the human subject for the exoskeletons configured to their maximum spring-assist settings compared with the no exoskeleton condition are shown in Fig. 4. The vests slightly increased the vibration transmission at some low frequencies but no meaningful effect beyond that. The effect of the vests on the vibration measured behind the ear (not shown) was negligible.

Tables 1 and 2 present the unweighted acceleration means measured on the skin of the human subject and on the frame of the exoskeletons, respectively. As indicated in Table 1, as the spring assistance increased, the acceleration at the wrist decreased while the acceleration at the shoulder increased. As indicated in Table 2, as the spring assist increased, so did the acceleration at the upper arm and shoulder sections of the exoskeleton frames.

Table 1. Unweighted acceleration means measured at three locations on the skin of the human subject.

Unweighted acceleration means (m/s^2)			
	Human Subject Location		
Exo condition	Wrist	Shoulder	Ear
No Exo	17.1	1.2	0.4
Exo 1 - no assist	17.2	1.0	0.3
Exo 1 - low assist	17.0	1.1	0.4
Exo 1 - max assist	15.4	1.5	0.4
Exo 2 - no assist	19.0	1.3	0.8
Exo 2 - low assist	17.2	1.1	0.8
Exo 2 - max assist	16.8	1.4	0.7
Exo 3 - low assist	17.0	0.9	0.5
Exo 3 - max assist	16.7	1.3	0.6

Table 2. Unweighted acceleration means measured at three locations on the frame of the exoskeleton vest.

Unweighted acceleration means (m/s^2)			
	Exoskeleton Location		
Exo condition	Upper Arm	Shoulder	Waist
Exo 1 - no assist	1.83	1.32	0.43
Exo 1 - low assist	1.93	1.74	1.26
Exo 1 - max assist	3.23	3.04	0.92
Exo 2 - no assist	1.89	0.96	0.42
Exo 2 - low assist	2.57	1.44	0.50
Exo 2 - max assist	3.94	3.75	1.41
Exo 3 - low assist	4.50	1.20	1.11
Exo 3 - max assist	4.84	1.73	1.38

Conclusions

Exoskeleton vests may provide a health benefit by reducing the forces required to lift and maneuver tools and by decreasing the vibration transmitted from power tools to the arms and some upper body locations of the vest wearer at certain frequencies. However, the use of exoskeletons can increase the daily time-on-task; so the use of such systems may actually increase daily time-weighted HTV exposures in some cases.

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Numerical modelling of vibration emitted by pneumatic chipping hammers

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Abstract (optional)

This paper presents numerical models of pneumatic chipping hammers to calculate the frequency-weighted r.m.s. acceleration a_{hv}. These models could be used for assessing hand-arm vibration exposure under specific operating conditions.

Keywords:

Numerical models, pneumatic chipping hammer, frequency-weighted r.m.s. acceleration.

Introduction

According to the Vibration Directive, the assessment of the level of exposure to hand-arm vibration is based on the calculation of the daily exposure value normalised to an eight-hour reference period A(8):

$$A(8) = a_{hv}\left(\frac{T}{8}\right)^{\frac{1}{2}}$$

where T is the exposure time and a_{hv} is the frequency-weighted r.m.s. acceleration specified in ISO-5349 [1].

Over the past two decades, numerical methods and software have been successfully developed. In some fields, such as mechanics, numerical simulations are sufficiently reliable to reduce or even to replace prototyping and experimentation.

In 2015, INRS launched a study to investigate the ability of numerical simulation to predict the frequency-weighted r.m.s. acceleration a_{hv} for various hand-held power tools and operating conditions with the aim of integrating the models into an exposure assessment method.

This paper presents the numerical modelling work carried out in this study and applied to pneumatic chipping hammers.

Methods

The study was carried out on 3 types of hammers: FK102G by Fröhlich & Klüpfel; RRF31-01 and RRC34B-01 by Atlas Copco. Each type was completely dismantled to understand how its percussion mechanism operated.

Assumptions for the numerical models were then formulated, some of which were verified by means of specific experiments. The numerical models were then solved using LS-DYNA3D, a commercial software dedicated to mechanics. Meanwhile, the model equations were expressed and solved independently of the commercial software.

Results

A pneumatic chipping hammer converts pneumatic energy into shock waves transmitted through the chisel to the material to be removed. This energy conversion is achieved through a percussion mechanism, i.e. a cylinder in which a piston moves back and forth. The piston thus divides the cylinder into two chambers, in which the compressed air does the work necessary for increasing the kinetic energy of the piston, and for returning it to the rear limit of its stroke. This cycle of events occurring in the two chambers is best illustrated by the so-called pressure-stroke graph [2] shown in figure 1.

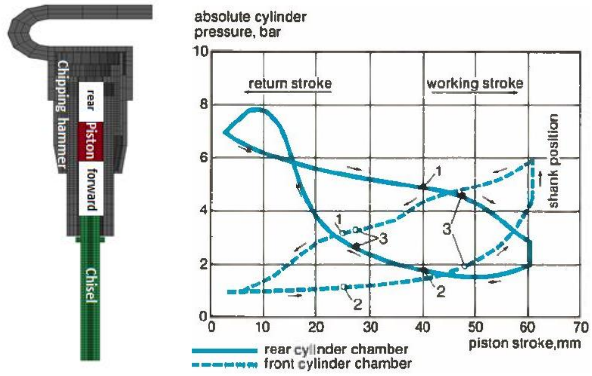

Figure 1: Pneumatic chipping hammer and its working cycle.

When the piston accelerates forward, a recoil force equal and opposite to the forward piston's force applies to the chipping hammer. When the piston returns to the rear end of its stroke, the recoil force is mainly exerted on the chisel and not on the hammer. Resulting from the fundamental principle of dynamics F=m γ, the hammer recoil acceleration was calculated by multiplying the piston acceleration and the ratio between the piston and hammer masses.

$$a_{hv} = \frac{m_{pi}}{m_{bu}} a_{wpi}$$

This relationship was validated by simultaneously measuring accelerations of the piston and hammer as the hammer was hung horizontally by two low-stiffness springs in order to reproduce conditions where the external force exerted along its impact axis can be neglected. This relationships shows that it is sufficient to know the acceleration-stroke curve of the piston to assess the frequency-weighted r.m.s. acceleration a_{hv} of the chipping hammer.

Numerical models were built for both Atlas Copco hammers using the characteristic acceleration-stroke curves of their percussive mechanism.

The a_{hv} acceleration was measured on both hammers under operating conditions close to those specified in the standard ISO 28927-10 [3]. The hammer was held vertically by housing the chisel in a fixed sleeve. The operator's pushing force was simulated by adding an additional rigid mass on the machine handle.

Figure 2: Measurement bench for chipping hammers

Figure 3 compares the measured and calculated frequency-weighted r.m.s. accelerations for the RR31-01 hammer with various additional rigid masses. There is a good agreement. The a_{hv} reduction observed by increasing masses on the handle is correctly reproduced by the simulation.

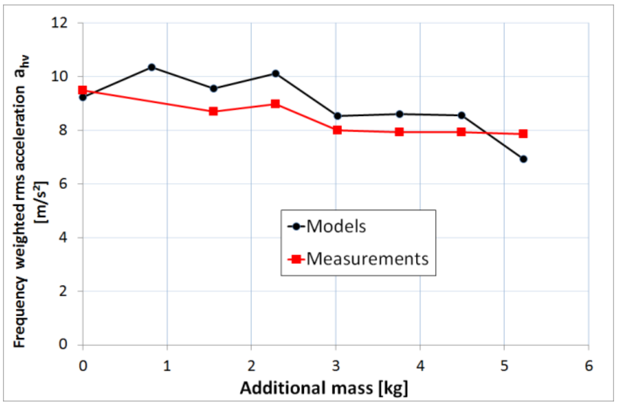

Figure 3: Comparison between measured and calculated a_{hv} values for hammer RRF31-01 with various masses.

For the FK102G chipping hammer, the acceleration-stroke curve was assumed to be rectangular. This means that the piston is constantly accelerated toward the chisel and no recoil force is exerted on the hammer as the piston returns to its initial position. Knowing the stroke C and the frequency f_0 of the hammer, the constant piston acceleration a_{pi} was calculated as:

$$a_{pi} = 8\,C\,f_0{}^2$$

By applying the W_h weighting filter to the idealised square periodic acceleration signal, the frequency-weighted acceleration piston was calculated as:

$$a_{wpi} = W_h\,(f_0)\,\frac{\sqrt{2}}{\pi}\,a_{pi}$$

Input data for the FK102G hammer were: mass of the piston m_{pi}=0.1 kg, mass of the chipping hammer m_{bu}=2.4 kg, stroke C=0.06 m, blows per minute = 3100 (i.e. f_0=51.6 Hz). At 51.6 Hz, the weighting factor is $W_h(f_0)$=0.314.

With those parameters, an a_{hv} value of 7.6 m/s² was calculated. This value was very close to the one declared by the manufacturer (7.8 m/s²).

Discussion

Numerical models developed to calculate the frequency-weighted r.m.s. acceleration a_{hv} were validated for 3 different pneumatic chipping hammers under specific operating conditions. The acceleration-stroke curve, which described how the percussive mechanism works is one of the main input parameters required by the model. Since it could not be easily measured, we had to completely dismantle a hammer to draw it.

All models were developed and validated under artificial operating conditions. It is therefore necessary to validate them with more realistic conditions. In particular, it is essential to improve the simulation of the dynamic coupling between the machine and operator's hand. Various studies such as [4] dealing with this issue have already been published. They follow the same methodology based on the design of a mechanical device reproducing the feed forces exerted by a human operator. A numerical model of such a device could be coupled with our models in order to take into account the dynamic coupling of the hand.

Conclusion

This study shows that it is feasible to predict the frequency-weighted r.m.s. acceleration a_{hv} by means of numerical models of hand-held power tools such as pneumatic chipping hammers. The numerical models are based on the laws of physics governing the generation of vibration and its transfer along the machine to the hand. Simplified models are proposed to implement them in a method for estimating the hand-arm vibration exposure.

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Modeling Analyses of the Vibration Response Characteristics of a Handheld Workpiece in Grinding Process

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Introduction

Grinding and polishing of handheld workpieces are manual processes used in the fabrication or repair of some components of sports equipment, tools, furniture, and dentures. Significant vibration may be generated during such processes, and it may be effectively transmitted to the fingers or hands of the workers holding the workpieces. A recent study reported that the prevalence of vibration-indued white finger (VWF) among workers performing the fine grinding of golf club heads in some sport equipment manufacturers was more than 12% [1]. The objective of this study is to enhance the understanding of the vibration response characteristics of handheld workpieces through modeling analyses. Such knowledge is very important for the further development of more effective intervention methods and technologies to control the vibration exposure and health effects.

Methods

The basic model used in this study is illustrated in Fig. 1, which was developed in our previous study [2]. It was established based on the vibration response functions (mechanical impedance of interface-workpiece-hand-arm system and the vibration transfer functions at the wrist and on the upper arm) measured in a laboratory experiment [3]. Its validation was further examined in the current study.

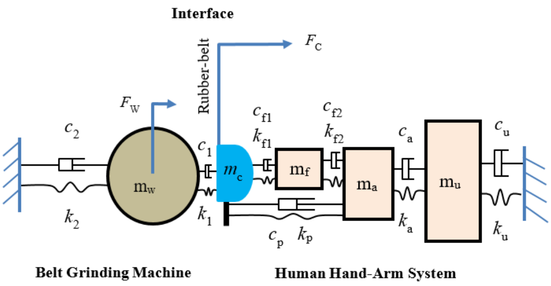

Fig. 1: A model of the grinding machine-workpiece-hand-arm system

The interface stiffness (k1) and damping coefficient (c1) in the model were further calibrated using the impedance data measured on three rubber interfaces (R45, R55, R65) cut from factory drive wheel treads of belt grinding machines used in a sports equipment manufacturer. The two types of vibration sources identified in a previous study [4] were considered in the modeling analyses, which include: (i) the grinding machine vibration primarily resulting from the imbalanced rotational motion of machine components; and (ii) the grinding vibration force primarily resulting from the complex cutting/abrasive processes, the irregular geometrical inputs to the grinding interface, and the uneven distribution of sanding materials on the grinding belt. These two vibration sources were represented by the vibration force acting on the drive wheel (Fw) and that acting on the workpiece or club head (Fc), respectively. Two grinding feed forces (15 N and 30 N) and two hand conditions (bare hand and gloved hand) were considered in the basic modeling analyses.

Results

In this study, the vibration transmissibility is defined as the ratio of a substructure vibration and the drive wheel vibration. Fig. 2 shows some examples of the vibration transmissibility spectra of the workpiece subjected to the machine vibration (Fw), together with those measured in a previous experimental study [3].

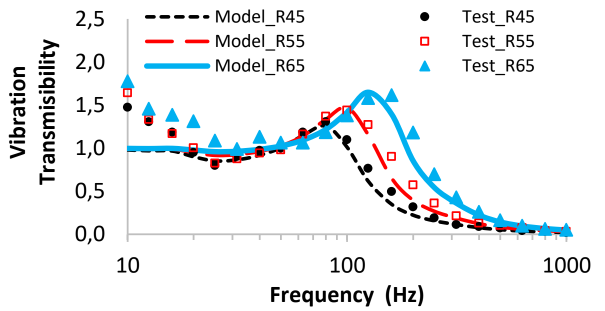

Fig. 2: Comparisons of modeling and experimental vibration transmissibility spectra of the workpiece under 15 N feed force on the three different interfaces (R45, R55, and R65).

The results reveal that the major resonant frequency of the workpiece on each interface (f_c) can be estimated from the workpiece mass (m_c) and the interface stiffness (k_1)as follows: $fc \approx \frac{1}{2\pi}\sqrt{k_1/m_c}$. The results also demonstrate that the vibration transmissibility approaches unity (1.0) with the reduction in frequency below the fundamental resonant frequency. At higher frequencies, however, the vibration transmissibility reduces with the increase in frequency, and it is close to zero at very high frequencies.

Fig. 3 shows some examples of the predicted vibration accelerations (Ac) of the workpiece subjected to a unity interface excitation force (or Fc = 1 N). Opposite of the basic trend of the vibration transmissibility shown in Fig. 2, the vibration response of the workpiece below a certain frequency (<50 Hz in this case) tends to zero. Then, it increases with the increase in frequency before reaching a peak value at a frequency marginally higher than the major resonant frequency. Then, it reduces gradually and approaches a limit with the increase in frequency. This limit is equal to Fc/m_c.

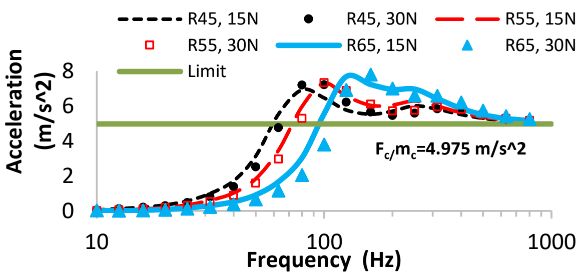

Fig. 3: Predicted vibration acceleration spectra of the workpiece subjected to unity interface excitation force (Fc =1 N) for the six simulation treatments (two feed forces: 15 N and 30 N. three interfaces: R45, R55, R65)..

It is reasonable to normalize the response with respect to its high-frequency limit as follows: $TFc = Ac/(Fc/m_c)$. To clearly differentiate the vibration motion transmissibility (TAw) resulting from the machine or drive wheel vibration, TFc is termed as force-motion transmissibility in this study. As an example, Fig. 4 shows the TFc for the 30 N feed force on the R55 interface, together with its corresponding TAw, as well as their sum (Sum). It is very interesting to note that TFc and TAw almost mirror each other with respect to the major resonant frequency in this case.

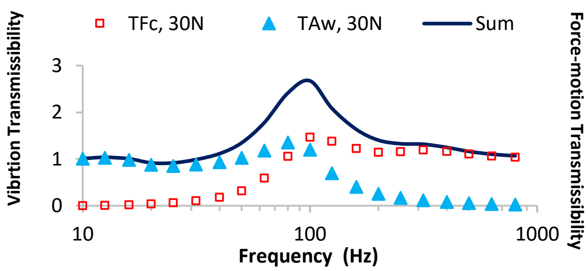

Fig. 4: Comparisions of the grinding force-induced motion-force transmissibility (TFc), the machine vibration-induced motion transmissbillity (TAw), and their summation (Sum).

Discussion

The comparison of the predicted transmissibility spectra with the experimental data shown in Fig. 2 futher confirms the validation of the model used in this study.

The two types of transmissibility spectra shown in Fig. 4 suggest that the vibration of the workpiece below the major resonant frequency of the workpiece is primarily associated with the grinding machine vibration. This characteristic indicates that the workpiece vibration in such a frequency range can be reduced by minimizing the machine vibration. This is very important to meet the standard exposure requirement, as the frequency-weighted acceleration required for the risk assessment in the current standard is primarily determined by the vibration components in this frequency range.

On the other hand, the two types of transmissibility spectra shown in Fig. 4 suggest that the vibration of the workpiece at frequencies higher than its major resonant frequency is primarily associated with the grinding interface excitations. Many studies have revealed that high-frequency vibration exposures cannot be ignored, and their minimization should also be considered in the development of intervention methods for protecting the fingers or hands. It may be difficult to minimize interface vibration sources without reducing grinding efficiency. In addition to balancing vibration exposure and productivity, other approaches such as changing the interface stiffness, increasing the constraints on the workpiece, and using vibration-reducing gloves or wraps may be considered to minimize the workpiece vibration.

The peak region of the summed spectrum shown in Fig. 4 means that the worst resonance will happen if both machine vibration and grinding vibration force have their major components in the resonant frequency range. This can be avoided using some of the above-mentioned methods.

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The Rotational Mechanical Impedance of the Hand-Arm System – A Preliminary Study

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Abstract

The mechanical impedance of hand-arm systems is well-known for translational excitation. However, in real world scenarios rotational vibrations are imposed on hand-arm systems in addition to translational excitation, which cannot be evaluated using the translational impedance. This contribution presents a preliminary study on the rotational mechanical impedance for an excitation of hand-arm systems around the forearm axis.

Keywords:

Rotational Impedance; Hand-Arm System

Introduction

In the field of hand-arm vibration the translational frequency dependent driving point mechanical impedance (MI) has become established as a quantity for describing the vibration properties of the hand-arm system. The frequency dependent translational MI of the hand-arm system can be calculated by

$$MI(i\omega) = \frac{F(i\omega)}{\dot{x}(i\omega)} \quad ; i^2 = -1 \tag{1}$$

where F describes the harmonic excitation force with the frequency ω and $\dot{x}$ the spatial velocity, both measured at the hand [1]. From the MI substitutional models with equivalent vibrational behavior compared to the hand-arm system can be derived. In the development of power-tools, the substitutional models are used to analyze and evaluate the interactions between user and machine either in simulations or in test bench experiments [1]. However, since present models are based on the translational MI the validity of results in power-tool applications with rotational excitation, like for instance fastening a bolt with an impact driver, is questionable. Lin et al. [2] presented a study on the rotational dynamic behavior of the hand-arm system up to 5 Hz; however, most power-tools exert frequencies higher than 5 Hz.

To meet these deficiencies this contribution aims on introducing a measurement environment for the analysis of the rotational vibration behavior of the human hand-arm system. Furthermore, a preliminary study on the rotational mechanical impedance at a wide frequency band will be presented.

The rotational mechanical impedance (RMI) can be described analogous to equation (1) by

$$RMI(i\omega) = \frac{T(i\omega)}{\dot{\phi}(i\omega)} \tag{2}$$

where T denotes the exciting harmonic torque and $\dot{\phi}$ the angular velocity, both measured at the hand [3].

Methods

For determining the RMI a user interaction test bench has been developed, which enables the translational and rotational vibration excitation of systems at a frequency band of 1-1000 Hz. The mechanical oscillations are generated by two electromechanical shakers (Pos. 1 and 2 in Figure 1), which are arranged at a right angle in respect to the shaker main-axes.

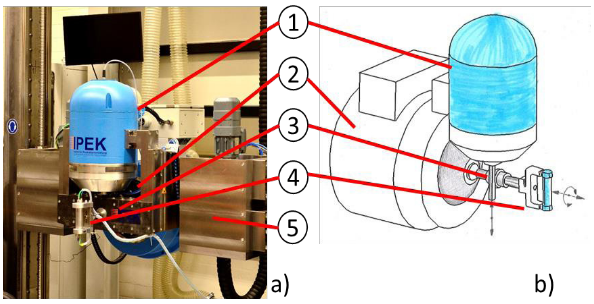

Figure 1: a) User interaction test bench; b) Schematic illustration of the shaker arrangement (based on [3])

Both shakers are coupled to a measurement handle (Pos. 4) by means of a backlash free gear unit (Pos. 3), which transduces the translational movement of shaker number one (Pos. 1) into angular motion at the handle. A superimposed translational and rotational excitation of the handle is possible due to mechanical decoupling of the excitation directions. Furthermore, the shaker unit is mounted in a carrier (Pos. 5), which enables the vertical adjustment of the measurement handle up to 2.8 m in height. In addition, the shaker unit can be tilted up to 90 degrees around the lateral axis in both directions. [3]

The measurement handle has been optimized for both rotational and translational excitation and is based on the handle described in DIN EN ISO 10819 [4].

Measurement Method

This preliminary study focused on determining the RMI of 10 male subjects.

For each subject three test runs have been conducted. This study aimed for a push and gripping force of 50 N. A feedback display was used to enable the subject to control the gripping and push-force.

During each run, the measurement handle was excited with a sequence of 18 discrete frequencies and selective angular acceleration amplitudes, both given in Table 2. The arm was excited with an angular oscillation around the axis of the forearm. The examined angular acceleration amplitudes $\ddot{\phi}$ have been set such that a defined acceleration and force signal was set apart from the noise level. The order of frequencies was randomized for each test run in order to avoid sequence effects.

The body posture of the subjects was based on DIN EN ISO 10819-2013 [4].

Evaluation Method

For evaluating the RMI, the bandpass filtered measured force and acceleration data for each frequency is fitted with a sine curve. Integration of the acceleration is conducted in the frequency domain to reduce numerical error. The second order bandpass was set with a bandwidth of ±20% of the excitation frequency to reduce signal noise. The handle was calibrated statically and dynamically and the inertia of the measurement handle was compensated during post-processing based on the method described by Dong et al [1].

Results

The RMI of the 30 individual test runs is plotted as magnitude and phase over excitation frequency in Figure 2. An overview of the results is given in Table 2.

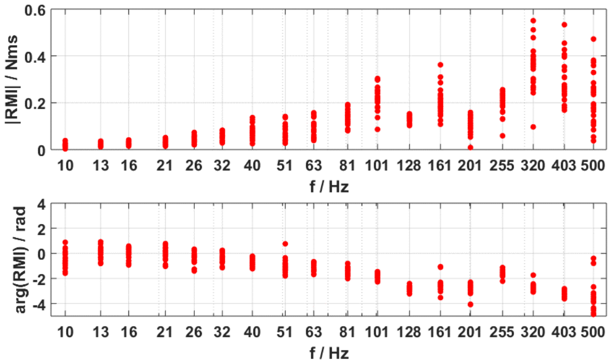

Figure 2: Magnitude and phase of the RMI for an angular excitation around the forearm axis

Table 2: Median values of magnitude and phase of the RMI and interquartile range (IQR) of the magnitude for an angular excitation around the forearm axis

f in Hz	**RMS($\ddot{\phi}$)** in 1/s²	**Median |RMI|** in Nms	**IQR(|RMI|)** in Nms	**Median arg(RMI)** in rad
10	4000	0.018	0.008	-0.43
13	6800	0.021	0.005	0.04
16	9800	0.022	0.011	0.01
21	15000	0.033	0.013	0.00
26	23000	0.048	0.021	-0.25
32	29000	0.055	0.033	-0.40
40	38000	0.074	0.037	-0.79
51	49000	0.070	0.044	-1.10
63	68000	0.100	0.050	-1.17
81	79000	0.140	0.044	-1.40
100	79000	0.255	0.051	-1.82
128	79000	0.113	0.020	-2.82
161	79000	0.204	0.078	-2.48
201	79000	0.103	0.056	-2.74
255	79000	0.208	0.050	-1.69
320	79000	0.358	0.116	-2.78
403	79000	0.269	0.115	-3.26
500	79000	0.184	0.138	-3.82

The test runs showed good reproducibility for most test subjects. Scattering of the phase angle at 10 Hz could be caused by the sine curve fitting procedure due to a higher noise level compared to higher frequencies. In general, the magnitude of the RMI for the subjects is in the range of 0.001-0.6 Nms.

Discussion and Conclusion

An increase of magnitude at higher frequencies could be observed, which indicates mass dominated behavior. A similarity to the MI curve for the x-axis of the hand, given in ISO 10068 [5], can be found. However, the magnitude is considerably lower, which indicates less resistance to oscillation excitation in rotational direction. Since in this study the test subjects can be seen as a non-constant parameter from the deviation in the RMI plots the following hypothesis for future research can be derived:

The anthropometric properties of the human hand-arm system have an influence on the rotational mechanical impedance.

This contribution aims on introducing a first insight on the RMI. With the knowledge of the RMI more sophisticated substitutional models can be derived as a first step to a complete hand-arm model, which will help in the understanding of the mechanical behavior of the hand-arm system. A valid representation of the RMI of the human hand-arm system could also contribute to the development of user protection systems, which avoid torque-induced injuries during power-tool application.

Acknowledgements

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Biodynamic responses distributed at the fingers and the palm of the human hand-arm system under different vibration sources

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Abstract

This study proposes a statistical analysis of a lumped mechanical model of the hand and upper arm gripping an object. The lumped mechanical model is represented by five degree-of-freedom. It simulates model the distributed biodynamic responses of the hand-arm system exposed to vibration. They can be used to further study the biodynamic responses and their applications.

Keywords:

Hand; Finger; Hand-arm vibration; Hand-transmitted vibration; Biodynamic response

Introduction

The objective of this study is to develop analytical models for simulating driving-point biodynamic responses distributed at the fingers and palm of the hand under different vibration sources [1]. It is evaluated the real part of the mechanical impedance in the frequency domain [2]. The responses of the proposed lumped mechanical model are analyzed under different hand actions. The evaluation is developed by statistical analysis, numerical approaches and experimental investigations. The results show that the responses predicted from the lumped mechanical model agree reasonably well with the measured data. The variations in the responses under different hand actions are discussed in view of the biological system behavior of human hand-arm system. The proposed models are considered to serve as useful tools for design of vibration isolation methods, and for developing a hand-arm mathematical model for vibration analysis of power tools [3].

Methods

The lumped mechanical model of the hand and upper arm gripping an object is represented in Fig. 1.
Kernel density estimation (KDE) is a non-parametric method to estimate the probability density function of a random variable. The characteristic frequencies of hand-arm system can be identified by KDE to develop the comparison between human hand-arm system and the 5-DOF model structure.
The analysis of variance has been developed by the Kruskal – Wallis Test, a non-parametric method.
The ratio between two successive characteristic frequencies can be described by the Markov Chains.

Results

In order to verify the differences obtained in the case of different persons, results are obtained with the following cases: combined position of wrist, elbow and shoulder (Wrist Extension, Wrist Flexion, Wrist Neutral 90° Bended Arm, Wrist Neutral Extended Arm); excitation along Xh- Yh- Zh-axis; different combinations of push force and grip force (Grip Force 20 N – Push Force 0 N, Grip Force 80 N – Push Force 0 N, Grip Force 80 N – Push Force 60 N and Grip Force 110 N - Push Force 0 N); vibration amplitude of a_w=15 m/s^2 and a_w=30 m/s^2 [4].

Discussion

The antagonistic action between grip force and push force influences muscle tension of human hand-arm system. The vibration amplitude influences also the stiffness coefficient of substructures represented by finger skin tightly in contact with the handle. Analyzing measured data along Xh- Yh- Zh-axis, it can be affirmed that the human hand-arm system is very sensitive to vibration direction in a wide frequency range. The process with combined position of wrist, elbow and shoulder shows the stabilizing effect of the wrist and the synergistic action between wrist and

fingers. There is strong interaction among elbow posture, wrist posture, and finger posture.
Distributions of measured data have long tails (outliers). The apparent mass due to the human hand-arm system approaches a very low value at high frequencies. The mass cancellation of the measured impedance data at high frequencies could also provoke errors in measured data.

Conclusion

The measured responses distributed at the fingers and palm have been reported in this study, conducted with four subjects and four different hand actions. The methodology proposed in this study provides a better evaluation of health risks associated with exposure to hand-transmitted vibration from power tools. The results obtained can also be used in handle design for new tools in order to minimize potential harm to operator's health.

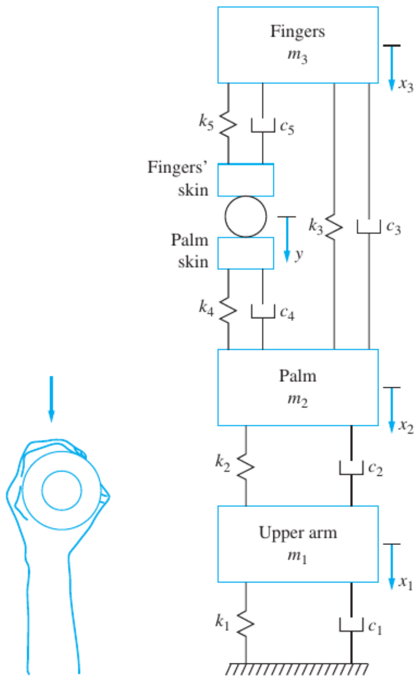

Figure 1: Lumped Mechanical System

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Hand-arm vibration exposure on a test track ride conforming to DIN EN 13059

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Abstract

With the aid of a defined test track, DIN EN 13059 [1] makes it possible to obtain whole-body vibration exposure values as required by the Machinery Directive [2]. The use of the test track by compact tractors shows that for certain vehicles the vibration exposure at the steering wheel can exceed the action value.

Keywords:

Hand-arm vibration, DIN EN 13059, test track, ride-on lawnmower, compact tractor

Introduction

DIN EN 13059 defines a method for measuring the vibration emission transmitted to the whole body of operators of industrial trucks in order to facilitate compliance with the requirements for the provision of characteristic values laid down in the Machinery Directive. It is intended that the findings obtained may also be used to compare industrial trucks of the same class or a given truck equipped with different seats, tyres, etc. This enables a prospective buyer to choose a low vibration vehicle. The whole-body vibration test is based on ride mode and thus complies with the requirements of DIN EN 1032 [3]. Studies have shown that the magnitude of hand-arm vibration on steering wheels or control levers of vehicles is usually less than 2.5 m/s², so no measuring method has been developed for this measurement.
The unit vibration of the IFA uses the existing test track of DIN EN 13059 to establish it for use by compact tractors and ride-on lawn mowers and to examine the need for a measuring method for determining hand-arm vibration. Figure 1 shows an example of a compact tractor.

Figure 1: Compact tractor

Methods

The test method of DIN EN 13059 involves a straight, level and smooth surface of length l = 25 m that has two rigid humps to create a defined surface. Figure 2 shows schematically the layout of the test track.

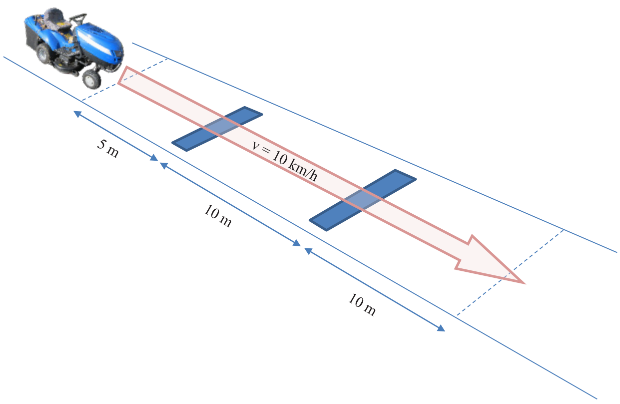

Figure 2: Test track conforming to DIN EN 13059

The tractor is driven over the test track at a constant speed of v = 10 km/h, negotiating humps across the track after a distance of 5 m and a further 10 m that expose the vehicle to a defined vibration. Figure 3 shows the measuring device for determining the a) hand-arm vibration exposure and b) the whole-body vibration exposure.

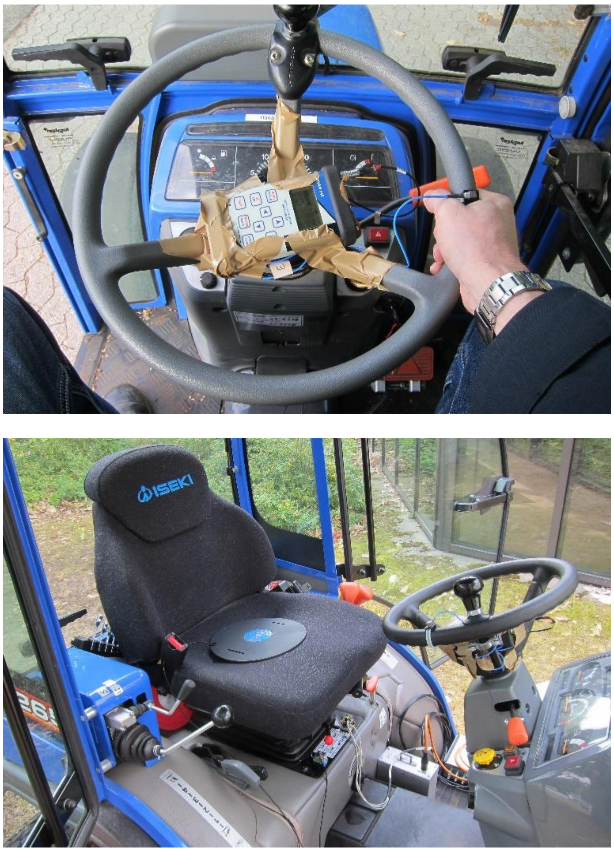

Figure 3: Attachment of the devices for measuring a) HAV and b) WBV

Results

Table 1 shows the vibration exposure at the steering wheel and at the seat mounting point during the test track ride. For the two compact tractors (Iseki 3265 und Iseki 4330), the vibration exposure at the seat mounting points is comparable but does not correlate with the vibration exposure at the vehicles' steering wheels. The vibration exposure at the seat mounting point of the rotary lawnmower (Iseki SXG19H) is below the measured values given above.

Table 1: Measurement results

Vehicle	Measuring point	Total vibration value a_{hv} in m/s^2	Effective value of frequency-weighted acceleration $a_{w,z}$ in m/s^2
Iseki 3265	Steering wheel	2.988±0.442	
	Mounting point		1.682±0.136
Iseki 4330	Steering wheel	1.424±0.057	
	Mounting point		1.645±0.176
Iseki SXG19H	Steering wheel	1.602±0.063	
	Mounting point		1.179±0.058

Assessment and Discussion

The vibration exposures measured at the seat mounting point differ for design reasons relating to vehicle category.
The assumption given in DIN EN 13059 that the vibration exposure at the steering wheel of industrial trucks remains beneath the value of a_{hv}=2.5 m/s² during the test track ride was not confirmed in this series of measurements on a compact tractor.
Consequently, in future test series it will be necessary to additionally consider the vibration exposure at the steering wheel and to report this to the prospective buyer so that they can choose a suitable vehicle that will minimise possible health hazards.

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Risk assessment for bone and joint diseases by working with motor chain saws

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Keywords:
hand arm vibration, risk assessment, motor chain saws, frequency composition, health risk, occupational disease

Introduction

It is known that exposure by hand arm vibration (HAV) may endanger employees' health. According to the Noise and Vibration Ordinance [1], preventive measures must therefore be taken depending on the level of exposure. However with high levels of exposure, chronic effects on the fingers and the hand-arm-system can also result in vascular and bone or joint damage [2, 3].

When handling chain saws, the users (e.g. forestry workers) are exposed to HAV. If the required conditions (exposure level and duration) are met, vibration-induced vasospastic syndrome can be recognized as an occupational disease (BK No. 2104). Until now the same exposure has not sufficiently been recognized as procedural requirement in the recognition process for bone and joint diseases as occupational disease (BK No. 2103). Chain saws allegedly should not sufficiently emit low-frequency vibration (≤ 50 Hz) to cause such diseases (see for example [4]). This assumption is based primarily on the paper of Dupuis et al. [5], where it was found that the main frequency range of chain saws meets over 50 Hz (see Table 1).

Table 1: Coupling and main frequency ranges for some devices - working conditions for BK-Nr.2103 [from 4, 5]

Machine	hand coupling		main frequency range	
	strong	weak	≤ 50 Hz	> 50 Hz
handheld machines Breaker …	x		x	
angle grinder	x			x
cut-off-grinder	x			x
chain saw	x			x
circular saw	x			x
handguided mach. plate compactor …		x	x	x

This assumption is corrected by the frequency-dependent evaluation of vibration measurements on chain saws and the associated risk assesment for bone and joint diseases presented here.

Methods

A method to assess the risk of bone and joint disorders or peripheral circulatory and nerve dysfunction from the proportions of the weighted acceleration below and above 50 Hz is proposed in Appendix D of VDI 2057-2 [6]. The applied method here uses the proportions $a_{hw(\leq 50Hz)}$ and $a_{hw(\geq 50Hz)}$, which are determined from available 1/3 octave spectra. These proportions are determined for bone and joint diseases in forearm direction and for vascular dysfunctions from the vibration total value. Twelve measurements, each resolved in third octave bands, were available for the investigation which were provided by two producers and a test institute. Further two frequency resolved measurements were determined graphically from [7].

Table 2: Acceleration in different frequency ranges determined on 14 motor chain saws

chain saw no.	acceleration in m/s²											
	main-/handhold or behind						secondary handle / handle tube or front					
	forearm direction			vibration total value			forearm direction			vibration total value		
	$a_{hw(8-1000Hz)}$	$a_{hw(\leq 50Hz)}$	$a_{hw(>50Hz)}$	$a_{hv(8-1000Hz)}$	$a_{hv(\leq 50Hz)}$	$a_{hv(>50Hz)}$	$a_{hw(8-1000Hz)}$	$a_{hw(\leq 50Hz)}$	$a_{hw(>50Hz)}$	$a_{hv(8-1000Hz)}$	$a_{hv(\leq 50Hz)}$	$a_{hv(>50Hz)}$
1	3,67	2,35	2,82	17,13	14,29	9,45	4,48	1,12	4,33	6,43	3,17	5,60
2 [1)]	9,87	5,42	8,26	9,87	5,42	8,26	9,87	5,42	8,26	9,87	5,42	8,26
3 [1)]	8,51	2,83	8,03	8,51	2,83	8,03	8,51	2,83	8,03	8,51	2,83	8,03
4	2,09	1,04	1,81	5,07	2,00	4,66	3,53	0,86	3,43	5,34	1,46	5,13
5	3,73	1,21	3,53	3,60	1,78	3,13	2,84	0,63	2,77	4,39	1,13	4,24
6	3,67	3,55	0,94	5,43	4,94	2,25	3,63	3,06	1,95	7,16	6,18	3,63
7	4,28	2,77	3,26	10,55	8,19	6,66	2,63	1,65	2,05	6,18	4,56	4,17
8	6,08	3,11	5,22	10,58	5,27	9,18	3,38	2,72	2,01	7,58	3,64	6,65
9	4,13	1,39	3,89	6,28	2,09	5,92	2,87	1,21	2,61	4,64	1,78	4,29
10	1,95	1,75	0,85	3,67	2,79	2,38	2,66	1,81	1,95	3,93	3,19	2,30
11	3,76	3,35	1,72	5,91	5,11	2,98	3,41	2,17	2,62	7,05	5,94	3,80
12	2,96	1,27	2,68	4,60	1,97	4,15	2,78	0,95	2,61	4,68	1,78	4,33
13	1,72	0,93	1,44	3,40	1,85	2,85	2,77	0,83	2,64	4,56	1,32	4,36
14	1,75	0,60	1,64	2,47	1,01	2,25	1,41	0,65	1,25	2,16	0,88	1,97

[1)] values derived from graphs in literature; measuring point as well as direction or vector unknown

Table 2 shows the values $a_{hw(8-1000Hz)}$, $a_{hw(\leq 50Hz)}$ and $a_{hw(>50Hz)}$ in the forearm direction as well as $a_{hv(8-1000Hz)}$, $a_{hv(\leq 50Hz)}$ and $a_{hv(>50Hz)}$ for the total vibration value obtained from the 14 motor chain saws analyzed. Except for number 3, all saws were equipped with AVS.

Results and Discussion

According to [6], the risk for bone and joint disorders, respectively vascular dysfunctions, is increased, if the proportion of $a_{hw(\leq 50Hz)}$ (in forearm direction) respectively $a_{hw(>50Hz)}$ on the respective total value $a_{hw(8\text{-}1000Hz)}$ is at least 75%. If such a classification is not possible, there may be a risk for both types of diseases. Of course, the total value (in conjunction with the duration of exposure) must be high enough for a health risk.

According to [1], at a daily vibration exposure value of $A(8) \geq 2.5$ m/s² (action value), a hazard for the employees can be assumed. Forestry workers have a typical daily exposure time for HAV by chain saws of 3.7 hours [8]. The action value will be achieved here by a vibration total value of 3.68 m/s². Pursuant to the 75% rule in [6], additional $A(8)_{(\leq 50Hz)}$ must be above 0.75 x 2.5 m/s² in the forearm direction for an increased risk of bone and joint diseases. This means $a_{hw(\leq 50Hz)} > 0.75 \times 3.68$ m/s² = 2.76 m/s². Analogously, for an increased risk of vascular dysfunctions for the total vibration value must be $a_{hv(>50Hz)} > 2.76$ m/s².

Without detailed knowledge of the exposure time, for forestry workers handling chain saws this results in:

1) The general risk of health hazards exists if $a_{hv(8\text{-}1000Hz)} \geq 3.68$ m/s² on a handle.
2) For increased risk of bone and joint disease 1) is necessary and in the forearm direction must be $a_{hw(\leq 50Hz)} > 2.76$ m/s².
3) For increased risk of vascular dysfunctions 1) is necessary and for the total vibration value must be $a_{hv(>50Hz)} > 2.76$ m/s².
4) Both types of disease are possible if both 2) and 3) apply. The risk is ambiguous if 1) is fulfilled, but neither 2) nor 3) applies.

The evaluation of the measurements on the 14 chain saws carried out according to this risk assessment is shown in Table 3.

Table 3: Evaluation with regard to the disease risks

chain saw no.	maximum $a_{hv(8\text{-}1000Hz)}$ in m/s²	maximum $a_{hv(\leq 50\ Hz)}$ in m/s²	maximum $a_{hv(>50Hz)}$ in m/s²	increased disease risk: generally	for bone and joint diseases	for vascular dysfunctions	both possible or indifferent
1	17,13	2,35	9,45	yes	?1)	yes	no
2	9,87	5,42	8,26	yes	**yes**	yes	yes
3	8,51	2,83	8,03	yes	**yes**	yes	yes
4	5,34	1,04	5,13	yes	**no**	yes	no
5	4,39	1,21	4,24	yes	**no**	yes	no
6	7,16	3,55	3,63	yes	**yes**	yes	yes
7	10,55	2,77	6,66	yes	**yes**	yes	yes
8	10,58	3,11	9,18	yes	**yes**	yes	yes
9	6,28	1,39	5,92	yes	**no**	yes	no
10	3,93	1,81	2,38	yes	?1)	no	yes
11	7,05	3,35	3,80	yes	**yes**	yes	yes
12	4,68	1,27	4,33	yes	**no**	yes	no
13	4,56	0,93	4,36	yes	**no**	yes	no
14	2,47	0,65	2,25	no	**no**	no	no

1) for the vector the portion $a_{hv(\leq 50Hz)} > 2{,}76$ m/s²

Except for number 14 all inspected chain saws may cause a general increased disease risk. The evaluation of the frequency distribution shows that 10 saws may have an increase risk of circulatory and nerve disorders and 6 - 8 saws may cause an increase risk to bone and joint diseases.

For 7 chain saws both is possible or the risk is ambiguous. Thus, for nearly half of the investigated chain saws the assumption is wrong that chain saws cant cause for bone and joint diseases as occupational disease.

The saws in table 3 are ordered tendencially ascending according to their production period. The risks tend to decrease with an increasing sequential number. Low-frequency vibrations leading to bone and joint diseases should only be of minor importance in modern motor chain saws corresponding to the state of the art. However, this risk must not be underestimated for older chain saws, which are relevant in current recognition procedures as occupational disease (BK No. 2103).

Conclusion

The presented analyses of vibration measurements, which are resolved in third octave bands and the therewith implemented risk assessment show that also at chain saws sufficiently high accelerations in the range ≤ 50 Hz can occur to cause bone ore joint diseases. The assignment based on the main frequency ranges (Table 1) has to be corrected and both frequency ranges must be marked also for chain saws.

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Vibration exposure during sausage production – vibration caused by fingers interacting with rotating contact surface

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Abstract

Due to the unusual nature of the cause of vibration on a rotating and grooved surface, measurements were performed on the test subject's fingernails. The measurement results were valided with a laser vibrometer. This article presents the measuring procedure and the results of vibration exposure.

Keywords:

Hand-arm vibration, sausage production, laser vibrometer, measurement on test subjects (humans)

Introduction

Vacuum filling machines have been in use in sausage production since the beginning of the 1970s. The sausage is filled and portioned with the aid of a "linking nozzle". In the process without a holding device, the nozzle has to be manually held during the linking operation.
The surface of the linking nozzle is provided with grooves so that during rotation vibrations are caused by holding the nozzle more or less firmly (see Figure 1). For this the hands are damp and, in accordance with hygiene regulations, in a cool environment.

Figure 1: Process of sausage production

Many years of daily exposure for several hours have resulted in vibration-related complaints calling for a measurement of vibration exposure.

Methods

Since, in this unusual process, vibration only arises due to the interaction of the fingers with the rotating and grooved linking nozzle, it was not possible to adopt the usual procedure of fastening the accelerator to the contact surface. Therefore, departing from the measuring procedure defined in ISO 5349-2 [1], the accelerometers were attached to the fingernails of the subject's ring finger and thumb. The extremely light sensors (1.0 gram) were fastened with thin double-sided adhesive tape and fixed with thin adhesive tape. The position of the measuring devices and the fastening of the accelerometers can be seen in Figure 2. Apart from this fastening of the sensors, execution and evaluation of the measurements conformed to the requirements of ISO 5349 [1]. A measuring instrument satisfying the requirements of ISO 8041 [2] was employed.

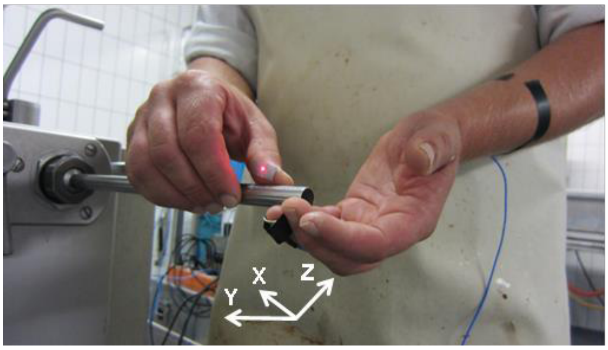

Figure 2: Fastening of the accelerometers with directions of measurement

For technical reasons, the measurements were performed in simulated working conditions without the processing of sausage.
To verify the deviations from the measurement standard, a reference measurement was performed with a contactless laser vibrometer [3, 4] on the finger surface (for measurement point, see Figure 2 and Figure 3).

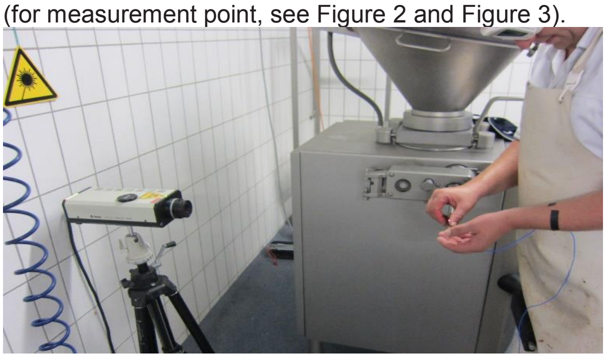

Figure 3: Reference measurement with laser vibrometer

Results

The results of each single measurement were obtained as the energy-equivalent average over the measurement duration of 10 s. The individual results of the repeat measurements were arithmetically averaged for the frequency-assessed acceleration and are given in the table separately for direction of measurement, measurement point and operating status.

Table 1

Machine: Vacuum filling machine (Sausage filling machine)

Operating Status: Filling sausage	**MP**	**Frequency-assessed vibration accelaration a_{hw} in m/s² for direction of measurement**			**Total vibration value**
		X	**Y**	**Z**	**a_{hv} [m/s²]**
188 per minute Vol. 54 cm³	R	2,32 ± 0,26	1,34 ± 0,04	4,90 ± 0,05	5,58 ± 0,12
125 per minute Vol. 133 cm³	R	2,75 ± 0,14	1,53 ± 0,08	5,27 ± 0,25	6,13 ± 0,28
130 per minute Vol. 54 cm³	T	2,72 ± 0,08	2,29 ± 1,09	7,16 ± 0,31	7,95 ± 0,69

R = ring finger T = thumb MP = measurement point

Assessment and discussion

If the vibrations during the observation period are considered and the standard deviation is added to the mean value, the total vibration value is a_{hv} = 5.7 to 8.6 m/s². According to the European Vibration Directive [5], the action value at this level of exposure is exceeded after 40 min to 1 h 32 min. The limit value is exceeded after 2 h 41 min and 6 h 9 min respectively.

A health risk due to intense work cannot therefore be excluded. Attention to this risk should therefore be drawn in the machine manufacturers' operating instructions.

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Measurements of exposure to single shocks in firearms testing

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Abstract

In manual firearms testing, the hand-arm system is exposed to powerful single shocks. The resulting vibrations cause discomfort to employees and can result in damage to their health. In this article, different firearms are investigated during testing. The article presents the measuring method and the results of vibration exposure.

Keywords:
Hand-arm vibration, firearms testing, single shocks

Introduction

The intensive use of manual firearms during testing (with 20,000 rounds per weapon) resulted in discomfort and the reporting of an occupational disease. Since the level of knowledge of repetitive single shocks is currently low [1], the acceleration effect was measured and a guide assessment was performed on the basis of the existing rules. The aim is to arrive at possible preventive measures.

Methods

The sequence of shots can vary greatly depending on the manual firearm and test subject (TS). For reasons of comparability, the individual shots were therefore fired at intervals of 3 s [2]. Measurements were performed on a total of 5 weapons, each with 3 different subjects per weapon. To minimise the effect of the test subjects, the firearms were each measured with the same persons. Each of the test subjects had to fire at least 30 shots per weapon sample. In addition, individual measurements were performed with fast, non-timed shot sequences. Furthermore, the movement of the weapon and of test subjects' hand-arm systems was recorded exemplarily with the aid of a high-speed camera (1000 frames/second). The measuring instruments used conform to the requirements of ISO 8041 [3]. The selection of measuring points and measurement axes is based on ISO 5349 [4] and ISO 20643 [5]. To ensure the mutual comparability of the firearms, the trigger guard was selected as the measuring point for all weapons (for example, see Fig. 1).

For technical reasons, the measurements were carried out on all weapons in the assumed main direction of excitation (Z-axis), i.e. in the direction of recoil and, as an example, only on one firearm additionally on the Y-axis.

The measurements were performed and evaluated in accordance with ISO 5349 [5].

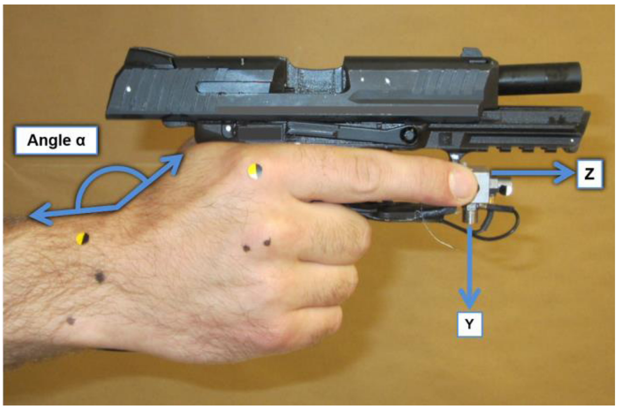

Figure 1: *Measurement direction Z and Y, attachment of acceleration sensor and wrist angle α*

The results of each individual measurement were determined as an energy-equivalent mean value over a fixed measurement period.

Results

Figure 2 shows the arithmetic mean values for each weapon and test subject with their scattering, grouped according to weapon type. Here a correlation can be assumed between the mass of the respective firearm and its effect on the acceleration value due to mass inertia.

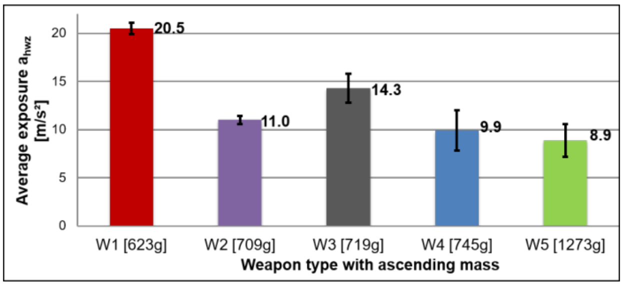

Figure 2: *Exposure level and firearm mass*

Table 1 compares the results of the mean values of the measurement series with individual shots and a rapid firing sequence (continuous firing) each for 3 weapons and 1 subject. For comparability, the values were converted into energy equivalent values and standardised to an integration time of T = 3 s. Taking the scatter into account, no significant differences can be identified.

Firearm	TS	$\bar{a}_{hwz,TS}$ [m/s²]	$a_{hwz,standardised\ 3\ s}$ [m/s²]
W5	2	20.8 ± 1.7	19.1
W3	1	11.9 ± 2.4	9.8
W2	1	9.7 ± 0.1	11.6

Tabelle 1: *Comparison of the results of continuous firing and individual shots (TS: test subject)*

Figure 3 shows the percentage deviation of the test subjects from the average measured vibration exposure a_{hwz}. The differences between individual test subjects are relatively large, as is the case with the emission measurements from machines.

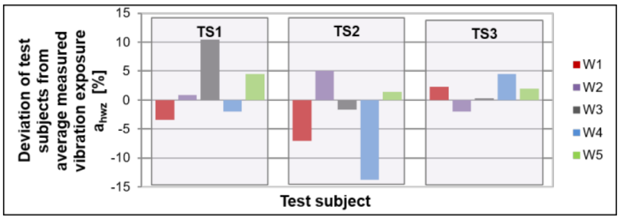

***Figure 3**: Percentage deviation of test subjects from the average measured vibration exposure a_{hwz}*

According to the current state of knowledge, there is a basic transgression of the action value of the daily vibration exposure A (8) = 2.5 m/s² and of the exposure limit value A (8) = 5 m/s² [8] after the following daily exposures (shooting events) given in Figure 4. For any weapon it is not therefore possible to set a uniform maximum number of shots per day.

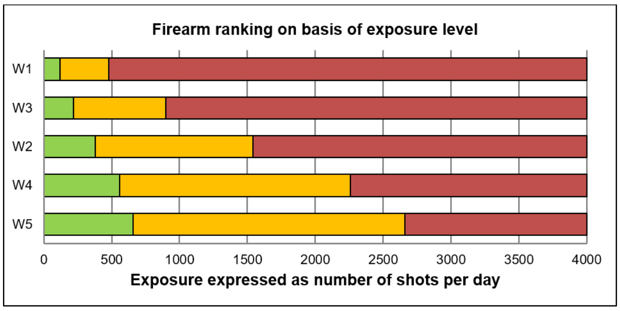

***Figure 4**: Number of shots until transgression of action and limit values*

To examine the relevant measurement axis, the additional evaluation according to ISO/TR 18570 was carried out exemplarily for a single firearm. Figure 5 shows the comparison of the two frequency weightings. Taking the new evaluation curve into account, the vibration exposures on the Z-axis are significantly higher. Although the a_{hw} values are higher on the Y-axis, the low-frequency compensation movement is also recorded and evaluated. However, this proportion does not lead to a reaction force, or the proportion is lower.

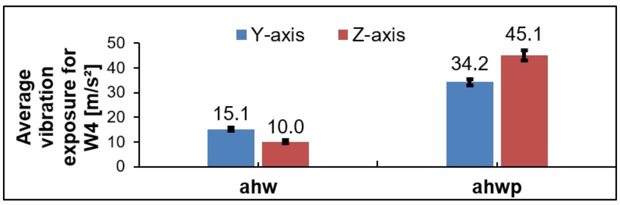

***Figure 5:** Comparison of different frequency weightings*

As an example, the change in angular velocity and wrist angle was recorded using the firearm (W2) with the aid of video analysis. The deflection of the wrist (radial induction) is not critical at 10° according to Drury [7], but the angular velocity is quite high.

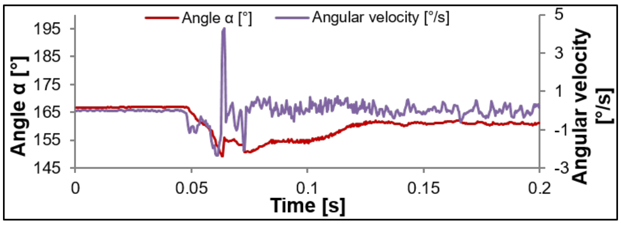

***Figure 6**: Change in angular velocity and wrist angle during a shooting event*

Discussion and Conclusion

Although the state of knowledge of the harmful effects of individual shocks on the hand-arm system has so far been low, the preliminary assessment according to ISO 5349 shows that there is a risk associated with the usual manual testing. With a daily number of shots between 120 and 660, the action value is already exceeded. The shock exposure should therefore be reduced as much as possible.

The investigations showed that further evaluation parameters such as the angular momentum on the wrist, the measurement axis and frequency range as well as the representativeness of the measuring point require further investigation.

A DGUV-funded research project, which is expected to yield further assessment criteria for exposure to single shocks, was launched in 2018.

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Dosimeter for detecting hand-arm vibration in a laboratory comparison with standard-compliant measurements

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Abstract

The determination of the daily dose for the evaluation of hand-arm vibration is an elaborate process with conventional measuring equipment. Standard-compliant measurements often interfere with the work process and are time-consuming and cost-intensive. As a low-cost alternative, systems (dosimetric auxiliary devices) worn on the person have been developed to provide the user with up-to-date feedback on his daily dose. The possible uses and application limits of such a dosimeter have been investigated. [1][2]

Keywords:

Hand-arm vibration; dosimeter; HAVwear

Introduction

The EU Directive 2002/44/EC [3] was implemented in Germany by the Noise and Vibration Occupational Health and Safety Ordinance (LärmVibrationArbSchV) [4] in March 2007 with the aim of preventing and preventing illnesses caused by occupational activities involving exposure to vibration.

The assessment of a workplace in accordance with ISO 5349-1 is essentially based on the daily vibration exposure value A(8), which is composed of the vibration total value and the exposure duration [5]. The vibration total value can either be estimated on the basis of the manufacturer's data or measured by expert personnel. However, determining the duration of exposure for an 8-hour working day presents a problem and it is often defined for an exemplary working day on the basis of estimates. Applying this to the individuality of a single working day is almost impossible. In addition, the information provided by users leads to faulty estimates. So that the duration of exposure for each individual working day can be determined, so-called dosimeters have therefore been developed.

As an example, this paper presents the suitability of a dosimeter for use under practical conditions and its measurement inaccuracy in determining hand-arm vibration exposure.

Methods

In the laboratory, examples of various hand-held tools with different vibration characteristics (orbital sander, impact wrench and hammer drill) were used by five test persons wearing a HAVwear dosimeter on their wrists. An acceleration sensor for standard-compliant measurement was attached to the tools during the execution of the tool-dependent work cycles. This sensor serves as the reference for the dosimeter and thus supplies information on the quality of the measurement results.

Dosimeter

The Reactec HAVwear is a dosimetric auxiliary device conforming to ISO/TR 19664 [6] for hand-arm vibration measurements, as it does not meet the requirements of ISO 8041 [7]. It is worn on the wrist like a wristwatch and can be used both as a personal vibration exposure gauge and as an exposure timer with an exposure calculation.

Figure 1: HAVwear dosimeter

RFID technology can be used to assign vibration characteristics to different vibration-emitting tools. According to the user's specifications, the manufacturer sets one of five sensitivity settings that vary the threshold value for vibration detection. Sensitivity setting 3 was used as well as setting 1 for comparison with a test subject.

Standard-compliant measuring instrument

The Svantec SV106 meets the requirements of ISO 8041 as a standard-compliant measuring instrument. It contains the frequency-weighting filters required for whole-body and hand-arm vibration measurements. This instrument was used with two different accelerometers that differ in size and sensitivity. Both sensors were attached to the tools used, in accordance with their vibration characteristics.

Results

The measurement results of the detected exposure durations over the total measurement duration with sensitivity setting 3 differed for the various hand-held tools. For the orbital sander and the impact wrench, the dosimeter reports up to 44 % lower exposure times and would yield a significant underestimation of the hazard. For the hammer drill, however, the detected exposure duration is 5 % higher than actual exposure.

Table 1: Percentage deviation of detected exposure durations

Tool	Deviation in %	
	Sensitivity setting 3	Sensitivity setting 1
Orbital sander	-44	+4
Impact wrench	-30	-25
Hammer drill	+5	+19

Even when using the dosimeter with sensitivity setting 1, different results are obtained for different tools. The exposure durations determined by the dosimeter are 4 and 19 % higher than the actual exposure for the orbital sander and the hammer drill respectively, but 25 % lower for the impact wrench.

Figure 2 shows an example of the vibration time curve for a measuring section. Sections with vibration exposure can easily be distinguished from sections without vibration exposure.

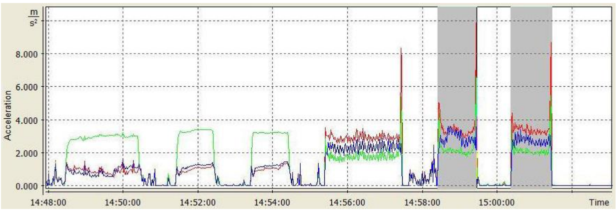

Figure 2: Example of a measurement signal

Discussion

The deviations of the dosimetric measurements depend on the sensitivity setting. The manufacturer's claim that at setting 1 more accurate results are obtained for tools with a main excitation frequency > 100 Hz is confirmed by the results for the orbital sander, whose main excitation frequency is approximately 160 Hz. The results for the impact wrench show a significantly lower improvement at setting 1 although its main excitation frequency is about 100 Hz. The exposure times detected for this tool are significantly lower than the actual times at both settings. With variation of the sensitivity setting, there is an increasing overestimation of the exposure duration for hammer drills with a main excitation frequency of approx. 80 Hz.

In practice it can be assumed that several tools with different main excitation frequencies are used by a single person. Choosing the correct sensitivity setting is therefore decisive for the accuracy of the result.

Conclusion

In the laboratory comparison of the HAVwear dosimetric auxiliary device for hand-arm vibration measurements and a standard-compliant measuring method, the results for the determined exposure durations differ strongly in some cases. Depending on the sensitivity setting on the dosimeter, the results differ to a great extent, thus causing under- or overestimation of the hand-arm vibration exposure. It is possible that software modifications assigning an individual sensitivity setting to each tool identified by RFID tag could yield exposure durations for individual working days that produce only slightly incorrect estimations.

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Jobs with single shock exposures – an explorative approach

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Abstract

The characterization, distribution and health-effects of isolated/single shocks are still under scrutiny. This work attempts to gather more information about work with single shock exposure by conducting an occupationally unselected online survey on possible exposure scenarios, and resulting health effects. As a result, the occupational distribution of especially hand-held single shock tools like hammers became obvious. Apart from that the relevant prevalence of hand-arm-complaints in an unselected occupational cohort which might (or might not) be associated with single shock exposures. This explorative cross-sectional approach is part of a larger project focussed at single shocks and early health effects.

Keywords:
single shock; hand-arm complaints; job-exposure matrix

Introduction

Single shock exposure is suspected to have more intense health effects on the hand-arm system in comparison to „normal“ vibration exposure. While some jobs and activities with machines and tools with single shock exposure, are well known, there is some doubt as to whether all relevant workplaces have already been identified, as it has already been discussed that the distribution of tools and machines with single shock exposure and the relevance for health effects are usually underestimated [1, 2]. Nevertheless, until now knowlegde about single shock exposures is still scarce. This explorative survey tries to fill this gap by an explorative approach.

Methods

An online questionnaire was developed which focuses on the exposure to some machines and tools which are known in the context of single shocks on the hand-arm system (hammer, axe, bolt-firing tool, nail gun, stapler gun), and also asks for other tools or machines and jobs in which these exposures occur.
Another focus of the questionnaire was on health problems of the hand-arm-system. In this context, participants were asked to report about problems in the respective structures of the hand-arm-system (finger, hand, wrist, forearm, elbow, upper arm, shoulder).
Finally, confounding factors (e. g. diseases, smoking status, physical activities were addressed in the questionnaire.
The online survey was realized with SoSci Survey [3] and available on www.soscisurvey.de. It was available online between September and December 2018 and participants of educational programs of statutory accident insurances without any limitation with regard to job or occupation were invited to participate (figure 1).

Figure 1: information and invitation flyer of the survey

Results

Altogether 162 volunteers participated in the survey. 83,5 % of the participants were men (age median between 51 – 55 years) and 45.8 % have never been smoking. 51 participants reported a job where the use of one of the above listed machines or tools was necessary. 52 (32.1 %) persons reported potentially counfounding general health issues which can have an effect on hand-arm-problems, e. g. diabetes, neurological disorders in the hand-arm-region, rheuma, arthrosis. Jobs represented in this survey were e. g.: automotive engineer, plumber, systems mechanic, merchant, carpenter. Depending on the reported job, the participants reported working with hammers, axes, nailguns, stapler guns, bolt-firing tools, and other tools/machines (e. g. air hydraulic impact wrench, drill hammer, power screwdriver for rails, hydraulically powered tools (e. g. jackhammer), chisel, power rammer), respectively. With regard to intensity of use, most participants reported a use pattern which was associated with less than 500 shocks per day (figure 2).

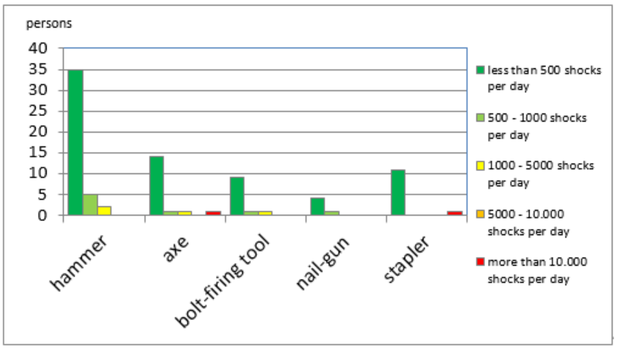

Figure 2: single shock tools and machines: reported exposure intensity

Nevertheless, altogether 15.4 % of participants had shoulder problems, 14.8 % reported finger problems, and 12.2 % problems in the hand joint (figure 3).

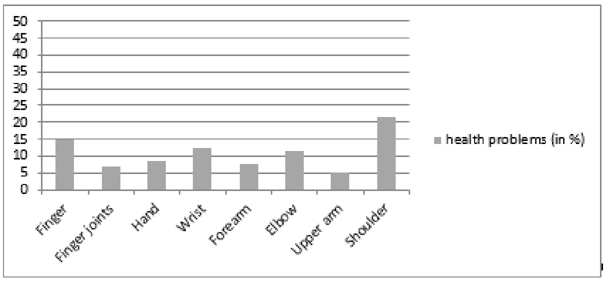

Figure 3: reported health problems (% of participants) in the hand-arm-system (N=115)

Conclusion

This cross-sectional snapshot of persons who use hand-held machines and tools, tries to broaden our view on exposure to single shocks on the hand arm system and health issues. Some job-exposure associations should be discussed and exposure scenarios should be modelled with mean values of acceleration. The results of this survey approach are part of a study with a focus on single shock exposures and health effects.

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Determination of hand-arm vibration exposure caused by single shocks taking the example of golf as a leisure activity

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Abstract

In the context of the Single Shocks and Health Effects (SSHE) project, IFA is investigating vibration exposure caused by single shocks in the leisure sector. This article presents the performance of testing and the evaluation for the measurement of single shocks taking the example of golf as a leisure activity.

Keywords:

Hand-arm vibration; single shocks; leisure activities; golf

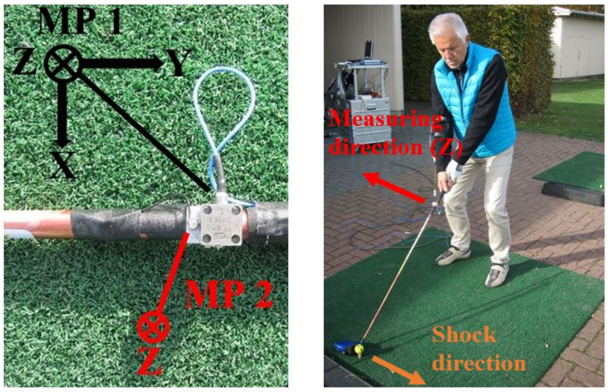
Introduction

Single shocks are a special case in the hand-arm vibration sector. In 2016, in a cooperative project between the Institute for Occupational Health and Safety (IFA) and KSZ Ingenieurbüro, an attempt was made to uniformly define and describe single shocks as a special case of hand-arm vibration [5]. However, the current state of knowledge regarding the physiological effects of single shock exposure is still low and is being investigated in a cooperative project (Single Shocks and Health Effects) by the Swedish RISE IVF research institute, the Institute for Occupational Medicine, Safety and Health Management of the University of Lübeck and IFA. In this project, IFA is responsible for the task of investigating the exposure caused by single shocks in the leisure sector. In addition to the determined loads, physiological examinations are to be carried out by medical professionals from the University of Lübeck to obtain information on the stressing of the test subjects on the basis of physiological parameters such as blood circulation.

Methods

Since the specification of the frequency range for single shock measurements is still the subject of research, and since there is also an interest in providing relevant data for future work and findings, all measurements in this investigation were carried out with a comprehensive frequency range of 10,000 Hz.

- Three experienced golfers (test subjects)
- Measurement in a real-life game situation:
  15 tee-offs per test subject from driving range
- Main direction of measurement (Z) parallel to the direction of teeing off (see **Figure 1**)
- Two investigated golf clubs



MP 1 = Measuring Point 1 (PCB 350B50)
MP 2 = Measuring Point 2 (B&K 4374)

Figure 1: Directions of measurement and testing of golf club 2

To cause as much load as possible, the test subjects were instructed to hit the golf ball as far as possible.

Results

To permit direct comparability of the measurement results for processes with different repetition rates, the results of each individual measurement are evaluated as effective interval values (T = 3 s) in conformity with ISO/TS 15694 [3]. The frequency weightings $flat_h$, W_p and W_h [4] are performed for all effective values. **Figure 2** shows the results for the two golf clubs in the dominant measuring direction (Z) averaged over all test subjects.

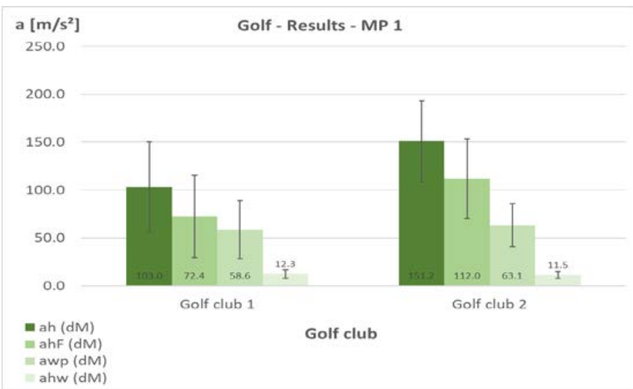


Figure2: Graphic representation of summarised results for both golf clubs in dominant measuring direction (Z)

In addition to the effective values of the dominant measuring direction (Z), **Figure 3** also shows the total vibration values for both golf clubs.

		Mean [m/s²]					Standard deviation [m/s²]				
Golf club	MP	a_h (dM)	a_{hF} (dM)	a_{wp} (dM)	a_{hw} (dM)	a_{hv}	a_h (dM)	a_{hF} (dM)	a_{wp} (dM)	a_{hw} (dM)	a_{hv}
Golf club 1	1	103.0	72.4	58.6	12.3	16.8	47.1	42.8	30.3	4.5	4.5
	2	112.0	80.3	60.5	13.2	/	51.4	43.1	30.6	4.7	/
Golf club 2	1	151.2	112.0	63.1	11.5	15.6	42.2	41.5	22.6	3.6	4.4
	2	177.1	114.5	65.9	12.9	/	48.9	41.5	23.3	4.3	/
MEAN	1	127.1	92.2	60.9	11.9	16.2					
	2	144.6	97.4	63.2	13.0	/					

Figure3: Table of summarised results for both golf clubs

Discussion

The total vibration values of 16.8 m/s² and 15.6 m/s² are of comparable magnitude for both golf clubs. If the ISO 5349-1 assessment procedure defined for harmonic and stochastic vibrations is used as a guide, a health hazard cannot be ruled out with the use of either of the two golf clubs and with intense exposure to the investigated shock processes (tee-offs) [1].

The standard deviations of the total vibration values, formed from the sum of all measurements for a golf club, are relatively high at 4.5 m/s² and 4.4 m/s². This is partly due to the fact that teeing-off in golf is a very personal process, which it is difficult to reproduce exactly. Furthermore, the scatter of the overall results is also attributable to the differences between the test subjects. Overall, for golf and the issues considered here, the test subject has a significantly greater effect on the measurement result than the golf club.

In the practice of golf as a leisure activity, the exposure shown is roughly comparable to that experienced by a test subject when using a bolt setter ($a_{hv} \approx 17$ m/s²). However, whether the two vibration exposures also cause a similar physiological reaction in test subjects has not yet been sufficiently investigated and is still the subject of the SSHE project.

Conclusion

Using the assessment procedure from ISO 5349-1 as a basis, those practising golf as a leisure activity are shown to be exposed to loads which may be relevant for the development of various diseases of the hand-arm system after many years of exposure. This assumption is confirmed by existing studies that show a series of possible injuries of the hand-arm system that can develop over many years of golfing practice [3]. However, since it has not yet been settled overall whether using the assessment procedure of ISO 5349-1 is advisable for the evaluation of shock events, these results should be interpreted with caution.

Furthermore, the test subject has a huge effect on the measurement result in the investigated leisure activity of golf. It can also be assumed that the selected playing situation also has a significant influence on the measured accelerations – for example, golf tee-offs from the driving range are very probably associated with significantly higher exposure than putting.

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Testing of new self-measuring power tools that supply the user directly with information on his daily dose

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Abstract

Thanks to development work by machine manufacturers, vibration sensors are integrated into handheld portable power tools to enable a simple and cost-effective method of recording vibration emissions. In this article, these daily dose values are compared with a standard reference system.

Keywords:

Hand-arm vibration; self-measuring power tools; daily vibration exposure

Introduction

According to the European Vibration Directive [1], as transposed into national law, the minimum requirements are that the exposure limit value is reached at a daily dose of A(8) = 5 m/s^2 and the action value at a daily dose of A(8) = 2.5 m/s^2. The determination of the daily dose is very time-consuming, since the measuring instrument must satisfy the requirements of ISO 8041 [2].

Thanks to development work by machine manufacturers, vibration sensors are already integrated into handheld portable power tools in order to enable a simple and cost-effective method of recording vibration emissions.

However, self-measuring power tools do not meet the requirements of a measuring instrument conforming to ISO 8041 [2]. Also, such power tools are not defined in ISO/TR 19664 [3]. According to the VDI report 2190 [4], these devices qualify as “human vibration indicators”.

As there are no specifications regarding the accuracy of these device-integrated vibration measuring instruments, the measurement accuracy was tested using a standard reference system.

Methods

The Deros 650 CV orbital sander from Mirka was tested. During operation, the device supplies the speed, vibration and daily exposure to an app for commercially available smartphones via Bluetooth (Figure 1).

A measuring instrument conforming to ISO 8041 [2] was used as the reference system. To compare the data supplied by the app with the data of the reference system, measurements were taken synchronously using the same power tool.

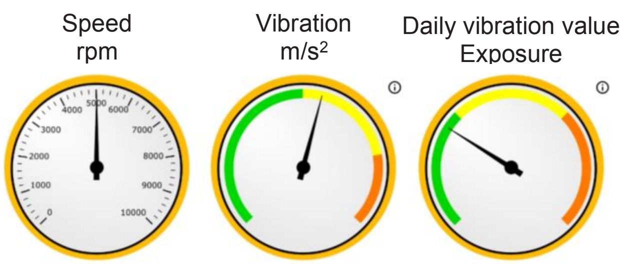

Figure 1: Graphical user interface of the app

Several repeat measurements were performed. The measurement location and the measurement directions of the reference system were chosen on the basis of ISO 28927-3 [5]. The accelerometer was coupled by means of an adhesive. To permit measurement under practical conditions in the working environment, the measurement was carried out in a car paintshop on car doors (Figure 2).

Figure 2: Sanding a car door

The measurements were performed and evaluated in accordance with ISO 5349-2 [6]. After each individual measurement, the current daily dose value of the app was stored. Since only the daily dose had a numerical scale, numerical values (A(8)) were generated from the diagrams (supplied by the app) using the Inkscape image processing program (Version 2, Free Software Foundation, Inc., USA). The a_{hv} for each individual measurement was then determined from the A(8) values.

Results

The percentage deviations of the a_{hv} supplied by the app from the a_{hv} of the reference system for each individual measurement are presented in Figure 3 as a histogram.

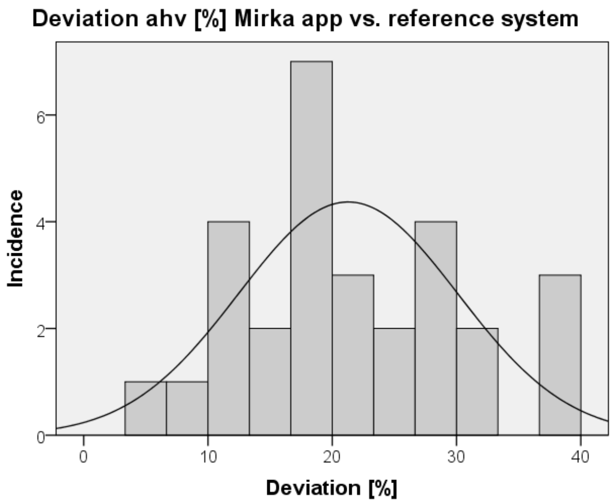

Figure 3: Percentage deviation of the a_{hv} of the app from the reference system

The a_{hv} determined by the app was constantly higher than the a_{hv} of the reference system. The arithmetic mean (± standard deviation) is 21 ± 9 %. Depending on the operating state, the deviations range from 7% to 38%.

Discussion

Based on the results, a systematic deviation of the a_{hv} of at least 7% is assumed. This means that the vibration emission tends to be consistently overestimated. This overestimation was found in a range of up to 38%.
According to the ranking list “Best practice for the use of different sources of information including uncertainty aspects” in the guidelines for vibration hazards reduction – Part 2: Management measures at the workplace [7], the use of this self-measuring power tool would have a high rating and would also exceed the manufacturer's data.

Conclusion

With this system, the user can monitor his individual exposure to hand-arm vibrations on the traffic-light principle and ensure compliance with the exposure limit value. Since the a_{hv} cannot be seen directly with the app, but can only be determined indirectly, the user has only the daily dose on the basis of a diagram scale. The device determines its daily dose value for the user with little effort and is more accurate for vibration emissions than the estimate based on the manufacturer's data. By using the app, the user can assume that the app does not underestimate the vibration emission. The estimation is not as accurate as a standard measurement but much simpler and cheaper and it can be used continuously during operation. Changes in the operating conditions can thus be recorded and evaluated.

Acknowledgement

This study was supported by the Berufsgenossenschaft Holz und Metall (German Social Accident Insurance Institution for the woodworking and metalworking industries). The authors thank Mr. Adler, Mr. Struß and Mr. Nigmann for their kind cooperation.

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Knowledge for performing and evaluation of measurements on human exposure to mechanical vibration (DIN SPEC 45674)

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Abstract (optional)

German national standards institution DIN and its deliverables. Function of DIN standards in the regulatory system. DIN/VDI Standards Committee Acoustics, Noise Control and Vibration Engineering (NALS). DIN Technical Report DIN SPEC 45674, providing guiding principles for the necessary competence of those performing vibration measurements in the presence of human exposure to mechanical vibration.

Keywords:

National standardization; National guidelines

Introduction

Presentation of DIN.

Overview of DIN SPEC 45674.

Methods

Standardization at DIN:

DIN German Institute for Standardization is a registered non-profit association supported by the private sector, founded in 1917.

On the basis of a contractual agreement with the Federal Republic of Germany, DIN is the responsible German standards body in European and international standards work.

DIN functions as a "round table" – and increasingly as an electronic platform – where stakeholders can develop modern consensus-based standards suited to market needs.

DIN's breakdown of revenue sources:

- 59 % own income
- 20 % project linked funding by industry
- 12 % project linked public funding
- 9 % membership fees

DIN undertakes to give priority to standards projects which are in the public interest

DIN undertakes to ensure that fair procedures allow less powerful stakeholders to participate in standards work

DIN will do everything in its power to ensure that DIN Standards do not conflict with international commitments by the German government to liberalize trade and remove trade barriers.

Standards within the legal system (Figure 1):

- Implementation of standards is voluntary
- Standards are only legally binding if they are part of a contractual agreement between parties, or if legislators stipulate conformity with them
- Standards are unequivocal (recognized) rules, and reference to standards in contractual agreements provides legal certainty
- In litigation, judges regularly accept DIN Standards to be "prima facie proof".
- A rebuttable legal presumption (reversal of the burden of proof)

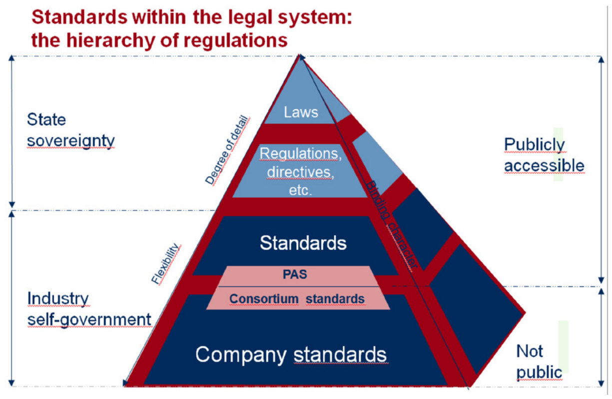

Figure 1: Hierarchy of regulations

DIN SPEC 45674:

Vibration measurements are often highly complex and require that the persons involved have suitable knowledge concerning measurement and evaluation of vibrations.

The DIN Technical Report provides guidelines for the required competence of persons carrying out vibration measurements to evaluate the effects of vibration on humans.

<u>The contents is as follows:</u>

Foreword
Introduction
1 Scope
2 References
3 Terms and definitions
4 Classification of the competence
5 Levels of competence
  5.1 General
  5.2 Level I
  5.3 Level II
  5.4 Level III
Annex A (informative) Subjects of the relevant levels
Annex B (informative) Subject weighting
Annex C (informative) Selection of relevant standards
Bibliography

Competence is classified for individual subject areas according to the scheme shown in Figure 1.

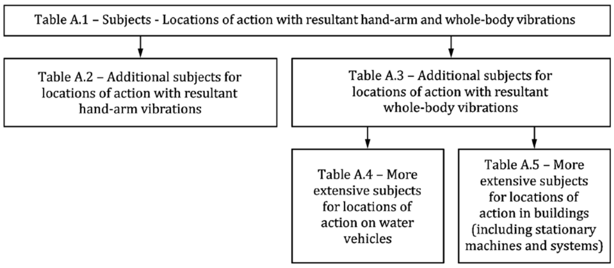

Figure 1: Classification of competence

Essential contents of the DIN SPEC 45674 about the expertise for the implementation of vibration measurements are dealt with in the following DGUV Principle: "DGUV Grundsatz 309-013" [2].

The "DGUV Grundsatz 309-013" [2] defines the training contents and the requirement for a test of proof of knowledge. The IFA carries out training in accordance with the "DGUV Grundsatz 309-013".

Conclusion

The aim of DIN SPEC 45674 is to ensure the required quality of measurements by avoiding errors in measurement and minimizing uncertainty of measurement.

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A study on influencing parameters in measuring hand-arm vibrations applying the international standard

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Abstract (optional)

Many activities in daily life confront us with hand-arm vibrations (HAV). Some of which are emitted at high levels and can pose the threat of changes to the hand-arm system. These changes are grouped under the term hand-arm vibration syndrome (HAVS). In order to appraise the risk, the international standard DIN EN ISO 5349:2001-12 contains directions on measuring and evaluating HAV. Yet, not all cases are covered by it in the same level of detail, leaving leeway in implementing it. Furthermore, previous studies have shown great deviation in measurements of HAV. There have been measurements done on the same device giving largely varying results. But an accurate measurement and the knowledge of the influence of the involved parameters are crucial for assessing the risk of the occurrence of the HAVS. As it is assumed that the variance among the results can at least partially be ascribed to the definitions in the standard, the goal is to ascertain the margin in the standard and to evaluate the influence of the freely configurable variables.

Keywords:

International Standard; Measurement

Introduction

The prevalance of hand-arm vibrations (HAV) in daily life in combination with the health effects (hand-arm vibration syndrom, HAVS) that can originate from the exposure to them and variation of the measured results give reason for questions. What is the origin of the rather large variance? Why do the results vary as much even though having been obtained by applying the same standard?

In order to answer those questions, the standards ISO 5349-1 [1], ISO 5349-2 [2] and ISO 8662-11 [3] have been compared. All of them contain sections in which an advice is given instead of a strict instruction on how to conduct the measurement. The measurements described have been conducted to obtain an appraisal of how the different implementations of the standards affect the measured vibration.

Methods

Comparing the standards several measurement parameters were determined which are not distinctly specified. It is assumed that the variation of those may lead to a different measured vibration. These parameters are listed in the following.

Parameters and their variations

- sensor: various positions
- affixing: different means
- measurement duration: time window
- grip strength: felt strength
- pushing force: perceived force
- rubber part of the handle: with and without

According to the found parameters, a staple gun was chosen as the tool for the evaluation. It's impulsive vibration allows the analysis of all of them. Hence the most suitable standard is [3].

Here the sensor position is defined as parallel to the axis of drive-in and as close as possible to the gripping position, whereas [1] specifies it as preferably close to the center of the gripping zone and [2] as close to the palm, between thumb and pointing finger. Even considering only [1] several different positions fulfill the provisions, hence four different measurement positions were included.

The fixing mechanism of the sensor to the tool is stated to be rigid in [1] and [2] and several advices are given in all the standards. Named options are a metal clamp, zipties, gluing or using an adaptor. All of those couple the sensor differently with the tool and are assumed to have a varying transfer properties. It was chosen to measure both with a metal clamp and glueing the sensor to the tool.

The measurement duration can be analyzed after the measurement by windowing the signal, yet in [3] it specified as 30 seconds including ten setoffs of the tool, which needs to be repeated five times. Due to different definitions in the other two standards the measured signal have been windowed afterwards with two fixed time windows.

Measuring the grip strength and its influence have been the subject of several studies [4,5,6,7], but due to the given options had to be restricted to a perceived distinction between normal and strong.

Operating hand held tools not only the grip strength can vary, but also the force with which the tool is pushed against the workpiece. It has been evaluated similarly to the grip strength. The measurements have been conducted with the participants being asked to push normally and strongly.

In [2] it is stated that it needs to be ensured that the rubber part of the handle has no influence. Otherwise it needs to be removed or a hose clamp has to be applied such that all the soft material is compressed. Due to a non-compressive rubber part of the used device it was not removed.

All of the above named variations are done in measurements with the named electric stapler and five participants. According to [3] a sandbed is used in which the workpiece, a wooden board, is placed. This setup is arranged such that the participants are operating the tool in an upright position and the upper and lower arm including an angle of 100°-160°

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The impact of contact force on the accuracy of hand-arm-vibration measurement

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Abstract (optional)

Keywords:

Contact Force Measurement; Hand-Arm-Vibration

Introduction

Measurement of hand-arm vibration with the use of a hand mounted sensor ensures achieving the most representative measurements, taken at the point of contact of hand with a vibrating tool. When measuring vibration on a hand, simultaneous measurement of contact force verifies whether the force magnitude is sufficiently rigid. The contact force also provides information on the operator's work schedule and may help to instruct operators if they are using excessive or too little force when working with hand-held tools.

Additionally, by knowing both the coupling force value and the vibration acceleration, it is possible to calculate actual vibration energy dose that has been transferred to a hand.

Methods

The accuracy of vibration measurements using hand-arm adapters has been tested in 240 measurements in total, performed at the Polish National Research Institute at the Central Institute for Labour Protection. The impact of coupling force on vibration magnitudes has been assessed with Svantek's SV106 human vibration meters and SV105AF hand-arm adapters (push force thresholds in tests were: 0 N, 20 N, 50 N, 100 N).

Results

The results proved that measurements taken with hand-arm adapters provide correct vibration results regardless of contact force changes and type of vibration signal. The study has also indicated that it is necessary to define a minimum force threshold in order to mitigate the uncertainty related to the contact between hand and a vibrating tool.

Discussion

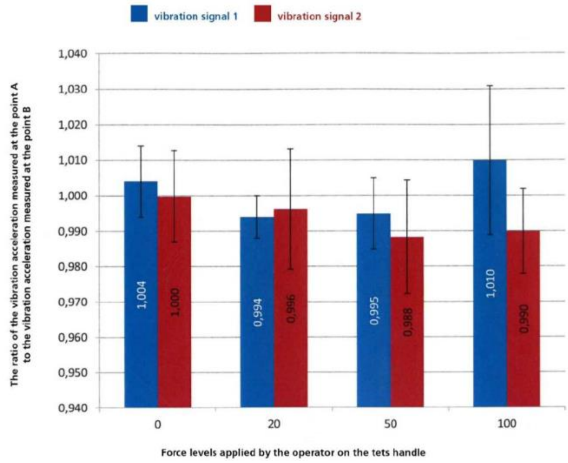
The conducted study proves that the effect of changes of the force thresholds applied by the operator are irrelevant to the measured vibration acceleration values. This assumption is valid for the forces above a threshold of 20 N, below which it is necessary to ensure the correct coupling between the hand-arm adapter and vibrating surface. Together with the force level drop below 20 N, the uncertainty related to the coupling increases rapidly.

Conclusion

For tools generating high vibration amplitudes, th threshold of 20 N may not guarantee perfect coupling therefore higher threshold levels should be established.

Figure

Figure 1: Position of the operator on platform during the measurements



Graph 1: The ratio of vibration values measured with the applied force against to the reference values with no forces applied.

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Tightening Tool Vibration Emissions

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Abstract

Handheld power tools for tightening are widely used in many industries. Several requirements shall be taken into account to select a suitable tool model. In the article, vibration emissions are considered as an assessment factor in relation to the general tool characteristics and performances.

Keywords:

Tightening Tools; Vibration

Introduction

Hand-held power tools, as many other industrial products, have to comply with various customer requirements on ergonomics and several working environment regulations. In particular, vibrations levels generated by tightening power tools may cause not only discomfort but also health issues such as injury and disease. Actually, hand-transmitted vibration may be associated with various vascular, neurological and musculoskeletal disorders, collectively designated as the Hand-Arm Vibration Syndrome (HAVS).
It is therefore crucial for operators performing repetitive tasks on production lines to use efficient tool emitting as low vibration levels as possible. In fact, the power tool performances shall ensure, in the same time, high productivity and appropriate working conditions for users. Therefore, power tool suppliers are required within the European Union to provide information on vibration emissions that reach or exceed the reference level of 2,5 m/s^2 measured and reported in accordance to several specific standards [1,2,3]. This information enables tool users or their employers to limit the vibration exposure to acceptable levels by selecting suitable machines or by planning tool usage during a shift.
In the present paper, the general features of handheld power tools used for tightening will be described and more specifically vibration emissions from the different types of tools will be in focus.

Tightening Technique

In many industries, product parts of all sizes have to be attached together in a reliable way. This operation can be achieved by means of different methods such as gluing, riveting or welding. However, by far, the most common technique of joining components is to use threaded fasteners comprising screws, bolts and nuts. This method provides several advantages including design simplicity and easy assembly or disassembly, which in turn implies high productivity and relatively low costs.

In all industries where productivity is paramount, handheld power tools are utilized systematically to perform tightening operations. Therefore, a large variety of tightening power tools with different characteristics and performances are nowadays available.
Moreover, major advances in power electronics have enabled the development of electrically driven tools that can be controlled very accurately by means of various built-in sensors. Assembly tools can be easily programmed to perform tightening operations precisely for different torques and angles at various speeds. In fact, several specific fastening procedures can be implemented in the controller and applied by the tool on the joint. The various torque patterns used to reach a specific target are usually designated as tightening strategies. Those different strategies present various benefits and disadvantages in terms of fastening quality, productivity and ergonomics.

Tightening Tools and Vibration Emissions

Pneumatic Impact Wenches

Impact wrenches are based on the same principle as a hammer striking a wrench when tightening a bolt or a screw, building up torque impact by impact. In fact, the rotor of an impact wrench is used as a rotating hammer pounding on a rotary anvil once or twice per revolution. In general, those tools present a very high capacity in terms of power and thus applied torque, especially in relation to their weight and size. As the reaction torque is not larger than the one required to accelerate the hammer, the reaction force transferred to the operator is extremely low, making the use of reaction bars unnecessary. However, the applied torque cannot be measured directly by the tool, which limits the possibility to achieve accurate torque control. In addition, the hammering of metal against metal causes wear and tear of tool components as well as high noise and vibration levels. In general, the vibration levels generated by this type of tool become large with increasing torque, as shown in Fig. 1. In fact, a vibration level of 7,4 m/s^2 is measured for a torque of 4450 Nm [2]. This corresponds to a tool trigger time of 55 minutes to reach the daily exposure action value of 2,5 m/s^2, as prescribed by the EU regulation [1]. For example, an impact wrench will be suitable for maintenance operations such as loosening rusty or stuck bolts in heavy industries. It is a compact and powerful tool that can be used for various applications demanding high torques but low degree of accuracy.

Continuous Drive Nutrunners

Continuous drive nutrunners driven by pneumatic or electric motors provide very high accuracy and operate quietly. In particular, electric nutrunners can be equipped

with transducers to monitor tightening torques and angles. Furthermore, high quality continuous drive tools have a durable design providing long service life.
Thanks to the continuous mode of operation, the vibration emissions from those tools are very low with declaration values below 2,5 m/s² even for torques as high as 3000 Nm. However, the drawback is the reaction force from the tool that may cause fatigue and potentially injuries to the users. A fixed reaction bar is therefore required to protect the operator for applied torques exceeding 7 Nm for pistol tools and 50 Nm for angle tools. For advanced electrically driven tools, special tightening strategies can be implemented to damp the reaction forces caused by the tool. Nevertheless, the effects of the transient vibrations generated by the tool reaction force cannot be assessed by the procedures described in the current ISO standards on human vibrations. Further research work on the subject is therefore required to develop relevant evaluation methods and establish limit values for reaction forces and shocks.

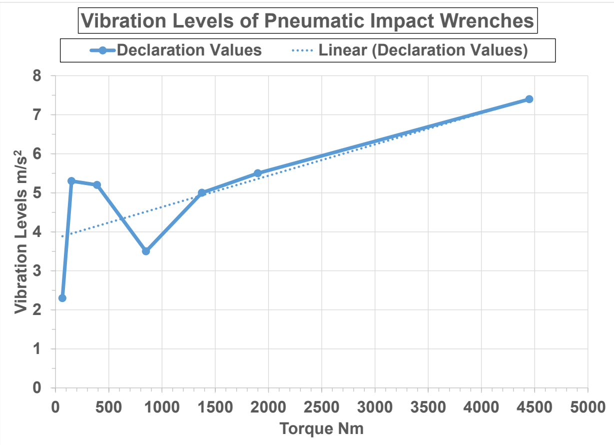

Figure 1. Declaration values for impact wrenches [2].

Pulsing Tools

In oil pulsing tools, the torque is built-up, not by metal to metal hits as for an impact wrench, but via a hydraulic pulse unit used to transfer the torque from the motor to the outgoing shaft connected to the joint. Generally, this technology enables good accuracy on applied torques for pneumatic nutrunners. Even greater accuracy is achieved for electric tools by using control sensors. Furthermore, the pulse unit acts as an oil cushion damping the vibrations and since the pulses are very short in duration, there is almost no reaction force in the handle.
Another type of pulse tools can be obtained by applying a specific control strategy on certain advanced continuous drive nutrunners. In this application, the torque is transferred by pulsing the motor and gears back and forth, which enables low reaction forces but implies metal to metal blows as for a classical impact tool, thus causing high vibration levels.
In Fig. 2, the vibration emissions measured on different pulsing tools measured according to ISO 28927-2 are presented with respect to maximum torque. The pneumatic oil pulsing tools generate vibration levels below 2,5 m/s² for torques lower than 40 Nm and a maximum level of 4,6 m/s² in the range from 40 Nm to 150 Nm. This maximum level enables a tool trigger time of 142 minutes [1], which should likely be considered as an acceptable productivity for many applications. Since pneumatic oil pulsing tools have very low reaction force, they present obvious benefits in terms of ergonomics. However, pneumatic tools do not usually provide the features needed for tightening monitoring and traceability. If those more advanced features are required, electric tools constitute a more adequate fit for tightening tasks.
In fact, electric oil pulsing tools provide the necessary characteristics on assembly control and they produce vibration emissions below 2,5 m/s² for torques up to 150 Nm, as shown in Fig. 2. In addition, those tools will imply low reaction forces thanks to the pulse technology. Therefore, electric oil pulse nutrunners will be very well suited for repetitive tightening of critical joints. The electric gear pulsing tools also have advanced features for tightening monitoring and generate low reaction forces. However, they produce high vibration levels, as observed in Fig. 2. For instance, the tool gives a vibration level of 5,3 m/s² at a torque of 12 Nm yielding a tool trigger time of 107 minutes [1]. Consequently, the vibration level will be a major factor limiting the tool usage. Since this type of tool is usually light (no hydraulic unit) and versatile (tool including different tightening strategies), it can still be used in pulse mode for occasional or quick tightening operations at low torques.

Conclusion

Various types of tightening tools from the classic pneumatic tools to the more advanced electric nutrunners with built-in transducers and wireless communication are available on the market. Therefore, the selection of a suitable tool model shall be made carefully in order to fulfill the requirements on productivity, accuracy and ergonomics. Vibration exposure in tightening is clearly a major factor (even for the most advanced tools) that shall be considered to optimize an assembly process and ensure the most appropriate working conditions for operators.

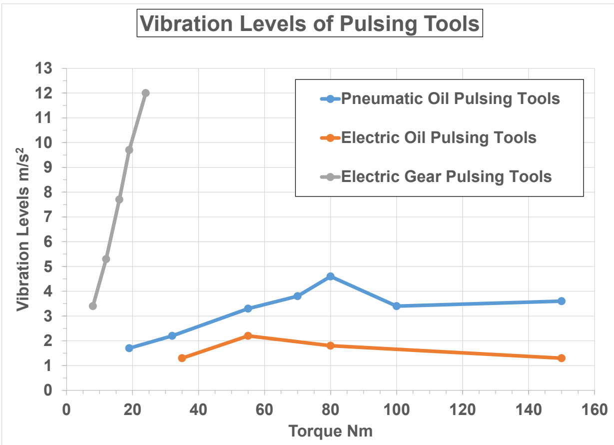

Figure 2. Declaration values for various pulsing tools [2].

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[2] International Standard ISO 28927 Part 1 to 12
[3] International Standard ISO 5349 Part 1 and 2

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HAV in motocross: exposure and effects of handlebar characteristics

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Abstract (optional)

This work describes the results of different tests performed to assess the HAV exposure of motocross drivers and to quantify its dependence from the handlebars and handlebar mounts characteristics. The vibration transmitted to the hand was measured on a single track in three experimental sessions, with 2 drivers and 2 different motorbikes. The w_h weighted vibration level along the fork axis ranged between 8 and 12 m/s^2. Laboratory tests were performed to quantify the effect of different materials by investigating the vibration transmissibility and the impedance of 9 different combinations between handlebars mount and handlebar. Results evidenced the limited effect of the antivibrating devices.

Keywords:
Motocross, vibration, measurement

Introduction

The adverse effect of HAV on motorcyclist has been documented by Mirbod et al. more than 20 years ago [1]. The prevalence of subjective symptoms in fingers or hand among motorcycle riding policemen was in the range of 0.5-19.3%, where 4.2% of the respondents suffered finger blanching and 13.4% had shoulder pain. Chen et al. [2] measured the whole-body vibration on 6 motorbikes and 6 scooters. Over 90% of the motorcycle riders had VDV(8) exceeding the upper boundary of health guidance caution zone recommended by ISO 2631. The studies on motocross in the current literature mainly focused on injuries [3] and no or little studies characterized the HAV exposure and the dependance of vibration from handlebars mount characteristics.

Methods

Track Test

Track tests aimed at measuring the vibrations transmitted to the steering plate-handlebar system. Different tests were performed on a single track. Two types of 4-stroke motorcycles were driven by two drivers: the first is a KTM EXC 350 F enduro driven by amatour driver (motorcycle 1); the second is a Honda 450 CRF cross driven by a professional driver (motorcyle 2).

Motorcycle 2 was tested in two different sessions characterized by different track and traffic conditions.

Both motorcycle were instrumented with a triaxial accelerometer (PCB 356 A21) on the steering plate, while a monoaxial acceletometer Endevco 27 F11 was located close to the throttle, thus neglecting the high frequency attenuation provided by the grips and the golves, that were characterized in dedicated laboratory tests. Data were sampled by a NI 9234 acquisition board, that was stored in a specifically designed case fixed on the lower and upper plates, in place of the number board (Figure 1). A miniPC, carried by the driver in a backpack, sampled the data that was analyzed offline.

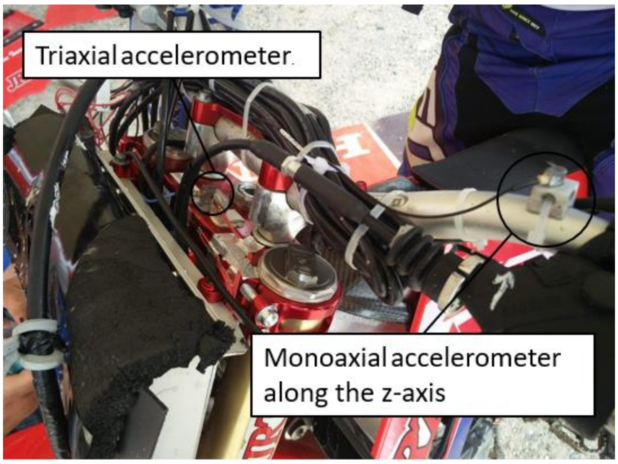

Figure 1: Experimental setup for field tests

Laboratory Test

Impact tests were performed to to evaluate the effect of different materials, by investigating the vibration transmissibility and the impedance of nine different combinations between handlebars mount and handlebar.

The vibration trasmissibility was evaluated along the vertical and fore-and-aft directions, the most severes according to data acquired during on-field tests. Six types of tests were performed: the handlebar was fixed to a plate; the impact hammer was used to provide the vibration stimulus; tests were performed with the handlebars gripped by two subjects and in free conditions. 3 different handlebar mounts and 3 different handlebars were testsed, for a total of 9 different configurations. The transmissibilities were computed using H estimators. Transmissibilities where then used to estimate the effects of different material combinations on data acquired during track tests.

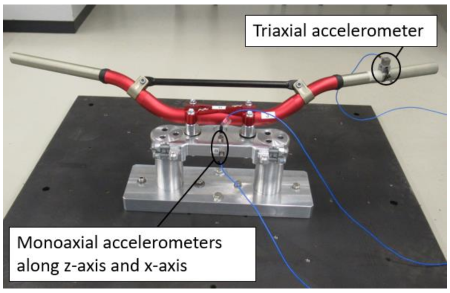

Figure 2: Experimental setup for modal analyses

Results

The w_h weighed vibration level on motorcycle 1 along X, Y and Z axes were respectively 5.0, 2.3 and 8.1 m/s^2 RMS. The same values, on motorcycle 2, were 8.0, 4.1 and 12.0 m/s^2 RMS The vertical values measured at the handlebar mount were respectively 9.1 and 5.2 m/s^2 RMS. The vibration measured on motorcycle 2 is much higher than that on motorcycle 1, but in both cases EAV is reached after a time compatible with the typical training time of professional and recreational drivers.

Figure 3 shows the spectra of the vibration measured at the steering plate with motorcycle 2; the vibration has different peaks: the first, in low frequency region (below 50 Hz), is the one generated by the track irregularities and by the jumps; the others (100 to 200, 250 to 400, 500 to 750 Hz) are the 1x revolution, 2x revolution and 4x revolution harmonics generated by the engine.

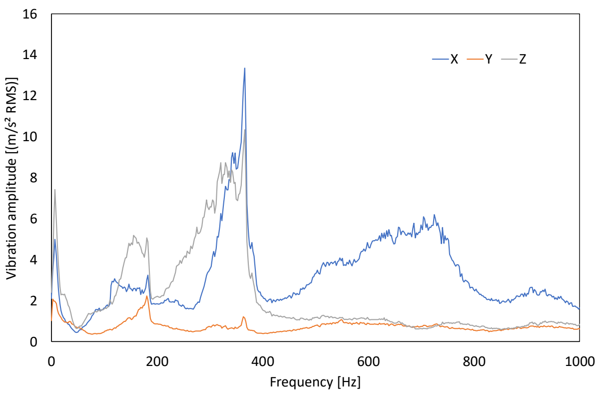

Figure 3: Vibration spectra measured along x (blue), y (red) and z (yellow) axes with motorcycle 2.

Results of laboratory tests evidenced the possibility of optimizing the transmissibility the differerent handlebars and steering plate. In particular, almost all the tested configurations evidenced resonances in frequency regions where the engine vibration are important. As an example, Figure 4 shows the transmissibility of a solution where the maximum amplification corresponded to the range in which the 1x revolution harmonics were more evident.

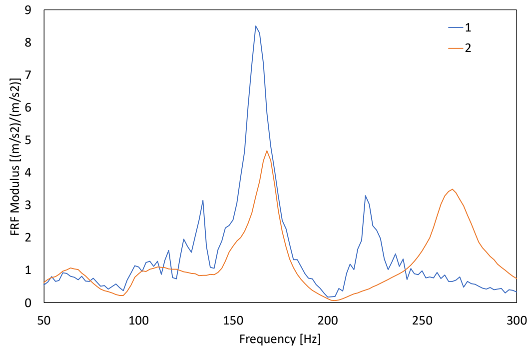

Figure 4: Transmissibility between the plate and the handle; tests performed by 2 different subjects.

Discussion and conclusion

Results evidenced the large vibration exposure of motocross drivers. The most severe vibration axis was the one aligned with the fork; laboratory tests evidenced the possibility of optimizing the frequency response function of the handlebars mount, by designing systems where resonances do not match with the fundamental engine frequencies. The next steps will be the development of a lumped parameters impedance model similar to that developed in other works [4, 5] in order to identify the optimal dampers characteristics.

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Measurement of Hand Contact Force on an Elastic Hand-Handle Interface

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Abstract

This study explored a flexible thin-film hand sensor for reliably measuring the contact force at the elastic hand-handle interface. Five male subjects were recruited to perform measurements of contact force under nine combinations of grip (10, 30 and 50 N) and push (25, 50 and 75 N) forces with three interface conditions (i) bare hand grasping an instrumented rigid handle (BH); (ii) hand grasping the handle covered by an anti-vibration (AV) material (MT); and (iii) gloved hand grasping the handle (GV). The contact force developed at the elastic hand-handle or AV glove-hand interface was measured with the hand sensor to investigate a relationship among the hand grip/push and contact forces, and effect of AV glove on grip strength. Results showed higher grip strength demand for gloved hand (GV) and hand coupled elastic handle (MT) compared to the BH condition for realizing the same level of grip/push force combination.

Keywords:

Gloved hand strength; hand-handle contact force; elastic hand-handle interface.

Introduction

The risk of hand-arm vibration syndrome (HAVS) among hand-held power tools operators is related to mechanical coupling of the hand with a tool handle apart from hand-transmitted vibration (HTV) exposure. Health and safety risks of HTV exposure are assessed using frequency-weighting and dose-response relationship defined in ISO 5349-1 [1], which does not address contribution due to hand forces. Studies have reported that the magnitude of hand force imparted on a vibrating handle affects the severity of exposure and hand-arm vibration biodynamic responses [2]. These have also motivated the development of an additional weighting factor to account for effect of hand-handle coupling force on exposure risk [3]. Hand-handle coupling is generally defined by hand grip and push forces or the sum of the two, denoted as the coupling force. Thin and flexible resistive and capacitive sensing systems have evolved for measurements of hand-handle interface pressure/force distributions. These have been used to establish a relationship among the grip, push and contact forces of the hand [2], which is limited only to bare hand coupling a handle. A tool handle enclosed by a vibration isolation material or an AV glove, however, constitutes an elastic hand-handle interface, which may affect distribution of contact pressure and thus the force. Through measurements of contact force on a rigid handle, it has been shown that AV gloves affect operators' grip strength in an adverse manner, suggesting higher musculoskeletal loads with an AV glove [4]. This may be due to visco-elastic properties of the gloved hand-handle interface, while measurement of contact force at an elastic interface has not yet been attempted.

This study presents a method for measuring hand contact force at an elastic interface formed by an elastic handle or a gloved hand. The data are used to propose a relationship among the grip/push and contact forces. It is shown that a gloved hand poses higher grip strength demand compared to the bare hand for developing identical grip/push forces on the handle.

Methods

Five right-handed male subjects were recruited to measure hand contact force imposed on a 40 mm diameter instrumented handle. The contact force was measured using a recently designed hand force sensor that could be fixed to hand or inserted inside an AV glove. The sensor comprised a total of 372 sensels capable of measuring peak contact pressure up to 2.76 bars. The experiment was designed to measure contact force considering three different contact conditions. These included the bare hand grasping a rigid handle (BH) and the handle covered with a vibration isolation material (MT), shown in Fig. 1a, and a gloved hand grasping the handle (GV). The hand sensor was fixed to palm and fingers of the hand, using medical tape, for the first two conditions (Fig. 1b). For the GV condition, an AV glove was positioned on the hand with the sensor (Fig. 1c). The glove made of gel material had shown M- and H-frequency range vibration transmissibility of 0.82 and 0.50, respectively. Contact force for each condition was measured under nine combinations of grip (10, 30, and 50 N) and push (25, 50, and 75 N) forces, which were measured by the instrumented handle.

Figure. 1: Pictorial views of measurement setup: a) handle covered with gel material; b) hand sensor fixed to hand; c) Gloved hand with sensor; d) subject's posture;

Each subject grasped the handle with a bare and gloved hand in a power grip manner for each force combination, while assuming posture described in [4], and shown in Fig. 1d. A total of 27 randomized trials, including three repeats, were performed for each handle condition and subject. Time-histories of grip/push and contact forces, obtained from the instrumented handle and the hand sensor, respectively, were recorded for 30 s for each trial. The mean force data were used to define the relationship between the hand grip (F_g), push (F_p) and contact (F_c) forces via a linear regression function, defined in [2]:

$$F_c = \alpha_0 + \alpha_g F_g + \alpha_p F_p \qquad (1)$$

where coefficient α_0 represents offset, if any, and α_g and α_p are grip and push coefficients, respectively.

Results

Measured contact force data showed good repeatability for all three handle conditions with intra-subject variability ranging from 2.1% for BH condition to 8.9% for the GV condition. The inter-subject variability of measurements was also small, which ranged from 3.4% for BH condition to 9% for the GV condition. Table 1 summarizes grip/push force regression coefficients obtained from contact force data for each subject and handle condition. Data acquired for BH condition were used to examine the validity of hand sensor using the relationship in [2], which reported mean grip and push force coefficients of 2.82 and 1.0, respectively, for a 40 mm diameter handle. The analysis of data acquired with hand sensor showed comparable values of mean coefficients (α_g =2.75; α_p =1.15).

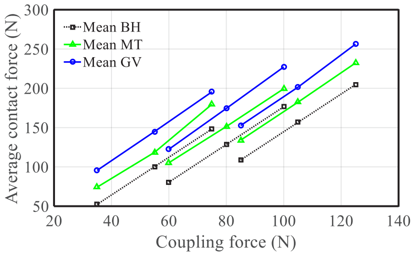

Figure. 2: Variations in the contact force with coupling force obtained for rigid (BH) and elastic contact conditions (MT, GV)

The addition of 5 mm thick AV material to the handle resulted in its effective diameter of 50 mm. Similarly, the use of AV glove would also lead to a larger effective diameter. The higher contact area of the larger handle yields lower contact pressure and thereby the contact force. The grip and push coefficients obtained for the BH condition were thus estimated for the 50 mm diameter handle using the relation in [2], in order to compare contact force (grip strength) with those obtained for MT and GV conditions. The measured contact force showed a linear dependence of contact force on both the grip and push forces, irrespective of the handle condition. The contact force is thus also linearly related to the coupling force, as seen in Fig. 2. The results suggest that elastic interface due to AV material or glove leads to higher contact force compared to the BH condition for the entire range of coupling force considered. This suggests that an elastic contact imposes greater grip strength demand compared to coupling with a rigid handle for generating an identical level of grip/push or coupling force. This is also evident from grip and push coefficients presented in Table 1. The MT and GV conditions show comparable but about 30% higher grip coefficients (MT- α_g =3.06; GV- α_g =3.16) than the BH condition. Identical push coefficients were obtained for the MT and GV conditions (α_p =1.4), which were nearly 24% higher compared to the BH condition.

Table 1: Grip and push force coefficients obtained from data for five subjects and different hand conditions

		A	B	C	D	E	Mean	SD
BH	α_g	2.74	2.63	2.60	2.92	2.86	**2.75**	0.12
40	α_p	1.17	1.10	1.27	1.21	1.02	**1.15**	0.09
mm	r^2	0.98	0.98	0.97	0.94	0.95	-	-
BH	α_g	$\alpha(D)$ = -0.0496D+4.878 [4]					**2.40**	0.26
50	α_p	$\beta(D)$ = 0.0022D+1.021 [4]					**1.13**	0.27
mm	r^2	0.99					-	-
MT	α_g	3.46	2.66	3.04	3.16	2.96	**3.06**	0.26
50	α_p	1.88	1.29	1.30	1.41	1.11	**1.40**	0.27
mm	r^2	0.91	0.93	0.97	0.90	0.92	-	-
	α_g	3.71	3.08	2.67	3.62	2.74	**3.16**	0.43
GV	α_p	1.74	1.67	0.99	1.29	1.29	**1.40**	0.28
	r^2	0.91	0.83	0.91	0.89	0.96	-	-

Discussion

The hand-handle contact force is a function of the effective contact area and magnitudes of distributed contact pressure. An elastic hand-handle interface caused considerably higher contact area compared to a rigid handle. Contact with a rigid handle, however, causes substantially higher pressure peaks compared to an elastic handle or gloved hand contact, while the elastic interface may yield relatively higher mean pressure. The elastic hand-handle interface thus results in higher contact force. The results suggest that the use of AV gloves will impose higher grip strength demand on the operator compared to the BH contact to generate same levels of grip and push forces.

Conclusion

The contact force developed by the gloved hand can be accurately measured using the thin and flexible hand sensor developed in the study. Results from this study showed higher contact force developed with the elastic handle and the gloved hand compared to the bare hand-handle contact. Working with AV gloves or handles with visco-elastic coverings may thus impose relatively greater grip strength demand on the operators.

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Hand-Arm Vibration Estimation Using A Commercial Smartwatch

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Abstract

Measuring Hand-Arm Vibration (HAV) exposure is important to prevent permanent injuries, such as the White Finger / Raynaud Syndrome. Current measuring solutions require an individual attachment of those work tools that emit considerable vibrations. These sensing instruments are expensive and usually require a setup by experts. Additionally, these attached sensors are bulky and wired, which may further increase the risk of accidents in occupational safety. For an easy use, we propose using a Smartwatch to estimate the HAV doses gathered throughout the day. By utilizing the Smartwatch's Inertial Measuring Unit (IMU) that is sampling up to 800Hz, we are capable of reconstructing vibrations up to 400Hz. This range sufficiently covers the majority of harmful HAV loads that occurs with work tools. Our approach is an inexpensive solution that provides a rough estimation to indicate a vibration overload. Our solution does not require the specific tool type or datasheet.

Keywords:

Hand-Arm Vibration Estimation; Smartwatch; Sensing; Accelerometer; HAV Exposure Dose.

Introduction

There have been many research investigations looking into understanding the risks of injury from hand-transmitted vibration and whole-body vibration by means of epidemiological studies [1]. The most crucial impact is the Raynaud Syndrome [3], which is a vascular spasm that negatively affects vessel blood flow. This can be caused when exposed to cold or stress, such as operating work tools that emit considerable vibrations [4] to the hand and arm. Vibrotactile perception in the fingertips can become numb on a short-term temporal or long-term basis [6].

When the human body to the exposure to vibrations without limits, symptoms such as coldness of the hands, the legs, hypesthesia of the fingers, tremor/shivering of the fingers, dexterity disturbance, weakness of the hands, mobility disturbance of the elbow, shoulder/neck stiffness, low back pain, fatigue, headache, dizziness, tinnitus, and hearing loss can occur. These symptoms have been evident among quarry workers in developing countries such as Vietnam [7], where occupational safety is not highly practiced.

Different methods and technologies based on measuring Hand-Arm Vibration [5], such as using high-sensitive accelerometers [8], are used to prevent such symptoms. These dosimeters are precise and provide sampling rates up to 5kHz. Since these technologies are usually expensive and instrumenting work tools with additional sensors may create an increased risk in occupational safety, using wearable technology such as a Smartwatch is a logical step. IMUs, in particular Accelerometers and Gyroscopes, that are implemented in Smartwatches so far only enabled sampling rates of up to 100Hz without kernel modifications. Determining an accurate HAV is insufficient with this sampling rate, since emitted vibrations can exist beyond this frequency. Research explored a work-around when attempting to measure HAV exposure doses with Smartwatches [2], such as using the accelerometer in conjunction with the microphone to identify the tool the worker used. Once the tool is known, it's specific HAV ratio is being looked up from a database. However, this requires the system to have access to a complete database with all HAV ratios from a great variety of work tools.

14th International Conference on Hand-Arm-Vibration,
21-24 May 2019, Bonn, Germany.

Method

In this paper, we propose an alternative approach, in which we use the IMU of a commercial Smartwatch to calculate a rough estimation of the HAV received at the user's wrist. This way, measuring the exact HAV exposure doses is not possible because of the signal absorption, signal coupling, and transmission loss between the vibration emitter (tool) and wrist (Smartwatch IMU).

In fact, the current Android Wear OS (2.9 – based on Android 8.0.0) provides a new direct channel to assess the acceleration sensor. Apparently, new devices will be able to sample the IMU with a frequency up to 800Hz. Following the Nyquist–Shannon sampling theorem, frequencies of 400Hz can be reconstructed accordingly. Although, this may still appear too low to sense the full spectrum of the vibration exposure, it enables us to read most critical root-mean-square (r.m.s.) acceleration magnitude - represented as a frequency weighting curve W_h *(see Figure 1)*.

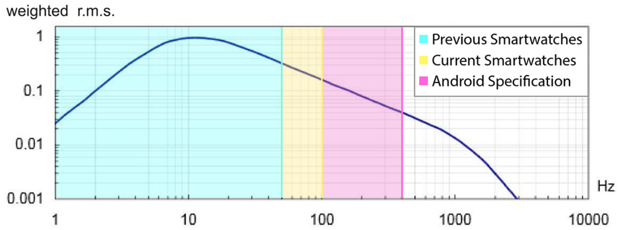

Figure 1. Hand-arm vibration frequency weighting curve W_h following ISO 5349-1:2001 [9]. The highlighted areas shows the coverable frequencies.

Therefore, our hypothesis is that a commercial Smartwatch is sensitive enough to provide an acceptable approximation of the actual HAV exposure doses.

Preliminary Field Study

We developed a smartwatch app running on an autarkic Android Smartwatch. We used the model Simvalley AW420-RX running Android 4.2. The watch has a Cortex A7, 1 GB RAM and incorporates a Bosch BMC050 IMU, which quantizes +/- 2 g (19,62m/s2) with 12bit. The weight of the watch is approximately 90 grams.

Figure 2. We ran a preliminary field study in metalworking / manufacturing. The participants were equipped with a smartwatch running our app, as well as with a microphone and a GoPRO to measure the ground truth data.

We selected a window size of 128 samples of acceleration tuples while using 50Hz. We assume that any harmful HAV occur between 0–25Hz, which can be measured by the Smartwatch. We calculated the significant acceleration of the Smartwatch within the 3D-area by this formula:

$$a_{3D} = \sqrt{(x-\bar{x})^2 + (y-\bar{y})^2 + (z-\bar{z})^2}$$

Our assumption concludes that tools with a slow motor and slow motions would also lead to a low acceleration.

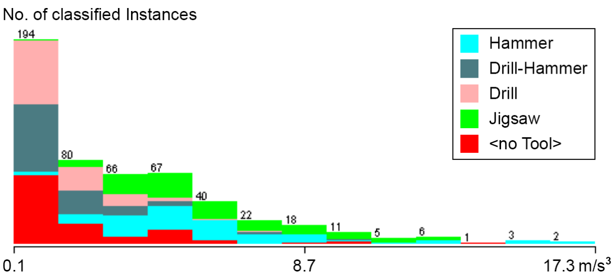

Figure 3. Distribution of measured 3D-acceleration (jerk) measured at the wrist.

It becomes clear by Figure 3 that not only emitted tool vibration is sensed, but also any other motion the worker performs in the workshop. Therefore, we suggest classifying typical motions that occur with <no Tool> and to subtract this from the daily exposure doses.

In our preliminary field study, we used a low sampling rate that is only capable of reading limited vibrations. For future research, we suggest utilizing Smartwatches with high sampling rates to capture a wider spectrum.

Moreover, we found that the measured 3D-acceleration force does not directly correlate to the HAV. We believe this is mainly due to the non-linear absorption of the vibration frequencies at the fingers, the hand, and the wrist. Also, we noticed that the wristband's tightness to have a significant influence on sensing the 3D-acceleration force.

Taking these factors into account, we believe reproducing the correct HAV exposure doses could be possible.

Discussion

As demonstrated in Figure 1, the most harmful HAV occurs in the lower frequency spectrum between 2.5–50Hz. Capturing these should be prioritised. While professional sensing tools are usually expensive and impractical, we propose using a Smartwatch to estimate these. However, an exact measurement is not possible due to various parameters such as the contact pressure between hand and tool, signal absorption by the joints, tightness of the wristband, etc. Aside from these factors, smartwatches are becoming increasingly powerful. They can provide a greater sampling rate and are capable of sensing an increased range of the frequency load. Nevertheless, a professional measurement equipment is still superior. The proposed work-around in AGIS [2] may still be the state-of-the-art when measuring a more accurate HAV with unmodified Smartwatches. In fact, the advance of the increased sampling rate with Smartwatches can also benefit a greater tool detection. Sampling the IMU with 800Hz may provide enough signal characteristics to identify tools based on the accelerometer only. Once the tool is identified, looking up the HAV intensity ratio from the datasheet for each tool would still be next step to calculate the daily dose. We see Smartwatches as the gatekeeper for calculating the exposure duration of harmful vibrations. In the future, we envision smart wearables to enter different industry branches, provided that the legislator paves the way. Furthermore, we see this technology as being capable of registering the exposures in a cadaster, namely to distinguish between regional and branch specific workloads.

Conclusion

The advancements in IMU sensing enables an estimation of HAV exposure with commercial Smartwatches. Still, an accurate measurement is yet problematic. In particular, we are required to account for the non-linear absorption of vibration frequencies into the hand and the tightness of the wristband. Calculating the exact HAV dose using a Smartwatch is feasible when running a tool detection, but which requires a large database and thus is impractical.

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Is real-time monitoring effective as a control measure to prevent Hand Arm Vibration Syndrome

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Abstract

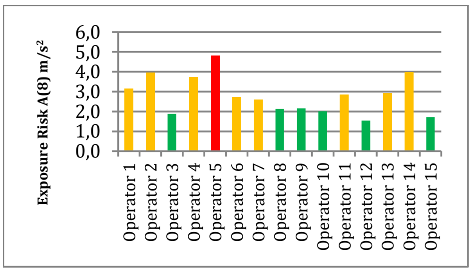
The most recent advances in sensor technologies have given rise to a proliferation of applications using frequently gathered data to continuously improve operational performance. The authors seek to illustrate whether such an approach is valid in the control of exposure to harmful vibrations from power tools. The authors investigate the range of exposure possible when closely monitoring a single task and analyse a large set of monitoring data from a wearable devise for possible under-assessment of risk. The investigators conclude that over reliance on generic risk assessments may place certain individual tool users at greater risk. Modern monitoring devices can help identify at risk individuals and assess the effectiveness of control measures

Key words:

Hand-transmitted vibration, monitoring, wearable sensors

Introduction

Employers who expose their workforce to hazardous vibration from mechanised tools need to develop an understanding of the magnitude of vibration and time of exposure to vibration that their workers have experienced often while using multiple tools within a day. ISO 5349-2 [1] was developed as an international standard to define how the time and magnitude of vibration exposure should be combined to quantify the risk to the individual. The standard requires the placement of accelerometers on the tool surface while in use and instrumentation of a nature which requires a skilled technician to interpret the gathered data. In essence the standard does not facilitate the economic collection of data across a range of tool users on a routine basis.



Step 1: the authors carried out a blind assessment of real-use exposure levels for a group of tool operators when assigned with the same task as part of a time in motion study to quantify the range of exposure across a group of experienced operators. The operators were deployed with an instruction to work share to control the expected exposure level.

Step 2: given the wide range of individual exposure found in the first exercise the authors then analysed a large data set of exposure monitoring data collected by a wearable sensor to assess how effective the access to real-time data was in controlling the operator's exposure. The wearable sensor was configured to collect data simultaneously based on a fixed vibration magnitude assumed for the tool and a real-time vibration magnitude detected during the tool's use by the sensor. This configuration allowed an assessment of how readily the wearable sensor assessed the risk relative to the assumed fixed vibration magnitude. Also with the fixed vibration magnitude acting as the control measure instructing operators to take action, to what extent would real time monitoring capture higher risk than expected from the assumption of traditional risk assessments of an assumed fixed vibration magnitude for each tool.

Consideration of range from a single task

To illustrate the variability from tasks a detailed risk assessment exercise was carried out on the work of 15 tool operators in multimen teams, each excavating a one meter squared hole within the same grade of road surface. Each operator used the same tool type for which the employer had determined a vibration magnitude of 12 m/s^2. Note this was well in excess of the tool vibration data declared by the manufacturer of 4.2m/s^2. A mix of site teams were used per excavation which consisted of between two and four man teams.

Results: The range across the excavations was +/- 40% with an average to inform a task based risk assesment per excavation equating to an A(8) of 4.2m/s^2. The employer assessed that if work was evenly shared, a two man team would be exposed to an A(8) of 2.9m/s^2 and a three man team exposed to an A(8) of 2.4 m/s^2 per excavation. A task based assessment will typically only account for an average exposure risk per task, not the actual exposure of individual operators. The individual exposure range was determined by plotting in Figure 1 the maximum exposure monitored for each individual in the exercise for just one excavation, with an A(8) exposure ranging from 1.7 to 4.8 m/s^2.

Figure 1: Maximum HAV risk exposure for each individual for one excavation

Risk Levels from a controlled environment of wearable monitors

Given the wide range of exposure for real-tool use the authors believe there is a need for real-time monitoring of exposure to HAV to be considered as a control measure and source of data for HAV management. The arguments for not doing so concern either fears that a wearable senor such as one worn on the wrist can adequately assess the risk and whether the access to real time exposure encourages employers to work individuals to the limit. In the second part of this paper the authors examine whether a wrist worn wearable sensor is likely to under estimate exposure risk by analysing a large data set where the wearable devise collected exposure data simultaneously based on trigger time with both a fixed vibration magnitude for each tool used and a real-use vibration magnitude determined by the sensor. The feedback of information to the tool operator was based on the fixed vibration magnitude. The authors analysed data from approximately 246,500 days of operator HAV exposure data, accrued from over 400 organisations across a range of industry sectors in a 9-month period between September 2017 and May 2018 involving 13,831 individuals with a devise collecting data as described in the introduction.

The fixed vibration magnitude for each tool used was selected by the employer to be that suitable for a risk assessment. The suitability of the wearable sensor to determine a vibration magnitude suitable for a risk assessment is assessed in a technical report by the IOM [2] while Maeda et al [3] examined the strength of correlation of the wearable's vibration determination and the human response to vibration. To assess the wearable's real-time assessment of risk relative to the employers assumed vibration magnitude, the data was sorted to identify the individuals with the greatest risk within the population set. As summarised in table 1 the individuals with greatest exposure had a materially higher risk when assessed by the wearable.

Table 1: Average daily exposure within population groups sorted by the most at risk individuals

% of overall population incurring stated % of overall exposure	Wearable assessment			
	# of operators	% of population	Population mean A(8) m/s^2 based on fixed vibration	Population mean A(8) m/s^2 based on wearable
Top 20%	97	0.7%	3.0	6.2
20 - 40%	319	2.3%	2.8	3.6
40 - 60%	694	5.0%	2.1	2.6
60 - 80%	1,506	10.9%	1.7	2.0
End 20%	11,215	81.1%	1.5	1.5

Discussion

Within a group of workers there will be a large variation of HAV exposure out with that expected from generic risk assessments as illustrated from both studies. When monitoring technologies are deployed human behaviour responds to the device alerts and provides a natural control as can be seen from table 1 where for even the highest risk group of individuals the average daily exposure is below the ELV as determined using the fixed vibration magnitude. However, the wearable devices assessment is generally higher and variance to the fixed vibration assessment is greatest where average risk of the group is highest. This is most likely caused by the fixed assessment being based on manufacturer's declared vibration levels. A stronger assessment of the effectiveness of monitoring would be to create a controlled experiment with monitoring with and without alerting.

Conclusion

A wearable devise can be effective in controlling exposure levels when an individual is alerted to their exposure levels. Monitoring data can be a useful source of information for informing tool selection, process controls and personnel skills.

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Isolated shock events acting upon the hand-arm system A proposal for a definition

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Introduction

Isolated shocks are a special type of hand-arm vibration while working with mechanized (e.g. nailers, bolt guns) or non-mechanized (axes, hammers) tools. Several different terms describing the form of vibration under investigation are in use (single shocks, repetitive shocks, impulse vibration). However it is uncertain whether different researchers all mean the same thing when using the same term. Therefore a standardized definition for shock exposures at the workplace is crucial [1].

Most investigations in the field of hand-arm vibration were done in the frequency domain. By contrast, the outstandig characteristics of shocks are located in the time domain. Figure 1 shows the time history of acceleration on the handle of different tools with more or less impulsiveness.

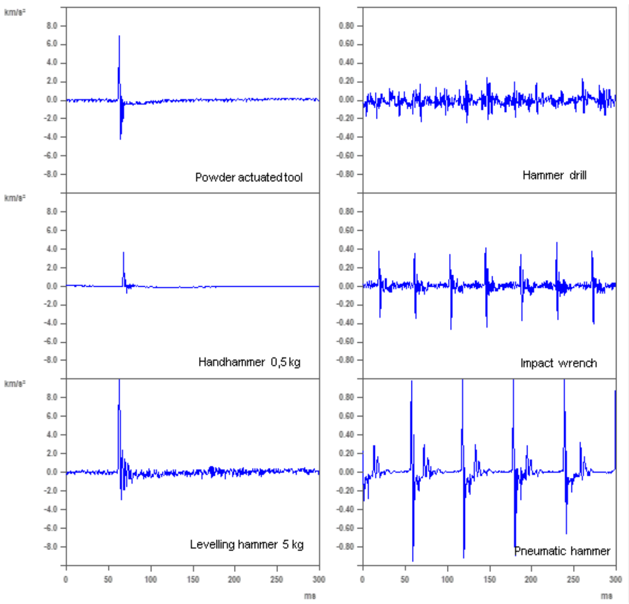

Figure 1: Acceleration-time signal of different tools. Note the different scaling factors left and right.

In context with measurement results on real tools [2] can be seen that isolated and repeated shocks are characterized by

- very short durations (rise time 0.5 – 2 ms)
- fast and complete decay within 3 – 50 ms
- long time intervals until the next shock (up to several seconds)
- very high intensities (peak acceleration up to several km/s²)

To get relevant information to establish a definition for isolated shocks two experiments were carried out with the aim to answering following questions:

1. Does a lower and/or upper limit exist for the duration of an event in order for it to be described as a shock?
2. Does a lower intensity limit exist for shocks?
3. Do the intensity and duration of a shock have an interdependency to each other?
4. How great must the interval between two successive shocks be in order for them still to be considered isolated shocks, or conversely how quickly must the shocks follow each other in order to be considered a series of shocks rather than isolated shocks?

Methods

A standard test arrangement comprising a function generator, power amplifier and electrodynamic shaker was used for the two experiments. A handle was fitted to the vibrating plate of the electrodynamic shaker. All measurement signals were recorded and analyzed by means of an eight-channel PC-based measurement system. The experiments were performed with a total of 24 male test subjects.

In experiment 1 repeated triangular pulses of different pulse duration were transmitted through the handle of the shaker into the hand-arm system of the test subjects.

Pulse duration: 1 ms, 2 ms, 5 ms, 10 ms, 20 ms, 30 ms, 50 ms, 80 ms, 100 ms

The test subjects had the task of varying the intensity of the pulse until the threshold of shock perception was just reached. The acceleration measured on the handle in the form of different root-mean-square values with different frequency weightings as well as positive peak values was evaluated for each combination of pulse duration and intensity declared by the test subjects as a "shock".

In the second experiment, the test subjects were presented series of pulses with adjustable periods between the isolated pulses. Repeated triangular pulses with a pulse duration of 3 ms were used. The test subjects had the task of setting two different thresholds for the strike rate, threshold A and threshold B, according to their subjective perception. Threshold A distinguishes between the range of the repeated isolated pulses (shocks) and the range of the pulse series (sequence of shocks). Threshold B distinguishes between the range of the pulse series and the range of perceived diffuse (stochastic) vibration. The strike rates in s^{-1} selected by the test subjects as threshold A and threshold B were analyzed.

A detailed description of the experiements can be found in [1] and [3].

Results

The results of experiment 1 were analyzed with the aim of producing curves of equivalent shock perception based upon the respective combinations of pulse duration and pulse intensity which were perceived by the test subjects as "shock". Figure 2 show the intensity just sufficient to be perceived by the test persons as a "shock" at a given pulse duration with different frequency weightings on a double-logarithmic scale.

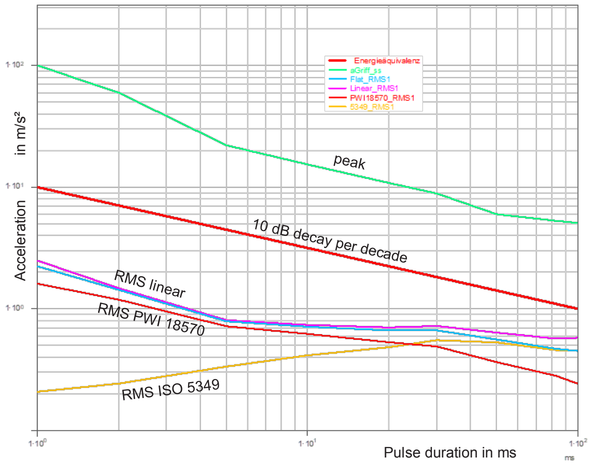

Figure 2: RMS and peak values wich cause a "shock" sensation at different pulse durations

The strike rate set by the test subjects in experiment 2 as the threshold between isolated pulses and series of pulses (threshold A) is on average around 15 s^{-1}, with a minimum of around 9.8 s^{-1}.The strike rate set by the test subjects as the threshold between pulse series and perceived diffuse vibration (threshold B) is on average approximately 25 s^{-1}. Figure 3 shows the three different perception ranges with the two thresholds A and B in combination with the measured values.

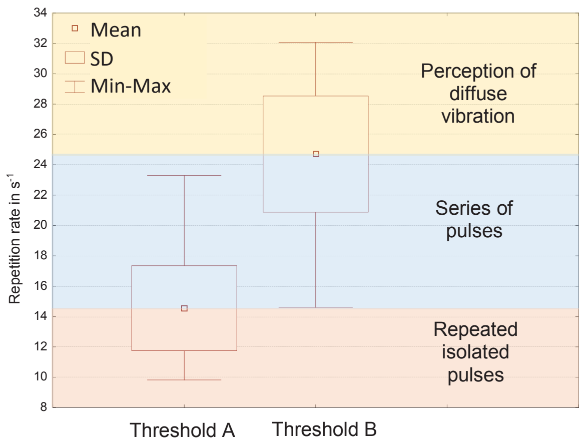

Figure 3: Results of experiment 2

Suggestion for a definition of shocks

Hand-transmitted shock (HTS)
A hand-transmitted shock is a physical process of impact of mechanical energy into the human hand-arm system arising during work with power tools or manual tools. It is identified by a very short impact time compared to the time until the occurrence of the next shock. When the impact event finishes, there are no impact forces driving the shock vibrations.
Note: Shock sensations on the affected persons may occur at relatively low intensity.

Repeated shocks
In practice HTS occur repeatedly, either periodically or with varying time intervals. Examples of repeated shocks occurring at workplaces in practice are breakers (periodically repeated shocks) and powder actuated tools (varying time intervals).

Repetition rate
For periodically repeated shocks the repetition rate is the number of shocks per second. For repeated shocks with varying time intervals a repetition rate can be defined only on a statistical basis (e.g. mean repetition rate).

Isolated shocks and continuous shock sequences
Power tools or machines usually produce a number of periodically repeated shock. Depending on the design of the machines very fast repetition rates are possible. Above a certain repetition rate the exposed person is no longer able to perceive the single isolated shocks. Based on current knowledge, shocks with a repetition rate above 15 s^{-1} are subjectively perceived as continuous shock sequences.

This definition text was discussed and coordinated with several experts. Many thanks to the members of the ISO/TC 108/SC 4/WG 3 ad hoc group for ISO 5349-1:2001 NP/Amd 1.

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Risk for VWF is underestimated in assembly industry using impact tools

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Abstract

Long term vibration exposure may cause vibration white fingers (VWF) as well as neurophysiological disturbances such as dampness and tingling in fingers and hands, reduced grip strength and difficulties in handling small objects. In an assembly industry of heavy vehicles in Sweden a high prevalence of VWF has been reported in spite of low vibration when measuring the A(8) value according to ISO 5349. The operation that expose the workers for vibration is very similar in the production line and consists of tightening nuts and bolts with an impact wrench and an anvil in form of a wrench. Measuring vibration at frequencies up to 50 kHz shows high acceleration peaks especially in the anvil but also in the impact wrench. These high amplitude peaks are suspected to constitute a significant contribution to the high prevalence of VWF and are not taken into account in the current ISO 5349 standard which is also stated in the scope.

Keywords:

Impact wrench, transient vibration, high frequency vibration, risk estimation

Introduction

The aim of the study is to investigate the reductions of vascular and neurophysiological symptoms as well as the improvement of symptoms and neurophysiological test results in workers by reducing the vibration level of the tools by redesign.

The vibration exposure is very similar in the production line and originates from tightening nuts and bolts with an impact wrench and an anvil in form of an wrench. The sizes range from M6 to M12. Fig 1. A large part of the nuts used are made oval in order to prevent untightening during operation. This means they will have a relatively high torque during operation which extends the time for tightening to on average 1.5 seconds.

The redesigned tools are ½ inch impact wrenches of oil pulse type (Atlas-Copco Ergo pulse) and anvils in form of ordinary wrenches of sizes 10 to 13 mm. The vibration reduction activities are mainly focused on reducing high acceleration peaks with high frequency content. There will be a follow-up medical study in approximately 1.5 y to investigate the effect of the measures.

This study is a part of a national project “Zero Vibration Injuries” which includes several types of industries with the aim of reducing vibration injuries by redesign of machines.

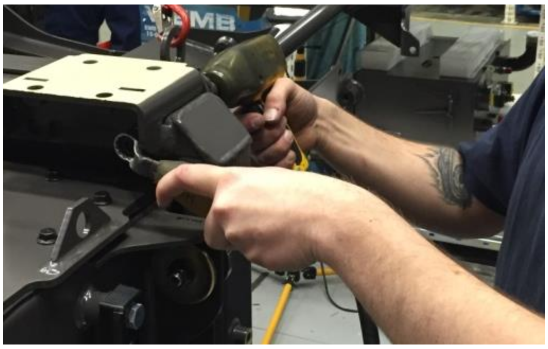

Figure 1: Assembly with impact wrench and anvil.

Material and methods

The study consists of 38 vibration exposed workers, 30 males (median age 40 y; range 22-62 y) and 8 females (median age 39 y, range 24-49 y) from a factory producing wheel loaders, using impact wrenches and anvils.

The participants signed a written consent and completed a questionnaire with questions about work and medical history, use of tobacco and alcohol, use of vibrating tools (years), symptoms related to vibration exposure as well as questions about the general health status. They were asked to avoid vibration exposure during the day of the measurement and coffee and tea at least one hour before the medical tests. Thereafter, a medical examination was performed by an experienced physician.

Vibration white fingers were diagnosed by the use of photos and/or color charts, as well as from the medical history. The neurophysiological findings were diagnosed by the determination of thermal (TPT) and vibration (VPT) perception thresholds, Baseline handgrip strength, 2-point discrimination, pain (needle) and Semmes Weinstein’s monofilament test.

The vibration from the impact wrench was lowered by mounting a 3 mm thick foamed polymer with closed cells on the handle. The redesigned anvil has a vibration isolated layer consisting of a foamed polymer between the part holding the nut and the handle. Fig 2.

The high frequency vibration was measured with an ultra-low weight MEMS shock accelerometer [1].

Figure 2: Vibration isolated anvil

Results

Thirteen of the 38 workers (34 %) reported vibration white fingers (3 subjects had stadium 1 according to the Stockholm Workshop Scale; 10 had stadium 2). Symptoms related to neurophysiological disturbances were even more frequent and were reported by 29 workers (76 %; 20 subjects had stadium 1 SN according to the Stockholm Workshop Scale; 5 had stadium 2 SN and 4 had stadium 3 SN). Only 9 out of 38 workers were free of vascular and neurophysiological symptoms.

The workplace is organized in teams with job rotation between five stations in average. The exposure time at the most exposed workplace is 225 +/-20 sec/day and the vibration level is 4 and 13 m/s^2_{haw} for the impact wrench handle and anvil handle respectively. This gives A(8)=1.1 m/s^2 for anvil hand and A(8)=0.4 m/s^2 for impact tool hand. Note that the average workplace has considerably less exposure time. Which hand that is holding the impact tool and anvil are shifted depending on the accessibilty of the bolt.

Measuring vibration at frequencies up to 50 kHz shows high acceleration peaks especially in the anvil but also in the impact wrench. A typical acceleration from the anvil is seen in Fig 2.

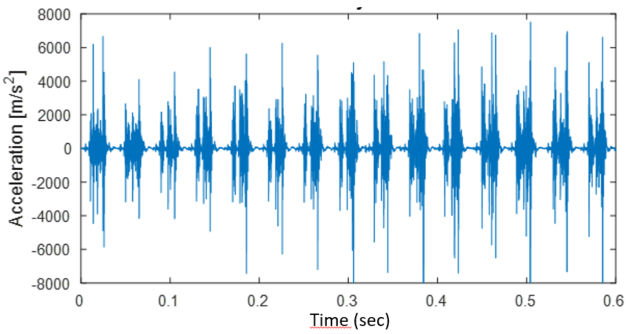

Figure 2: Vibration from original anvil

The change in vibration of the redesigned tools is found in table 1.

Table 1: Tool vibration before and after redesign

Tool	Original vibration		Vibration after redesign	
	ISO5349 weighted rms (m/s^2_{haw})	Vibration < 50 kHz (peak m/s^2)	ISO5349 weighted rms (m/s^2_{haw})	Vibration < 50 kHz (peak m/s^2)
Impact wrench	4 +/-1	2000 +/1000	4 +/-1	400 +/- 100
Anvil	13 +/-2	7000 +/-2000	6 +/-2	< 200

Discussion

The prevalence of vibration white fingers and neurophysiological disturbances was high and only about one quarter of the material reported no symptoms. Furthermore, the majority of the studied workers also reported some form of musculoskeletal symptoms. The exposure time for the tightening of each nut is about 1.5 seconds. Approximately 150 nuts at most are tightened by a worker during each shift, and thus the total vibration time is just a few minutes. As the ISO 5349-1 filters out frequencies over 1250 Hz, the high acceleration impact from the peaks are not considered. Despite this and the relatively short exposure time we can still observe an injury rate that far exceeds the figures reported from factories using low-frequency vibrating tools such as grinders in foundries. Thus, it is very important with further in-depth studies of the risk of vibration caused injuries from transient vibration exposure. As evident from our study, there is a clear risk of underestimating the biological effects of transient vibration exposure with the current legislation.

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Measurement of the exposure of medical personnel to individual impacts during shockwave therapy

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Abstract

For medical treatment, hand-held tools can be used for many hours daily, and this can cause hand-arm disorders. However the effect of these vibrating tools on their users is not well investigated. The shockwave therapy tool, for instance, is often used to treat kidney stones and in physical therapy and orthopaedics. Field measurements have therefore been conducted to investigate the effects of this device in terms of hand-arm vibration, by using two different methods. The results indicate that the limit value can be reached after 2 hours.

Keywords:

Medical vibrating device, hand-arm vibration

Introduction

Hand-arm transmitted vibration by hand-held power tools can cause disorders, best-known among construction, forestry and craft workers. By contrast, the effects of vibrating tools for medical applications is not well known. There are only few studies devoted to medical personnel exposed to hand-arm vibration.

Dentists and dental technicians, for example, are exposed to high-frequency vibration when they use dental handpieces. They have been shown to have a high frequency of finger-related and other upper limb symptoms and a high prevalence of osteoarthrosis in the distal interphalangeal joints [1].

Another study has investigated hand-arm transmitted vibration among orthopaedic surgeons who routinely use hand-operated saws [2]. From using this equipment, the results suggest an exposure limit value of 1 h 33 min (beyond which vibrating equipment must not be used for the rest of the working day).

In many other medical institutions as well, hand-arm vibrating tools are used for many purposes. A shockwave therapy tool, for example, is a common treatment method for muscle and bone conditions.

Since the hand-held tool can be used for many hours daily, it can cause hand-arm vibration induced disorders such as white finger syndrome.

To investigate the effects of a shockwave therapy tool, field meaurements were conducted in this study to analyse the hand-arm vibration exposure for physiotherapy purposes.

Methods

Measurements were conducted during a typical working process in accordance with VDI 2057 [3]. An experienced physiotherapist was studied with multiple repeat measurements. Two different settings for the process were chosen for analysis: a process using a ham as substitute tissue (Serrano Ham Reserva, 1.75 kg) and one with a patient for a heel treatment. The shockwave therapy tool weighing 0.8 kg is operated at high pressure (handpiece with applicator Ø6 mm / 2.7 mm axial). The working pressure is 4 bar and repetition frequency 15 Hz (Figure 1).

Figure 1: Hand posture and two different settings for analysis

Daily vibration exposure was expressed as rms acceleration magnitude normalised to an 8-hour day ($A(8)$), [3, 4]

$$A(8) = \sqrt{\frac{1}{T_0} \cdot \sum_{i=1}^{n} a_{hvi}^2 \cdot T_i}$$

where a_{hv} is the vibration total value of the rms acceleration of tool i,. T_i is the duration of the i^{th}operation with tool i in hours, and T_0 is the reference period of 8 hours.

In this study, two different weighting function for acceleration analysis have been implemented. Firstly, by means of the standard frequency weighting (called W_h) according to ISO 5349-1 [4]. Secondly, by using a new form of frequency weighting for hand-transmitted vibration (called W_p), which is a supplementary method for improving the assessment of the risk of vibration-induced vascular disorders following ISO/TR 18570 [5]. Compared to the ISO frequency weighting W_h, the hand-arm vascular weighting W_p gives more weight to intermediate and high frequency vibration.
The attachment of the sensor to the vibrating tool **is** illustrated in Figure **2**.

Figure 2: The attachment of the sensor on a shockwave therapy tool

Results

The results of each single measurement were determined as the energy-equivalent average over a fixed measurement time of 20s using the substitute tissue and 10s in the process involving a real test subject. The individual results of repeat measurements were then arithmetically averaged for the assessed acceleration and are given in **Table 1**. Six repeat measurements were conducted.

Shock wave therapy tool	a_{hv} (a_{pv})	Time until value is exceeded	
Test object:	[m/s²] Mean ± SD	Action value T_i	Limit value T_i
Ham as substitute tissue	3.41 ± 0.26 (22.35 ± 1.13)	3h 43 min	>8h
Heel treatment	4.34 ± 0.69 (31.77 ± 3.76)	1h 59 min	7h 54 min

Table 1: Results for hand- arm vibration exposure to a shockwave therapy tool expressed as a_{hv} and a_{hp} vibration total value (following W_h and W_p Weighting) and times until action and limit values are exceeded considerung W_h standard frequency weighting

On the basis of the current state of knowledge and taking account of measurement accuracy, the action value for daily vibration exposure A(8) = 2.5 m/s² and the exposure limit value A(8) = 5 m/s² [6] are basically exceeded after the daily exposure times given in **Table 1**. To take account of repeat accuracy, the standard deviation was added to the mean value.

While the limit value for both methods at roughly 8 hours of exposure time is not reached, the action value for heel treatment is reached after 2 hours.

The current assessment method applies at present only to periodic, aperiodic and stochastic vibrations. The effect on humans of repeatedly occurring individual impacts as in the present case and the action mechanism are not fully known.

Discussion

When applying the measured values to other workplaces, it should be noted that the repeat accuracy has been taken into account.

It should also be noted that the vibration exposure only just reaches the action value, although the exposure to vibration during the activity is perceived as highly unpleasant. A higher vibration value is thus subjectively assumed than that actually measured. Further studies on several test subjects should therefore be conducted here and, after development of a substitute method, further studies should be undertaken to consolidate the measured values. Although wearing vibration protection gloves can be assumed to reduce vibration, it is not at present possible to define the degree of hazard reduction when these gloves are used in practice.

Temperature influence is known as a contributory factor. Unless opposed by hygiene considerations, coating the metal handle with damping layers can reduce heat transmission and reduce vibration.

Conclusion

The shock wave therapy tool used by physiotherapists induces hand-arm vibration, which can be very unpleasant. The results of measurements show that vibration exposure just reaches the limit value (5.03 m/s²). Preventive measures should therefore be taken. The effect of noise, as one of several other factors, is below the action value, but the combined effect of these factors is still unknown. The effect of shocks could also be relevant. More studies are therefore needed to yield an understanding of the health effects of shockwave therapy tools.

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Effect of shelf aging on vibration transmissibility of anti-vibration gloves

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Abstract

Anti-vibration (AV) gloves have been used in real workplaces to reduce vibration transmitted to the hand. The mechanical characteristics of resilient materials used in AV gloves are influenced by environmental factors such as temperature, humidity, and photo-irradiation, which cause material degradation and aging. This study focused on the influence of shelf aging on the vibration attenuation performance of air-packaged AV gloves following 2 years of shelf aging. Effects of shelf aging on attenuation performance of AV gloves were examined according to the ISO 10819 (1996) test protocol. The findings indicate that shelf aging induces the reduction of vibration attenuation performance in air-packaged AV gloves.

Keywords:

Anti-vibration glove; transmissibility; Shelf aging

Introduction

AV gloves are widely used as a personal protective equipment (PPE) to reduce the vibration transmitted to the hand. A variety of materials are used for a vibration attenuation material in anti-vibration gloves, most of which are resilient materials composed of certain synthetic and/or composite polymers. Thus AV gloves with different vibration attenuation materials show different vibration attenuation performance in vibration frequency contents, useful life and so forth.

There have been concerns regarding the long-term stability of vibration isolation performance and the useful life of AV gloves. Glove users do not know how extent the vibration attenuation performance of AV gloves in the present situation is enough to reduce exposure to hand-arm vibration or when the useful life of AV gloves is reached.

The aim of this study was to investigate the influence of shelf aging on the vibration attenuation performance of AV gloves following 2 years of shelf aging by assessment of the vibration transmissibility in accordance with ISO 10819 (1996) [1] test protocol. This study addressed the issue of shelf stability of air-packaged AV gloves, the hypothesis being that shelf storage leads to reduced vibration attenuation performance of AV gloves.

Methods

A single-axis hand-arm vibration test rig [2] that can vibrate horizontally was used to examine the glove attenuation performance. Vibration transmissibility of AV gloves was measured according to the test protocol specified in ISO 10819 (1996).Two types of random vibration spectra M and H were used as test signals, which cover a middle frequency range of 16-400 Hz and a high frequency range of 100-1,600 Hz, respectively.

For each test spectrum, the corrected vibration transmissibility of AV gloves TR_s is calculated as follows:

$$TR_s = \frac{TR_{sg}}{TR_{sb}}$$

where TR_{sb} is the vibration transmissibility of the bare hand and TR_{sg} that of the gloved hand. TR_s calculated twice for three subjects were averaged to obtain the mean vibration transmissibility (*TR)*. The *TR* values required for AV glove in ISO 10819 (1996) are less than 1.0 for spectrum M and less than 0.6 for spectrum H.

According to the ISO test requirement, three healthy male subjects participated in this study. The size of the subjects' hands is stipulated as between size 7 to 9 as specified in the European standard EN420. The experiment was approved by the Research Ethics Committee of the National Institute of Occupational Safety and Health, Japan.

Three types of AV gloves (Gloves A, B, and C) were prepared to be measured in this study. These gloves use different types of vibration attenuation material. Shelf aging was performed for these gloves under normal ambient conditions in an air-conditioned laboratory for periods of 2 years.

Results

Table 1 shows change in the TR values of three AV glove samples up to 2 years of shelf aging in air. In the control condition, all the glove samples showed the TR values less than 1.0 at M spectrum. In contrast, only the Glove C sample showed the TR value more than 0.6 at H spectrum.

After 1 year of shelf aging, the Glove A showed the TR value more than 1.0 at M spectrum. The TR values of Gloves B and C at M spectrum were less than 1.0; the TR value of Glove B increasing significantly from 0.850 to 0.890 and that of Glove C decreasing a bit from 0.867 to 0.863 (not significant). In contrast all the glove samples showed increase in the TR values at H spectrum.

After 2 years of shelf aging, Glove A showed the TR value more than 1.0 at M spectrum. The TR value of Glove A reduced a bit from 1.087 after 1 year of shelf aging to1.034 (no significant). The TR value of Glove B did not change during the second year of shelf aging. The TR value of Glove C significantly increased from 0.863 after 1 year of shelf aging to 0.885. In contrast all the glove samples showed marked increases in the TR values during the second year of shelf aging.

Table 2 shows percentage reduction in the TR values of three AV glove samples up to 2 years of shelf aging in air. After 1 year of shelf aging, Glove A showed the TR value reduced by more than 10 % below the initial TR value at spectrum M. The percentage reductions in the TR values of Gloves B and C up to 2 years of shelf aging were less than 5.0 % at spectrum M. In contrast at spectrum H the percentage reductions in the TR values of Gloves B and C steeply increased to more than 15.0 % during the second year of shelf aging.

Discussion

The results obtained in this study show that shelf aging up to 2 years reduced the vibration attenuation performance of air packaged AV gloves. The TR values, measured at the time when the AV glove samples were taken delivery of, were defined as the control TR values in this study. However shelf aging starts just after AV gloves are manufactured. At this point this study underestimated the period of shelf aging, which does not include a period when the gloves are kept in stock in manufacturers before shipment and in retailers after shipment. The reduction of vibration attenuation performance of AV gloves due to shelf aging is associated with oxidative degradation of vibration attenuation material used in the gloves. Alternatively vacuum packaging might be effective in minimizing shelf aging to maintain the initial vibration attenuation performance until the gloves are delivered to end users.

Only Glove A sample showed steep degradation of the TR value at spectrum M after 1 year of shelf aging. In contrast steep degradation of the TR value appeared at spectrum H after 2 years of shelf aging in Gloves B and C. One reason why Glove A began to degrade earlier than the other two glove samples did is that the vibration attenuation material used in Glove A consists of multi layers of viscoelastic gel foamed materials [5], whose mechanical and chemical characteristics are more sensitive to the ambient temperature and humidity than those of rubber materials used in Gloves B and C. Another reason to be considered is related to the period of shelf aging. Among the glove samples used in this study Glove A only has been manufactured in a foreign country. It takes long time for gloves shipped from oversea to be delivered to domestic end users, which suggest that Glove A has been shelf-aged longer than Gloves B and C.

The useful life of AV gloves has to be appropriately determined in relation to the initial TR values of the gloves and be announced to end users with helpful information about the condition of use of AV gloves in real workplaces. For example an AV glove with the initial TR values less than 0.83 and 0.50 for spectrum M and H, respectively, can afford to be satisfied with the TR value requirements specified in ISO 10819 (1996) even after 20% of degradation in the glove vibration transmissibility. This is the case with the Glove C sample, which has the initial TR value at spectrum H less than 0.50. According to the EU standard EN 420, the useful life of gloves that is reached when the TR values have increased by 20% beyond the initial TR values has to be stated with the condition of use. If this statement in EN 420 is applied to Glove C, the glove cannot be used as AV glove because of the reach of useful life in spite of the TR values for spectrum H less than 0.6 at 20 % vibration attenuation performance loss.

Conclusion

Consequently shelf aging up to 2 years reduced the vibration attenuation performance of air packaged AV gloves. This study is the first step of a research that focused on the change in the vibration attenuation performance of AV gloves dure to aging and its useful life. The mechanical and chemical characteristics of the resilient materials used in AV gloves are prone to be influenced by environmental conditions such as temperature, humidity, and photo-irradiation, which result in oxidative degradation during shelf aging. Also the vibration attenuation performance of AV gloves disperses individually and depends on manufacturing conditions. Moreover in usage of AV gloves in workplaces, the vibration attenuation performance is affected by many factors: aging, the ambient temperature and humidity, creeping, high contact pressure and so on. Future works are required to examine the effect of other factors mentioned above on the vibration attenuation performance and useful life of AV gloves.

Table 1 Change in the TR values up to 2 years of shelf aging in air ($p< 0.05$).*

		TR_M			TR_H		
		Control	1 year of shelf aging	2 years of shelf aging	Control	1 year of shelf aging	2 years of shelf aging
Glove A	Av.	0.916	1.087*	1.034*	0.744	0.773*	0.816*
	SD	.023	.0044	.015	.031	.013	.0095
Glove B	Av.	0.850	0.890*	0.892*	0.504	0.531*	0.585*
	SD	.073	.0030	.024	.047	.016	.014
Glove C	Av.	0.867	0.863	0.885*	0.460	0.475*	0.545*
	SD	.0021	.059	.034	.0035	.035	.050

Table 2 Percentage reduction in the TR values up to 2 years of shelf aging in air.

	Percentage change in TR values (%)			
	TR_M		TR_H	
	1 year of shelf aging	2 years of shelf aging	1 year of shelf aging	2 years of shelf aging
Glove A	18.8	13.0	3.87	9.63
Glove B	4.74	4.99	5.28	16.1
Glove C	-0.40	2.15	3.44	18.6

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Anti-vibration gloves certification: does the laboratory represents what happens in field?

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Keywords:

Anti-vibration glove; certification

Introduction

Certification of anti-vibration gloves is nowadays performed following UNI EN ISO 10819:2013. This certification is a laboratory standardized protocol. It is well known that field measurements differs from laboratory in many points: posture, grip and variability of engine speed. While in lab a static posture is assumed, field posture is far from static and grip varies in a wide range.

The purpose of this paper is to compare a couple of certified anti-vibration gloves in field with their certification data on a specific tool: chainsaw.

This work is part of a wider picture in which there will be a database for anti-vibration gloves in the italian Physical Agent Portal (PAF: http://www.portaleagentifisici.it/).

Methods

Five male participants experts in the use of chainsaw were recruited. The task was to cut pine trunks (diameter 15-20 cm) in a perpendicular direction to the axis of the trunk. For each participant, at first the bare-handed transmissibility (T_0) and then the gloved hand transmissibility (T_1) was assessed, as:

$$T_0 = a_{hv,h}/a_c \quad \text{and} \quad T_1 = a_{hv,g}/a_c$$

$a_{hv,h}$, $a_{hv,g}$, a_c are vibration total value of frequency-weighted r.m.s. accelerations as defined by ISO 5349-1 measured, respectively, on bare hand, on the gloved hand and on the chainsaw handle. Acceleration on the hand was measured using a PCB SEN026 accelerometer inserted in a handheld adapter, while acceleration on the handle of the chainsaw was measured using a PCB SEN026 accelerometer fixed with wax and tape. The adapter is similar to the one described in the UNI EN ISO 10819:2013 but modified to accomodate also two Futek button load cells for monitoring the push force. All signals were acquired with the Bruel & Kjaer Pulse multichannel analyzer.

Posture and grip force were not standardized, even if the push component of grip was measured. Movement and rotation of chainsaw was admitted to reproduce real field operation.

Calculation have been performed as in ISO 10819: 5 subjects for three measurements each, with and without gloves. In order to have the prescribed transmissibilities in medium and high frequency the signal was split in these two frequency range. Two gloves have been fully characterized untill now, while other gloves and tools are under way.

Results

Actual results are depicted in Table 1, referred to the handle of the chainsaw; in which are reported, for comparison, certification data declared by manufacturer. In Table 2 are reported transmissibilities referred to the bare hand. Those latter are measured in two different cutting session: one for the bare hand and one for the gloved hand.

Table 1

Worker	Ansell 07-112		Ergodyne 9015	
	Tm	Th	Tm	Th
1	1,11	0,67	0,97	0,67
2	0,75	0,66	0,78	0,68
3	0,74	0,68	0,46	0,30
4	0,93	0,76	0,50	0,76
5	1,04	0,72	0,45	0,45
Average	0,91	0,70	0,63	0,57
Stand dev	0,17	0,19	0,21	0,22
Declared	0,90	0,52	0,80	0,57

Table 2

Worker	Ansell 07-112		Ergodyne 9015	
	Tm,h	Th,h	Tm,h	Th,h
1	0,98	0,89	0,86	0,89
2	0,88	0,80	0,91	0,83
3	1,02	0,98	0,64	0,44
4	1,16	0,91	0,63	0,91
5	1,40	1,03	0,60	0,64
Average	1,09	0,92	0,73	0,74
Stand dev	0,20	0,17	0,19	0,20
Declared	0,90	0,52	0,80	0,57

Discussion

The difference between on field transmissibility and declared values (laboratory) is, with only one exception, small and well in the standard deviation of field measurements. It is possible to notice that in high frequency the attenuation is bigger than in medium frequency and that path is reproduced, with two exception, in the transmissibility computed with reference to the bare hand instead of the handle.

Transmissibility values calculated relatively to the bare hand and those referred to the handle are rather near each other. This is particularly so when compared to the standard deviation of multiple measurement of a single subject (not reported for space consideration). This is interesting because there is not any synchronicity between the measurement with the glove and that with bare hand. But the grip changes in both measurements in the same way, presumably, while in the handle measurement the coupling force is constant.

Conclusion

Actual data seems to confirm the goodness of the certification protocol, confirming declared data with measured ones. It seems reasonable, from the high standard deviation, that on field a bigger number of subjects would be desirable, to keep in count the greater variability. Anyway it seems that posture and grip are a lesser concern than assumed.

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Database KarLA

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Keywords:
vibration database; immission and emission values; tools for risk assessment

Introduction

Vibration databases are important sources of information, among others for risk assessment at the workplace. The importance of these information sources is currently being strengthened by international efforts within the scope of CEN to establish guidelines and requirements for the quality of such databases [1].

Methods

The database KarLA (acronym for catalogue of representative noise and vibration data at work) is provided by the "Landesamt für Arbeitsschutz, Verbraucherschutz und Gesundheit" (OSH Authority) [2].

Figure 1: Bi-lingual Homepage of KarLA

KarLA has been available for any interested person via internet now since nearly 20 years. By showing immission as well as emision data the database serves vibration experts, occupational health and safety practitioners and users of vibrating machines.

Results

The provided noise and vibration data – e.g. from self-propelled machines, tractors, trucks, fork-lift trucks, buses or from hand-held machines such as drills and saws – can be used both preventively (for risk assessment) as well as retrospective (e.g. in the recognition process of cases of occupational diseases). Furthermore, KarLA also supports manufacturers of outdoor machinery (in accordance with Directive 2000/14/EC to declare the emission data and fulfill their obligations to notify the competent authority including the EU Commission.

After a fundamental revision of the database structure and a face lift KarLA got a new user interface showing emission and immission values. While emission values (in accordance with the Machinery Directive 2006/42/EC) serve primarily the comparison between different machines, e.g. at purchasing, the imission values are directly suitable for the risk assessment, presuming that the conditions here are similarly.

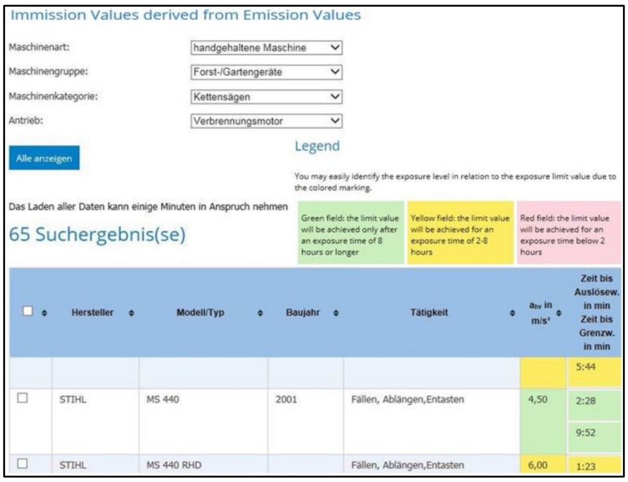

Figure 2: Example of search for immission value at HAV

In the case of hand arm vibration (HAV), a distinction is drawn between measured and immission values derived from emission values by means of correction factors [3].

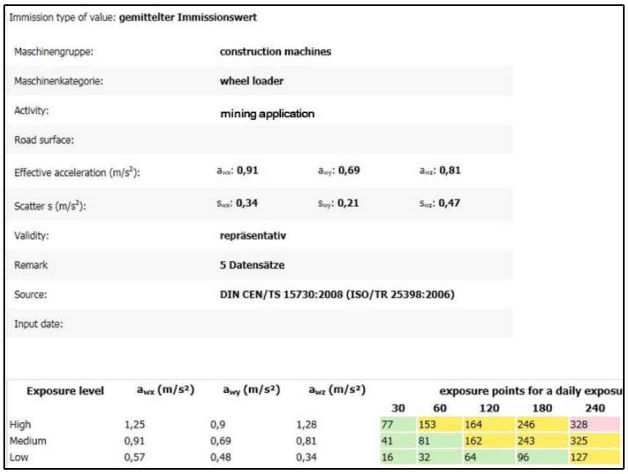

Figure 3: Example of detailed information at WBV

In the case of whole-body vibration (WBV) in addition to measured values there are also averaged immission values for some machine categories, obtained by averiging over different measured values. Also these values can be used to assess the risk, presuming that the conditions at the working place are similarly. Additional all search results offer detailed information if needed. In the case of immission values (see Figure 3), the exposure points obtained with regard to the duration of exposure are also displayed with corresponding colour coding with respect to the action values of the Noise and Vibration Ordinance [4].

Users can now determine averaged vibration values on machines they have selected and also enter their own data, which will be shown after internal testing in KarLA.

Survey of the entered load sections

Group/machine	Category/Type	Activity	Severity	Time (h)	$A_x(8)$	$P_{l,x}$	$A_y(8)$	$P_{l,y}$	$A_z(8)$	$P_{l,z}$	
Bagger	Raupenbagger	Baggern	normal	2		19		7		9	Löschen
Planiermaschine	Planierraupe	Planieren (dozing)	normal	2		55		33		49	Löschen
Muldenfahrzeuge	Muldenfahrzeug mit Starrrahmen/Dumper	Beladungsprozess	hart	1		8		8		8	Löschen
Muldenfahrzeuge	Muldenfahrzeug mit Starrrahmen/Dumper	Fahren ohne Last	hart	2		85		96		144	Löschen
Summary				**7**	**0.65**	**167**	**0.60**	**144**	**0.72**	**210**	

Daily exposure A(8)

Total duration	Daily exposure value	Daily exposure points	Relevant direction	Notes
7	$A(8)=0.72\ ms^2$	P=210	z	Auslösewert ist Überschritten

Figure 4: Result by calculator for earthmoving machines

Changes in the database KarLA and its interface are always in the interests of the users. Thus, the service part was extensively expanded. Figure 4 shows the newly implemented WBV load calculator for drivers of earthmoving machines. With the provision of relevant regulations as well as the exposure calculators for WBV, HAV and noise plus further working aids of our State Office, a complex service is supplied for the risk assessment.

The database KarLA currently comprises 1,327 data records on WBV, 2,291 data records on HAV, 1,319 records on noise (in addition about 1,700 data on outdoor equipment). The transfer of more than 1,000 vibration data from the mining sector is planned.

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A new, user friendly design of the Swedish national vibration database to be used for preventive work

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Keywords:
Database; Mobile; Vibration; Hand-arm; whole body; prevention

Introduction

Raynaud's phenomenon, neurosensory injury and carpal tunnel syndrome due to exposure of hazardous levels of hand-arm vibration is still a major problem in the Swedish work force. Prevention is an important tool to avoid these injuries. The Swedish national vibrationdatabase was developed to help with the prevention of hand-arm vibration related injuries by giving employers, occupational hygienists and others with basic concept of risk managment a tool to assess the vibration exposure among workers. The use of the database has been declining in recent decade. This may be due to less up to date measurement values in the database and a less user friendly design for employers or safety representatives. In a project financed by AFA insurence, Sweden, we have redesigned this database to be more user friendly and organized the work of collecting new mesurements to the databes. This newly design databese will launch in Sweden in the autumn of 2019.

Methods

A new user friendly design has been developed by the project group in collaboration with other occupational hygienists , unions, employer organisations, and consultants on design in Sweden (Figure 1). It is developed both in Swedish and English language for international users. It will be evaluated by a group consisting of employers, safety representatives, and occupational hygienists. We developed a design where the user choose from machine categories and machine types to assess workers exposures. The vibration values are based on field measurements of vibration from 1999 and onwards. CE values are used if there are no field measurements. After selecting machine type, the user enter the usage time for a working day. The user can select several machines for one assessment and then get a report sent to them from the database. For more advanced users there is an option were they can select specific models and also choose vibration levels from different decades. This feature has been added after wishes from occupational hygienists and researchers. The new design is also adapted to be easy to use on mobile phones

Results

The new design has been developed for both hand-arm vibraiton and whole body vibration measurements. It is available both in Swedish and English for interantional users. This new design will be presented for international audience at the conference.

Discussion

The new design will be launched in autumn of 2019. It will be evaluated among employers, occupational hygienists and safety representatives. Hopefully this new design will help companies in Sweden with their preventive work and evaluation of vibraiton exposure among workers.

Conclusion

A new redesigned Swedish national vibration database will be leaunched in Sweden and available for international users this autumn of 2019. It has two main options. One option is based on the user choosing machine categories and machine types and one advance option for specific models. This new design will help the preventive work among employers, occupational hygienists and safety representatives in Sweden and internationally.

Figure

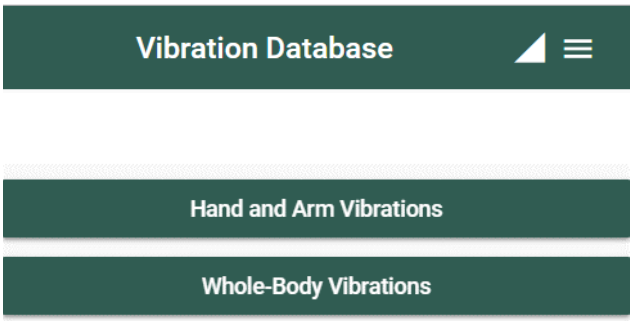

Figure 1: Homepage of the redesigned Swedish National Vibrationdatabase.

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A safety factor for the vibration generated for tools in the construction of hydroelectric project in Costa Rica

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Abstract

The vibrations go through the material and generate changes, now or tomorrow, the human being does not escape this reality. The studies of exposure to vibrations in the human body are limited in the different occupations in Costa Rica and the construction area is not an exception. From the study of a series of tools usually used in the construction processes of the hydroelectric projects, a safety factor was obtained to determine the acceleration levels to be used in the calculation of the maximum exposure times to vibrations per tool. The use of this factor is recommended in the case of not having means to perform the measurements for the tools used in each case. With the results obtained it is evident that the acceleration levels generated by each tool are higher than those delivered by the manufacturers, hence the importance of this factor.

Keywords:
Costa Rica; factor; vibrations.

Introduction

In Costa Rica studies to know the levels of hand-arm vibration to which workers who work with pneumatic, electric and combustion hand tools are scarce, therefore controls have not been designed to reduce exposure to them .
It is known by the National Institute for Working Life of Sweden, a database on the levels of vibration measured in various machines for manual use, but most vibration levels correspond to values declared by manufacturers, or values obtained in laboratory conditions (Santurio et al., 2006). The data obtained in laboratory conditions show acceleration levels above the action level established by the European Union is 2.5 m/s^2 and even above the maximum exposure level of 5 m/s^2.
Therefore, the question arises that if the manual tools used in the construction of a hydroelectric project in Costa Rica exceed the maximum permitted levels, which acceleration levels should be used in the calculations.
With this research we want to evaluate the exposure to hand arm vibrations generated by electric, pneumatic and combustion tools in the construction of a hydroelectric project, in order to know the real levels of acceleration and make decisions with a preventions approach.

Methods

Study area

The area where the research study was developed is in the south of the Province of Puntarenas in the canton of Buenos Aires, obtaining the data between 2011-2012, during the exploration phase of the hydroelectric project. The conditions of the environment were characterized by being of high humidity with a value higher than 80% and with temperatures between 27 and 33 Celsius degrees at a height of 397 meters above sea level, according to the National Meteorological Institute of Costa Rica.
Obtaining samples and data
The tools selected to perform the study correspond to those indicated in Table 2, the sample was selected randomly and according to the inventory of the tools in the research site.
For each tool, 40 samples were taken to obtain statistical sufficiency. Table 1 shows the names, models and vibration level of the study tools according to the manufacturers.
The tools were reviewed by technical staff of the project to verify a good state of operation before executing the measurements.

Table 1: Analyzed tools

Tool	Model	Manufacturer	Energy	Aceleration (m/s^2)
Lawn mower	R 152SV	Husqvarna	Gasoline	2,5
Boot foot compactor	SRV 66	Weber	Gasoline	10-20
Compactor Plate	CF-4	Weber	Gasoline	12,2
Sander	BO3700	Makita	Electric	N/D
Drill	D21805 KS	Dewalt	Electric	4,5
Rock Breaker	TEX 32PS	Atlas Copco	Air	13,7
Push Foot Driller	BBC 34 WS	Atlas Copco	Air	18

The methodology for taking the data that was used is the UNE-EN ISO 5349-2001 part 1 and 2 for the vibrations transmitted to the hand arm system specifically.

The measurements were carried out with the QuestHAVPro vibrometer equipment with a triaxial hand arm accelerometer 072-010. The equipment was programmed so that each measurement had a duration of one minute on the W_h frequency (6.3Hz to 1250Hz). In order to fix the accelerometer to the handle of the tools, metal garters were firmly secured.

Statistic analysis

To analyze the data, hypothesis testing was used through the Minitab software, in order to contrast the manufacturer's value against the values obtained during the measurements. The value delivered by the manufacturer was used as H_0 and the data obtained during the measurements as H_1. The test that was performed was unilateral where $H_0 = \mu \leq \mu_0$ and $H_1 = \mu \geq \mu_0$, the pvalue selected was 0.05 as the statistical sufficiency value. For each data set the normality test was performed, its mean and standard deviation were obtained.

Results

The results obtained from the vibration levels for each tool are shown in Table 2. As part of the results, the Pvalue obtained from the normality test is also shown to corroborate the statistical significance of the data.

Table 2: Acceleration levels obtained

Tool	Aceleration (m/s^2)	StDev	Maximun time (hours)	Pvalue
Lawn mower	10.18	0.65	5.60	0.13
Boot foot compactor	17.14	1.56	4.32	0.56
Plancha Compactor Plate	20.96	1.56	3.90	0.83
Sander	6.92	0.244	6.80	0.338
Drill	16.74	1.55	4.37	0.145
Rock Breaker	25.46	1.88	3.54	0.25
Push Foot Driller	18.77	2.43	4.12	0.06

Discussion

All the results of the acceleration levels of the tools under study are higher than the maximum level of exposure and that indicated by the manufacturers, concordant with previous studies carried out in South Africa (Nyantumbu et al, 2007).

When corroborating that the acceleration levels are usually higher than indicated by the manufacturers, there is a need to execute preventive methods that do not require complex equipment in order to know the levels of vibration and take actions to restrict the exposure times of the workers.

Based on the above, and observing how acceleration values reach up to almost four times higher than the theoretical values in the case of the drill, it is recommended to establish a protection factor of twice the maximum theoretical value provided by the manufacturer and so with this value calculate the maximum exposure time per tool for each worker. When using this methodology for 4 of the seven tools under study, it is possible to establish exposure times complying with the standard of $5m/s^2$. It is possible that this methodology also works for the sander but we do not know the value of the manufacturer.

I agree that the ideal is to make the measurements of the acceleration levels for each tool, in the different construction projects, since even the materials on which it works affect the acceleration generated, but this is very rarely possible in these types of projects.

Conclusion

- All acceleration levels obtained for each tool exceeds those of the manufacturer.
- The recommended safety factor is twice the acceleration level given by the manufacturer.
- The methodology proposed in this research is an option in the absence of a vibrometer to perform a study of the acceleration levels for each tool.

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Bringing Together Machine Weight, Hand-Arm Vibration and Noise Health Risk Information in the UK Rail Industry

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Abstract

Weight, hand-arm vibration emission and noise emission are three machine characteristics that individually present quite different health risks for the user. In the rail industry, there was a desire to have a rating that combined the three risks, which, if used appropriately, will quickly highlight those hand-held power tools likely to have lower combined risk.

A "WVN" classification method has been developed, based on the weight, hand-arm vibration and noise emission data that enables a simple comparison of machines of similar type or equivalent function. However, a machine with a low rating may still present a risk. It is therefore important that individual hazards information is not lost when presenting this type of rating.

Keywords:

Weight; hand-arm; vibration; emission; noise; classification; combined rating;

Introduction

Weight, hand-arm vibration (HAV) emission and noise emission are three characteristics of a machine that individually present quite different health risks for the user. Regular exposure to loud noise from machinery can lead to hearing damage and can have an impact on safety. Hand-held vibrating machines used regularly can be responsible for various types of damage to the fingers, hand and arm. Heavy machines that need to be lifted or manoeuvered manually are associated with musculoskeletal injuries, usually to the back.

The Laboratory of the Health and Safety Executive (HSE) was asked by the UK rail industry to consider whether it is possible to take a holistic approach to gauging the health risks from power tools used in the rail industry, by combining the risk factors of weight, HAV and noise in a way that usefully presents in one place the risk from machine weight, HAV emissions and noise emissions.

A combined indicator has the potential to help managers and users select lower-risk machines or tools for a specific task; this is likely to be particularly useful when comparing machines used for similar tasks.

Industry information

In the UK, Network Rail maintain a datasheet[1] that reproduces some of the data from machine manufacturers are required to provide under the Supply of Machinery (Safety) Regulations 2008 (SMSR)[2] including: mass (referred to as weight in the datasheet), vibration emission and emission sound pressure level.

General observations

Links between machine weight and vibration or noise risk

There is no widely accepted method of quantifying the benefits to vibration risk of using lower weight machines. A method for adjusting HAV exposure values based on the coupling force at the hand is defined in a European Technical Report, published in the UK as CEN/TR 16391:2012. However, the UK national foreword to PD CEN/TR 16391[3] contains the following advice:

> *"it is not appropriate to use coupling forces to modify workplace assessments of vibration exposure in relation to the EU Physical Agents (vibration) Directive (implemented in the UK as the Control of Vibration at Work Regulations 2005) or the measures of vibration emission as required by the EU Machinery Safety Directive (implemented in the UK as the Supply of Machinery (Safety) Regulations 2008)."*

Clearly for machines that are only partially, or not supported by the operators, the relationship between weight and coupling forces during vibration exposures becomes less relevant.

There is no evidence for a link between noise risk and machine weight or between noise risk and vibration risk.

Risks from machine weight

The risk of musculoskeletal injury, from the manual handling of large machines, is associated with the weight of the machine (see HSE guidance web page on Musculoskeletal Disorders[4]). If the user has to support the machine's weight, a lighter machine is generally regarded as a better option than a heavier machine.

For some machines the operator does not support the weight of the machine during use. These machines may be jig-mounted, track-mounted or hand-guided, for example:

- "Electrical magnetic drill" (magnetically mounted).
- "Rail-head scrubber" (rail-mounted descaling tool).
- "Vibro-plate compactor", (hand-guided).

For these machines, weight is only an issue if the operator has to lift or manually transport the machine into the working position.

Development of combined rating schemes

A number of different combined rating schemes were trialled using information from issue 40 of the Network Rail datasheet. The most useful scheme was based on the use of class values, shown in Table 1. For each risk factor, the machine is assigned a class value between 0 and 6. The overall class value is the average of the three individual risk factor class values, which is then used to assign a WVN class label, colour coded from green ("A") to red ("G"). For example, a machine of weight 11.5 kg, HAV emission 1.5 m/s² and noise emission of 103 dB(A) would have class values of 4 (weight), 1 (HAV) and 5 (noise). The average of these class values is 3, and the machine therefore receives the WVN label "D".

Table 1: WVN classification system

Class value	Weight range (kg)	HAV range (m/s²)	Noise range dB(A)	WVN Class Label
0	< 1	< 1	< 75	A
1	≥ 1, < 2	≥ 1, < 2.5	≥ 75, < 85	B
2	≥ 2, < 5	≥ 2.5, < 5	≥ 85, < 90	C
3	≥ 5, < 10	≥ 5, < 10	≥ 90, < 95	D
4	≥ 10, < 15	≥ 10, < 15	≥ 95, < 100	E
5	≥ 15, < 30	≥ 15, < 20	≥ 100, < 110	F
6	≥ 30	≥ 20	≥ 110	G

Discussion

Manufacturers' data

The work reported here is based on analysis of declared data for weight, HAV and noise, which machinery manufacturers are required to provide by the SMRS.

Comparisons of tools and machines based on their weight, HAV emission and noise emission are only meaningful if the data have been determined using comparable measurement methods under the same operating conditions. For noise and HAV, manufacturers' data are most likely to have been determined using harmonised European Standards. There is no harmonised standard for declaration of machine weight, so it is important that information is recorded consistently (e.g. without without fitted components).

Combined rating schemes

There are many machine characteristics that impact on its suitability for a particular application. A combined rating cannot highlight potential health risks associated with individual hazards and therefore should not replace individual assessments of weight, HAV and noise. These individual risks must be evaluated separately; a combined rating cannot replace appropriate consideration of the individual risk factors.

Combined ratings need to be based on good quality, up-to-date, HAV and noise data, which represent the emissions during the intended uses of the machine.

Combined ratings must be provided alongside individual data for weight, HAV and noise; not doing so may give a false impression of the risks from a machine. Labelling schemes used on food products in the UK and Europe may provide a model for how to present machine information. Figure 1 shows an example of how machine classification information might be presented.

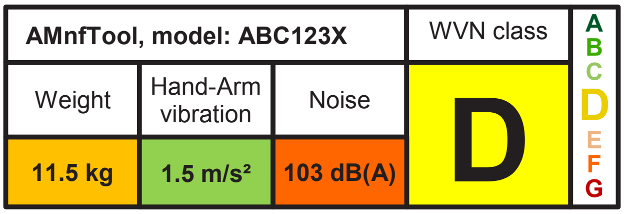

Figure 1: Possible format for presentation of risk information

Conclusions

A combined rating system is not intended to replace an evaluation of the risks presented by the three individual agents (machine weight, HAV emission and noise emission), as the health risks from these three agents are quite different and largely unrelated.

A combined rating scheme, based on reliable machine data and used in the appropriate way, could provide a quick and easy way of comparing the overall combined risks presented by machines. Such a system could be used to help the selection of machines, and for defining purchasing specifications.

Any rating scheme is directly dependent upon the quality and relevance to the workplace of the data from which it is derived. It is therefore important to critically review the underpinning weight, HAV and noise data before it is applied to a formalised rating scheme.

Combined rating schemes based on classification of the individual hazards of weight, HAV and noise are likely to be most effective at identifying overall risk. The WVN class scheme using letters from A to G may be a simple method of raising awareness of the machine hazards and aid effective machine selection in the workplace.

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Zero vibration injuries by introduction of machines with low vibrations

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Abstract

Vibration injuries causes significant costs for society, great personal suffering and often need for relocation of personnel within the company. The project "Zero Vibration Injuries" is a Swedish initiative with the objective to take a holistic approach on the problem. The project's vision is "Zero vibration injuries". This is achieved by addressing the source of the problem; by reducing vibration levels in handheld machines.

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Keywords:

vibration injuries; hand held machines

Introduction

Every day, 400,000 workers are exposed more than two hours per day to vibrating machines in Sweden. This causes significant costs for society, great personal suffering and often need for relocation of personnel within the company. Vibration injuries is today the most common cause of occupational disease in Sweden[1]

In the ongoing project the objective is to reduce vibration injuries by addressing the source of the problem by reducing vibration levels in handheld machines. The project has the motto Machines do not need to vibrate and hurt people!

In this context also the high frequency content of vibrations, above 1250 Hz that ISO 5349 does not include, is included and is to be reduced since it is a potential risk for causing substantial vibration injuries[2-5]. Meanwhile, waiting for a new standard or supplementary standard, the high frequency vibrations should be handled by a precautionary approach.

The project "Zero vibration injuries" is now in the third and last step, *figure 1*. In step 2 machines were redesigned in order to demonstrate the possible reduction of vibrations. Machines included were e.g. impact wrench, drill hammer, chisel machine, dental tool and a rammer plate, which represents the majority of machines that causes vibration injuries.

In stage 3 focus is vibration free demonstration environments. To demonstrate and evaluate the redesigned machines they are introduced and implemented in industrial demonstration environments. These are discrete industrial production environment of a full-activity enterprise with associated productivity and quality requirements. This enables an extended period of testing and evaluation of the low vibration machines. The environments are selected to represent a wide range of industries e.g automotive industry, construction site, foundry, stone industry and dental care.

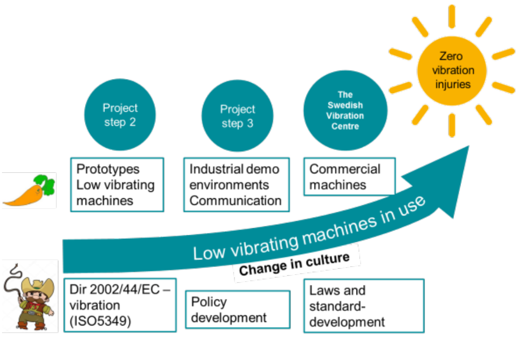

Figure 1: Project overview "Zero Vibration Injuries".

A cultural change should be created around the companies' behavior regarding vibration and how to reduce vibration injuries. This includes e.g. knowledge of vibration reduction solutions, understanding and acceptance throughout the organization for the vibration problem, and also to raise awareness about the risks for injury from high frequency vibration.

Methods

The work is based on three main activities:

- Show that it can be done
- Facilitate selection of low vibrating machines
- Establish a cultural change

To show that it can be done: Introduction and implementation of the redesigned machines in industrial demonstration environments. The vibration levels is measured before and after the introduction of the new tools. Other vibrating machines, which are used in the environment, are also included in the measurement to create an overall picture. Also health studies are made.

Vibration is reduced in the machines by design solutions based on balance rings, Auto Tuning Vibration Absorber (ATVA) and traditional vibration isolation. The machines included are e.g. impact wrench, drill hammer, chisel machine, dental tool and a rammer plate.

To facilitate selection of low vibrating machines: In order to enable machine users to require, assess and purchase low vibrating machines, equipment for measuring and assessing ISO and high frequency vibration is developed. Additionally, a "Vibration Map" is developed to assist the user to choose the right machine.

To establish a cultural change: This concerns companies behavior regarding vibration and vibration injuries, also including high frequency vibrations, and to a greater extent solve the problem by choosing low vibrating machines. An evaluation is made regarding how new machines are received in the demonstration environments also including obstacles and barriers at the workplaces based on the work situation and work organisation. Obstacles may be attitudes, behaviours and levels of ambition at several different organisational levels – the skilled workers themselves, supervisors, managers and senior management.

Acknowledgement

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Strategies for occupational safety and health to prevent the effects of the exposure to hand-arm vibration

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Abstract

The risks of vibration both to the hand-arm and to the whole-body systems have gained attention in many countries (UK, France, Belgium and Germany).

Keywords
Occupational Safety and Health; Risk assessment

Introduction

The main objectives of this study are to provide an overview of the application of hand arm vibration directive in some countries (UK, France, Belgium and Germany) in order to establish the principal risks and the prevention measures to improve occupational safety and health (OSH) [1]. The procedures of risk assessment enable the employer to prevent or to control the exposure of workers to hand-arm vibration. The risk assessment should identify where there may be a risk from hand-arm vibration; estimate employees' exposures and compare them with the exposure action value and exposure limit value; identify the available risk controls; identify the steps to control hand-arm vibration risks; and to record the assessment.

Methods

This study examines emerging physical risks related to occupational safety and health (OSH). The aim is to propose an overview of the challenges facing the occupational safety and health (OSH) in the context of the application of the vibration directive.

Results

The health effects of hand-arm vibration depend on regular exposure to vibration that can lead to hand arm vibration syndrome (HAVS) and carpal tunnel syndrome (CTS).

Discussion

It is proposed an overview of the application of hand arm vibration directive in some European countries.

In United Kingdom, the plan aims to engage organizations, individuals and companies to share knowledge and expertise to work towards developing an improved health and safety awareness across the nation. The strategy covers six main themes:

1. Acting together: Promoting broader ownership of workplace health and safety.
2. Tackling ill health: Highlighting and tackling the burden of work-related ill-health.
3. Managing risk well: Enabling productivity through proportionate risk management, simplifying risk management.
4. Supporting small employers: Giving simple advice that can help them manage their health and safety responsibilities.
5. Keeping pace with change: Anticipating and tackling the challenges of new technology and ways of working.
6. Sharing and Promoting the benefits of Great Britain's approach in health and safety system.

In France, the labor code (Code du travail articles from R. 4441-1 to R. 4447-1[2]) obliges employers to prevent the risk of vibrations [2]. In France, inspectors may ask employers to show what they have actually assessed the vibration exposure of operators. If this has not been done, the employer may be required to pay a Notified Body to carry out this assessment. Inspectors use a list of tools and machines likely to expose operators to vibration above limit values. This list is produced by

INRS. In addition, the CRAM (French insurance system) asks to its eight regional laboratories to assess vibration exposure at work.

In Belgium, the SOBANE strategy consists of four levels: Screening, Observation, Analysis and Expertise. The level of screening begins with a complaint or an accident in the work situation. If the Screening level has not solved the problem, the Observation, Analysis and Competence levels are executed. Screening and Observation levels are inexpensive. The Analysis and Expertise levels are more expensive. The strategy identifies different stakeholders: the people of the companies to carry out the levels of Screening and Observation, the external consultant for the Analysis and a specialist for Expertise.

In Germany, modules with action instructions and calculation aids are available to assess activities involving predominant load on the finger-hand-arm area. The guide presents a screening method, but requires a good knowledge of the work to be evaluated. The screening method detects work-related deficits and suggests measures that can reduce the risk of adverse health effects. Risk assessment of physical work load situations is evaluated by Key Indicator Method Manual Handling Operations (KIM MO). The probability of a physical overload is evaluated. If the 25 risk score limit is adhered to, the activity can be carried out by all workers without any risk of a physical overload. Above 50 risk scores, however, there is a risk for all workers of physical overload with consequences for human health.

Conclusion

Symptoms of vibroacoustic diseases are generated by long-term exposure to low frequency noise and vary from gastrointestinal diseases, pharynx infections, bronchitis, urinary organs disorders and metal allergies, to bleedings in the nose and intestinal tract, varicose veins, ulcer, colitis, arthralgia and muscular disorders, and neurological disturbances after a ten-year exposure.

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Belgium: http://www.emploi.belgique.be

Germany: http://www.baua.de

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Hand-transmitted vibration assessment on the human as an indicator of health risk

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Abstract

This study investigates the concept of assessing hand-transmitted vibration on the individual tool operator through the use of wearable technology as an indicator of health risk. Health risk to individual tool operators was quantified through the determination of temporary threshold shifts (TTS) in vibrotactile perception while performing live tool activities. Concurrent measurements were taken at the tool handle in accordance with ISO 5349-1 and on the subject utilising wearable sensors. The results indicate that a strong positive correlation exists between assessing hand transmitted vibration on the subject and the health risk.

Key words:

Hand-transmitted vibration, Temporary threshold shift, wearable sensors

Introduction

Employers who expose their workforce to hazardous vibration from mechanised tools are required by law in many countries to assess the severity of the risk faced through the use of tool vibration emission data. However, limitations identified of on tool assessment are recognised and listed within Annex D of ISO 5349-1 (1). CEN/TR 15350 (2) further identifies the difficulties of obtaining a precise value for probable vibration and the cost prohibitive nature of wide scale in-situ tool testing in live industrial environments. The effect on vibration transmission of many of the limitations identified within Annex D of ISO 5349-1 have been studied (3) and it is accepted that these limitations in reliable exposure data limit the ability to predict the pathogenesis of the condition within an exposed population.

Existing risk assessment methodologies based on static tool vibration emission data and tool use studies seldom capture the effects of task variation and or human interaction with the tool in the form of operator proficiency and coupling forces. Therefore, it may be desirable to assess the actual received dose by the operative in order to increase the likelihood of predicting risk of future disease and initiate more timely preventative intervention.

In this study the investigators seek to examine whether vibration dose assessment on human subjects using wearable sensors could capture the effect on transmitted energy of limitations identified within in Annex D of ISO 5349-1.

Method

A series of tool test scenarios where developed in order to recreate realistic tool use cases within a controlled laboratory environment. Workpieces were mounted to a custom reaction frame sufficient to provide a range of postures. A range of commonly used mechanised tools where employed in several different postures by test subjects to conduct live tool tests against appropriate substrates.

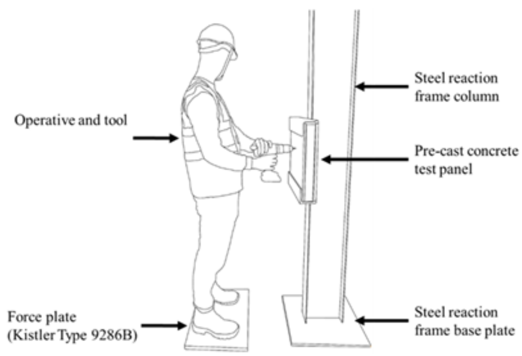

Figure 1 Test subject, reaction frame and force plate configuration

Test subjects varied in physiology and proficiency in tool use, therefor within the scope of the experiment multiple variables effecting vibration transmission were captured. Push force for each of the tool test activities was maintained at a predetermined force level (50 N) through the use of a force plate and digital display (Kistler Type 9286B). A typical test configuration can be seen in Figure 1.

Simultaneous measurements were taken on the subject to determine hand-transmitted vibration using a wrist mounted wearable device (HVW-001, Reactec Ltd.) and on the tool using conventional ISO 8041 compliant analysis equipment to determine tool emission vibration. Mounting and frequency weighting filters were undertaken in compliance with ISO 5349-1 (BSI, 2001a).

Results

The test results are examined to determine the coefficients of correlation for the hand-transmitted vibration as assessed on the subject with the assessment of human response as measured by the TTS method relative to the coefficients of correlation for tool emitted vibration to that same human response. The results indicate that a positive linear relationship exists between vibration determined on the subject and the human response. The strength of this relationship could be seen to increase further when examined on a subject by subject basis as illustrated by figure 2.

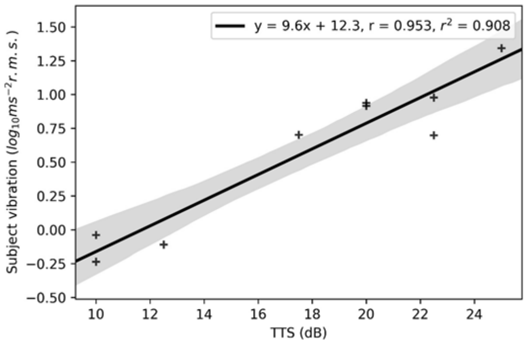

Figure 2 Vibration on subject correlating with TTS

Also evident within the results is a lack of correlation between on tool emission vibration and human response when examined across a subject group performing the same task and using the same tool as illustrated in figure 3. Despite a broad range of human response being visible through TTS the vibration measured on the tool remains essentially unchanged. This lack of correlation for tool emission data contrasted with a positive linear relationship present for on subject assessment for the same data set as illustrated in figure 4.

Discussion

The positive linear relationship between TTS and the hand transmitted vibration assessed on the subject seen in the results would support

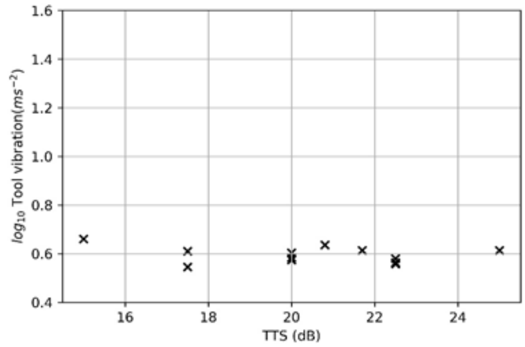

Figure 3 Broad range of human response against on tool vibration

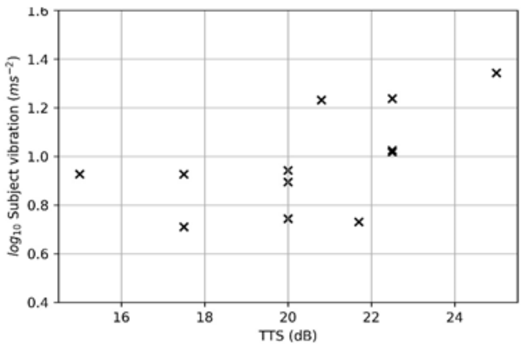

Figure 4 Broad range of human response against on subject vibration

the use of such data as an indicator of exposure risk. Very strong correlations in the data when analysing on an individual operator level supports the hypothesis that an individual's interaction with the tool heavily influences transmission and associated risk. The results for multiple operatives conducting a single test condition indicates that the measurement on the tool is not effective in discriminating the effects of the human physical interaction and other limitations listed within Annex D of ISO 5349-1.

Conclusion

The investigation concluded that wearable sensors can be useful as an indicator of potential harm to the individual. The research also concluded that the effects of human interaction with the tool on potential risk faced by the operator are not adequately captured by existing methods and that wearable sensors may be useful in addressing this limitation.

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The agreement between subjective and objective estimations of exposure duration among carpenters exposed to hand-arm vibrations

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Keywords:
Vibration measurement; trigger time; exposure dose.

Introduction

To prevent work-related injuries, the Vibration Directive 2002/44/EC states that work with vibrating machine tools shall be risk assessed and the daily exposure dose to hand-arm vibration (HAV) should be compared to limit- and action values [1]. The daily exposure, A(8), is obtained from the vibration magnitude (expressed as frequency-weighted acceleration) which requires measurements of vibrations with technical equipment and the total daily duration of exposure to the vibration from each tool or process being used. A period when a worker has put the machine down or is holding it but not operating it should not be counted. This is called trigger time (TT) and is the time that the hands are exposed to the vibration from the tool or workpiece. TT (hours/day, days, weeks, year) is difficult to estimate, especially long-term or lifetime TTs. Observational, interview and questionnaire-based instruments are the most common methods of choice for estimating TTs. In the current standards, which is the basis for the EU directive, the limit-values are based on estimated user times [2].
A better knowledge of both amplitude and duration will facilitate the understanding of how the use of vibrating hand tool is associated with the onset and development of vibration induced injuries and also how to decrease the future risk.

Specifically, in HAV-studies, TT has been explored among dental personnel, engineering- and maintenance personnel, among workers predominantly working with grinding [3 - 5], and in a more extensive study with many different occupations [6]. Subjective time estimates have been compared with objective measures, showing an overestimation of self-reported TT. Some factors appear to influence the agreement such as the type and duration of the task, continuous versus intermittent task and if the task was composed of subtasks.
We can identify at least two issues/problems concerning TT measurements, which may hamper the estimated exposure dose. First, we are not aware of how much the workers may overestimate or underestimate the TT, and second, we do not know the “real” exposure time, because it is seldom precisely measured.

No study of TT has been conducted among carpenters, who have an intermittent work with different tools and variability in work content over weeks and years. Further, we are not aware of any study that instead of using observation of worker as the golden standard, uses a technical measurement system equipped to the machines. The objective of this study was to evaluate whether TT can be measured accurately with a machine activated automated measuring system (AMS) compared to observations and subjective estimates for calculation of the daily exposure, A(8).

Methods

The study was carried out at three construction companies in southern Sweden. Measurements were conducted on carpenters installing interiors for kitchen and bathrooms (three persons during four workdays) and on carpenters doing demolition work (two persons during one workday). In total six full-day measurements, see table 1.

Table 1: Full day measurements

Measure-ment	Task	Operator	Work day
1	Interiors	A	I
2	Interiors	A	II
3	Interiors	B	III
4	Demolition	C	IV
5	Demolition	D	IV
6	Interiors	E	V

TT was assessed using three methods; by a questionnaire, by direct observations and by AMS. The questionnaire was handed out to all participants by the end of the workday. The carpenters were asked to list the tools that they had been using during the day and to try to estimate the total TT for each of the tools. Observations were made for all workdays. The tool use was observed and the TT for each tool was recorded using a stopwatch. A retooled AMS originally intended for garden tools was used to measure TT automatically. Each machine was equipped with a sensor that detects the engines speed and thus when the machine was turned on. Each operator carried a personal logger that registered his machine usage by triangulation of closeness between logger and sensor. The recorded data was then transmitted to a cloud service for online accessibility. Vibration measurements on the tools was carried out in accordance with ISO 5349-1 [2]. The exposure dose for an 8 h-working day, A(8), was calculated using the three different time estimates.

Results

As can be seen in Figure 1 the carpenter's estimated trigger time (ETT) always exceeded both the observed trigger time (OTT) and the measured trigger time (MTT). There was a good compliance between MTT and OTT (Figure 2).

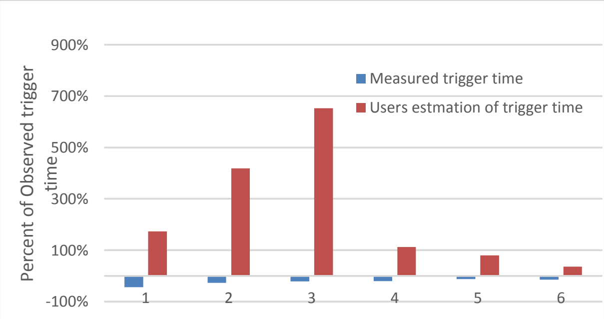

Figure 1. The sum of measured and estimated trigger time as a percentage of observed trigger time for each workday

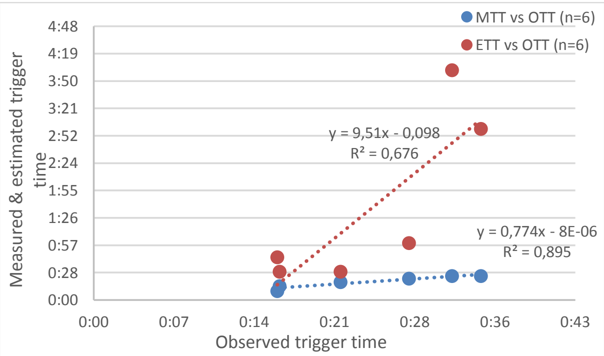

Figure 2. Measured and estimated trigger times vs corresponding observed trigger times.

Table 2 shows the A(8)-value per person and workday, calculated using MTT, OTT and ETT. There is an up to third-fold overestimation of the A(8)-value depending on which TT measure method chosen. On average A(8)-value based on ETT exceeds OTT-based 1,9 times while MTT-based A(8)-value is 10 % below OTT-based.

Table 2: Exposure dose value, A(8), with different time estimates and ratio between MTT, OTT and ETT.

Measu-rement	A(8) [m/s²] MTT	OTT	ETT	A(8) MTT /OTT	A(8) ETT /OTT
1	0,09	0,12	0,24	0,75	2,0
2	0,72	0,79	1,9	0,91	2,4
3	0,67	0,66	2,2	1,0	3,3
4	1,4	1,7	2,4	0,82	1,4
5	1,4	1,4	1,9	1,0	1,4
6	0,94	0,98	1,1	0,96	1,1
	Mean:			**0,9**	**1,9**

Discussion

On average the overestimation of the A(8)-value based on ETT is 2 folded compared to OTT, also seen previously in the literature. The level of overestimation is probably largely due to personal time perception.

The machine activated AMS, MTT, A(8)-values proved to correspond well with the observations. The 10 % underestimation compared to OTT is most likely because of human error and the difficulties of writing down time exactly, especially with intermittent tasks. There are some minor problems with the AMS that can occur if two operators come near each other. In some cases, the logger had trouble keeping them apart. Nor does the AMS measure the vibration level but it can be added to the online system.

While the current limit-values are based on subjective estimates of the trigger time it will no longer be suitable if MTT are used for risk-assessments, since the risks will be underestimated

Conclusion

The machine activated AMS proved to be a reliable and time-saving way to determine trigger-time when using hand-operated machine-tools and on par with trigger-times from observed trigger times. Estimated trigger-times proved to give highly varied results and on average overestimated the exposure dose two-fold.

In a future where machine activated AMS can be assumed to be standard the current limit-values for vibration must be revised.

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Correlation between Finger Dexterity and Vibration Transmissibility while Wearing Anti-Vibration Gloves

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Abstract

This study is aimed to explore correlation between finger dexterity and vibration isolation performance of anti-vibration (AV) gloves. The effects of AV gloves on finger dexterity were evaluated using ASTM F2010 standard test. The vibration isolation performance was subsequently measured following the ISO 10819 standard. Two different weightings (W_h and W_p) were applied to evaluate the hand-transmitted vibration (HTV) at the palm and fingers. Fifteen male subjects participated in both the tests with nine different AV gloves and one conventional glove. Regression analysis of the palm vibration transmissibility and dexterity scores showed poor correlation. Correlations between the index and middle finger vibration transmission and dexterity scores were also weak with coefficients of determination (R^2) of 0.43 and 0.32, respectively. The results suggest that dexterity performance of AV gloves is dependent on glove design factors such as thickness and bulkiness. AV-gloves can be designed to preserve finger dexterity, which is likely to promote their usage.

Keywords:

Anti-vibration gloves; Finger dexterity; Vibration transmissibility

Introduction

Continued exposure to hand-transmitted vibration (HTV) arising from hand-held power tools has been associated with an array of disorders of the hand-arm system. Various designs of AV gloves have evolved to effectively reduce HTV exposure. AV gloves, however, adversely affect operators' grip strength and job precision due to loss of manual dexterity [1,2]. The operators may thus be reluctant to wear such gloves, especially while working with hand-held power tools in conjunction with other manual tasks. Although vibration performance of AV gloves has been extensively studied, their manual dexterity is attempted in a single recent study [1]. It is shown that manual dexterity performance of gloves decreases nearly linearly with increase in glove thickness. Moreover, finger dexterity performance of a glove is strongly influenced by many other design factors such as fitting and bulkiness. Design of AV gloves with adequate dexterity and vibration attenuation is vital for promoting their usage.

In this study, the finger dexterity and vibration transmission performance of 10 different gloves, including a conventional glove, are measured using standardized test methods with fifteen subjects. The correlation between the finger dexterity and vibration transmissibility of gloves is explored via linear regression analysis. The results showed a weak correlation between finger dexterity and vibration isolation performance of AV gloves. The design factors affecting finger dexterity were further explored. A design guidance for AV gloves is formulated to achieve good vibration isolation, while preserving good finger dexterity.

Methods

The finger dexterity and vibration transmissibility performance of 10 different gloves were measured in two different experiments. Fifteen male subjects participated in both the experiments with hand sizes ranging from 8 to 10. The selected gloves included: five AV gloves with gel materials, denoted as gel1,.., gel5; two gloves with air pockets material, denoted as air1 and air2; one hybrid glove with air pocket material in palm region and gel in the fingers regions, denoted as hybrid; one rubber glove, denoted as rubber; and one fabric glove, denoted as fabric.

The ASTM F2010 [3] test method was used to evaluate fine thumb and index finger dexterity of the dominant hand. In this method, the subject is required to pick and place 25 steel pins, one by one, in holes on a pegboard (Fig. 1) following a defined sequence. The experiment involved a total of 11 hand treatments (bare-hand and 10 gloves) and the order of measurements with different gloves was randomized. Measurements with each subject-glove combination involved multiple trials until the coefficient of variation in completion time of the last three trials was less than 8%. The manual dexterity score (MS) of a glove was computed as the mean completion time (T_g) normalized with respect to the bare-hand completion time (T_b), such that:

$$\mathrm{MS} = \frac{T_g}{T_b} \quad (1)$$

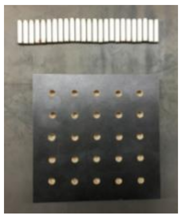

Figure 1: ASTM F2010 test apparatus

The second experiment involved measurements of palm and finger vibration transmissibility using methods described in [2,4]. Measurements were performed with 15 subjects and same 11 hand treatments. The index and middle fingers' vibration responses were measured using miniature three-axis accelerometers mounted on Velcro adapters, tightly positioned on middle phalanges of the fingers. Measurements with each glove-subject combination were repeated three times, and mean palm and fingers' vibration transmissibility values were obtained for the medium (M: 25~200 Hz) and high (H: 200~1250 Hz) spectra using respectively the W_h and W_p frequency weightings. Resulting vibration transmissibility at the palm and fingers were further normalized by those obtained with the bare-hand.

Results and Discussions

Figure 2 illustrates dexterity score, and palm and finger vibration transmissibility (TR) of the gloves for the M spectrum. The results show manual dexterity score of all the gloves in excess of unity value, which suggests that all the gloves reduce finger dexterity. The rubber and fabric gloves exhibit the best dexterity (lowest scores), but do not meet the AV acceptance criterion. The air1 shows worst dexterity (highest score) followed by gel1 and gel3 gloves. All the AV gloves, with exception of rubber, gel1, gel3 and gel4, satisfy the palm vibration acceptance criteria for the M- and H-spectra. Although the hybrid design meets the AV acceptance criteria, it doe not meet the material uniformity requirement.

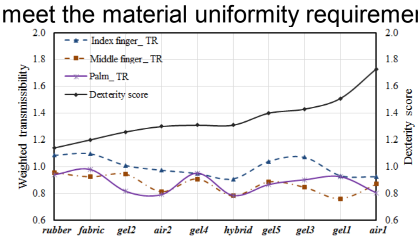

Figure 2: Manual dexterity score, and W_h-weighted palm and W_p-weighted fingers vibration transmissibility of gloves for the M-spectrum

The index and middle fingers' vibration responses of the bare-hand showed comparable peak magnitudes of 1.69 and 1.76, respectively, corresponding to the frequencies of 123.8 Hz and 212.5 Hz. These are comparable with those reported in [2]. Among the AV gloves, rubber, gel2, gel3 and gel5 showed amplification of handle vibration transmitted to the index finger, while all the gloves revealed slight reduction in middle finger vibration.

Linear regression analysis were performed to study correlations between mean dexterity scores and M- and H-spectra fingers vibration transmissibility ratios (TR) of the gloves. Results showed the absence of correlation of dexterity with H-spectrum TR, and a weak correlation with M-spectrum TR values (Fig. 3). Determination coefficients (R^2) of dexterity and M-spectrum index and middle finger transmissibility were 0.43 and 0.32, respectively. Similar R^2 values were also obtained for unweighted and W_h-weighted fingers TR values. Hybrid glove was excluded, since it does not meet AV glove definition of ISO 10819. Results suggest that there is no strong correlation between finger dexterity and vibration isolation of AV gloves, although a negative trend is evident.

A strong positive correlation was observed between dexterity score and glove thickness in the fingers region. Relatively thin rubber and fabric gloves showed best dexterity, although these do not satisfy the AV criterion. The 7.2mm thick air1 glove revealed worst dexterity (1.73) but satisfactory AV performance. The 6.7mm thick air2 glove, on the other hand, showed better dexterity (1.3) and AV performance comparable with air1. The gel2, air2 and hybrid gloves with comparable thickness (5.7~6.6mm) showed satisfactory AV performance with better finger dexterity (1.26-1.31). These gloves used soft leather covering with a lesser width of the fingers sections leading to relatively tight fitting. Poor dexterity of air1 glove was attributed to its bulky design with highly stiff cowhide leather covering and wide fingers sections. These suggest that AV performance of a glove at finger section is not dependent on material thickness, while the dexterity performance is related to many other factors apart from the thickness. Anti-vibration gloves with proper fitness and minimal protrusions beyond fingertips, greater flexibility in the dorsum, soft covering materials with non-slip texture, and optimal material thickness in fingers region can provide improved dexterity.

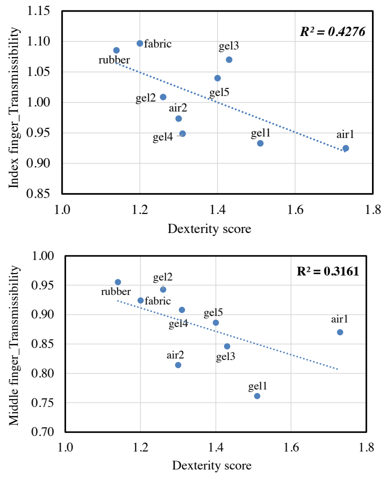

Figure 3: Correlation between dexterity and W_p-weighted vibration fingers transmissibility: (a) index; (b) middle

Conclusions

The study revealed a weak correlation between finger dexterity, and index and middle fingers vibration transmissibility of AV gloves. AV glove designs with adequate fitting and minimal protrusions and greater flexibility in the dorsum can provide good dexterity and anti-vibration performance. Such a design will help promote usage of AV gloves in the workplace.

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An Evaluation of Experimental Methods for Measuring the Vibration Transmissibility of Vibration-Reducing Gloves at or on the Fingers

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Introduction

The effectiveness of a vibration-reducing (VR) glove for attenuating the vibration transmitted to the human fingers is usually assessed through the measurement of the glove vibration transmissibility. The methods used for this measurement can be broadly classified into two categories: to-the-finger methods and on-the-finger methods. With to-the-finger methods, the vibration at the glove-finger interface and that on a tool handle or a handheld workpiece are simultaneously measured to determine the glove transmissibility at the fingers. Finger-held adapters have been developed and used to measure the interface vibration [1,2]. With on-the-finger methods, the vibrations on the dorsal surface of a finger with and without wearing a glove are separately measured to estimate the glove transmissibility [3]. The objectives of this study are to enhance the understanding of these two methods, and to identify their major advantages, limitations, and pitfalls, which are important for their selection and appropriate application.

Methods

Six subjects participated in this study. As shown in Fig. 1, the experiment was conducted on a 1-D hand-arm vibration test system suitable for the standard glove vibration test [4]. An instrumented handle fixed on the shaker of the test system was used to deliver and measure the vibration input to the fingers along with the applied grip force. Each subject was instructed to grip the handle at a pre-determined force level with a posture shown in Fig. 1. The test treatments included four hand conditions (bare hand, wearing one of three gloves: gel-filled VR glove, air bubble glove, and ordinary work glove), and three locations on the fingers (distal, intermediate, and proximal phalanges). For the measurement on the intermediate phalange, three grip forces (15 N, 30 N, and 50 N) were used to examine the force effect. At the other two measuring locations, only one grip force (30 N) was used. For the to-the-finger method, a newly developed two-fingers-held adapter was used to measure the vibration at the glove-finger interface [1]. The glove transmissibility was directly determined by taking the ratio of the vibration measured with the adapter and the instrumented handle. For the on-the-finger method, together with the instrumented handle, a 1-D laser vibrometer was used to measure the vibration transmissibility on the dorsal surface of the fingers, as also shown in Fig. 1. Then, the glove transmissibility was estimated by taking the ratio of the transmissibility data for the gloved and ungloved fingers.

Each tested glove was slit on the sides between middle and ring fingers of the glove to insert the finger adapter at the measurement locations, and holes were cut in the glove finger's dorsal surfaces to allow laser measurements at the skin surfaces of the fingers at similar locations on the middle and index fingers. For each test treatment, two series of tests were performed.

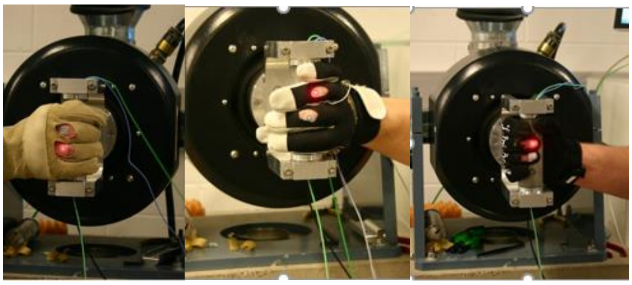

Fig. 1. Experimental setup with three measurement locations

In the first series of tests, the finger adapter and the laser vibrometer were used to simultaneously measure the vibrations at the interface and on the fingers, respectively. The glove transmissibility directly measured by the to-the-finger method and estimated by the on-the-finger method were compared. In the second series of tests, only the laser vibrometer was used to measure the vibration on the fingers. The results were compared with those measured in the first series of tests to identify the effect of the finger adapter on the finger vibration.

Results

As an example, Fig. 2 shows the vibration transmissibility spectra simultaneously measured with the adapter and the laser vibrometer in the first series of tests. The transmissibility spectra measured at the interface with the adapter for both bare hand and ordinary work glove were near unity in the entire frequency range of concern. The transmissibility spectra measured on the dorsal surface of the fingers for these two hand conditions exhibited a major peak corresponding to the resonant frequency of the fingers at their intermediate phalanges (160 to 200 Hz). The major peak frequency was 80 Hz for Glove 3 and 100 Hz for Glove 2. These resonant frequencies were also consistent with those of the adapter-measured transmissibility spectra when these two gloves were used. The other basic trends were also similar to those measured on the fingers using the laser vibrometer.

As another example, Fig. 3 shows the laser-measured transmissibility spectra at the intermediate phalange from the first series of tests with the presence of the finger adapter (A) and the second series of tests without the finger adapter (L). They were generally very consistent, which suggests that the finger adapter did not substantially change the vibration of the fingers.

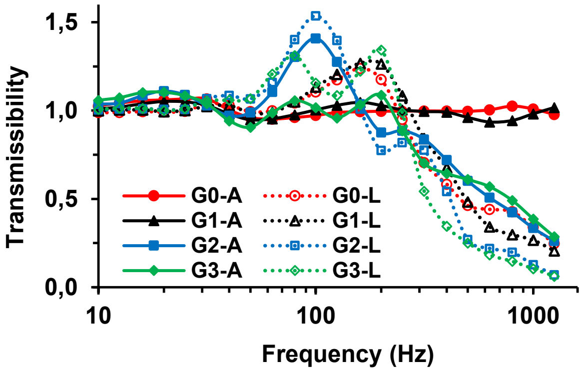

Fig. 2. Averaged transmissibility spectra mesured using adpter method (A) and Laser method (L) at the intermediate phalange of six subjects, each applied 30 N grip force under four hand conditions: bare hand (G0), ordinary work glove (G1), gel glove (G2), and air bubble glove (G3).

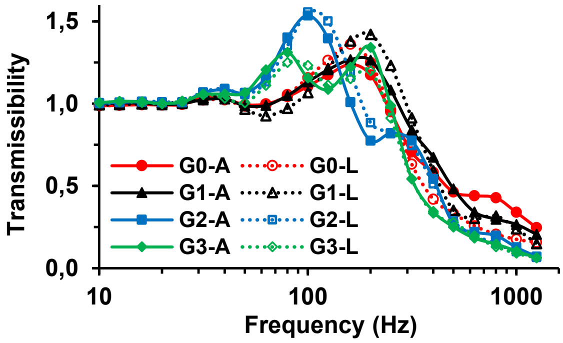

Fig. 3. Six subject averaged vibration transmissibility measured by 1-D laser with applied finger adapter (A) at the glove/finger interface and without the finger adapter (L).

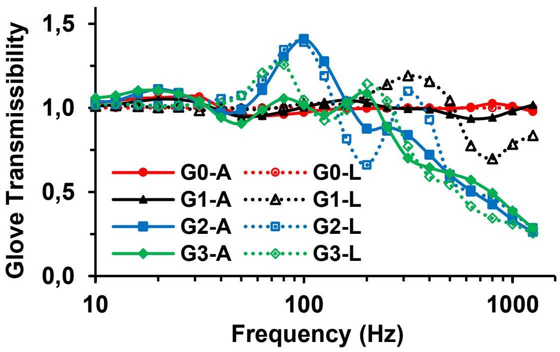

Fig. 4. Glove transmissibility measured directly by finger adapter (A) and estimated with laser measurements (L).

Fig. 4 displays the transmissibility spectra of the gloves measured using the to-the-finger method or the finger adapter method (A), together with those estimated using the on-the-finger method or from the laser measurements (L). Their basic trends and characteristics are similar, except that the spectra estimated with the on-the-finger method showed more fluctuations at frequencies above 160 Hz.

Discussion

Besides the desired cushioning function, a glove may also affect the grip force, grip dimension, finger orientations, contact pressure distribution, and interface friction coefficient. These additional glove effects may directly or indirectly affect the biodynamic properties of the hand-arm system. They should not substantially influence the to-the-finger methods because the vibrations input to and through the glove primarily required to determine the glove transmissibility are simultaneously measured, and any change in the biodynamic properties can be automatically taken into account in the measurement. However, the glove-induced changes in the biodynamic properties may significantly affect the results of the on-the-finger methods, because the vibrations required to estimate the glove transmissibility are separately measured with and without glove use. The results shown in Figs. 3 and 4 suggest that if these additional glove effects are eliminated or minimized, the results from these two methods are similar, which is consistent with the reported theoretical prediction [5].

Theoretically, the on-the-finger methods may provide a more thorough assessment of VR glove effectiveness than the to-the-finger methods, because the on-the-finger methods can take into account all the glove effects in the assessment. However, some of the additional glove effects may introduce artificial errors in the assessment. For example, the glove-induced change in the grip size may largely alter the finger orientation around the handle, which may make the vibration responses of the gloved and ungloved fingers not comparable, especially on a 1-D vibration test system. Furthermore, this method may not be reliable for estimating the high-frequency glove transmissibility. As shown in Fig. 4, the transmissibility at such frequencies is low. Any measurement uncertainty may result in large errors in the estimated transmissibility. These observations may partially explain the large differences among the reported glove finger transmissibility data [1-3].

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Evaluating the Effectiveness of Vibration-Reducing Gloves for Attenuating Finger Vibration from Angle Grinders.

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Abstract

The objective of this study is to explore whether vibration-reducing (VR) gloves can effectively reduce the finger vibration exposure of workers operating angular grinders. Two angle grinders with different motor frequencies while free running and cutting into an iron disc were considered in the experiment. The evaluation was performed using 3 different vibration reducing gloves. The vibration at the finger-glove interface was measured using an adapter equipped with a 3D accelerometer[1], which was placed at the distal phalanx of ring and long finger. The result of the evaluation is highly dependent on the grinder motor speed, work task performed and the use of weighting curves. When applying the finger weighting only the thickest and heaviest vibration reducing glove could achieve attenuation at the fingers for the small and fast angle grinder. In other finger weighted trials in this study the attenuation of the high frequencies could not compensate for the resonance and high glove transmission values around the motor frequency.

Keywords:

Handarm vibration; Vibration reducing glove; weighting curves; Angle grinder

Introduction

All hand held vibrating tools have their acceleration values spread in a frequency spectrum, typically a peak at or close to motor frequency and a gradually increasing acceleration starting around 400-500Hz and above. Accelerations at high frequencies are usually strongly correlated with the work task.

Translation of unweighted acceleration into an approximation of expected human injury is done by applying different weighting curves. Unweighted accelerations have an upper and lower cut off limit. In this test, 2 different frequency weighting curves have been used. The ISO 5349 standard is used to calculate the weighted average acceleration[2]. The ISO weighting emphasizes the low frequencies that corresponds well to resonance frequencies in the wrist and arm. NIOSH/HELD provided a weighting curve that is more closely in line with resonance of the fingers.

The objective of this study is to explore whether vibration-reducing gloves can effectively reduce the finger vibration exposure of workers operating angular grinders.

Methods

Two angle grinders with high and low motor rpm were selected, both with different disc sizes but approximately same speed at the edge of the disc.

Table 1. Angle grinder information

	Angle grinder small – Makita	Angle grinder big – Ryobi
Model	GA5030R	EAG2000RS
Nominal rated speed	11 000 rpm	6000 rpm
Net weight	1,8 kg	6,0 kg
Power	Electric, cable	Electric, cable

Acceleration at the side handle of the angle grinder was measured by attaching a small 3D accelerometer with a hose clamp. Gloved finger acceleration was measured at distal phalanx of ring and middle finger. The small 3D accelerometer was glued to a special designed small and flat plastic pin. The plastic pin was placed between glove padding and finger through punched holes in the glove side between the ring and middle finger distal phalanx.

Five operators with hand sizes between 8 and 11 have been operating the angle grinders. The operators stood upright with the angle grinders side handle vertically while gently cutting into a 10kg disc of cast iron. Operators were trained to deliver a contact force of approx. 10N. A time period of 15 seconds with a high degree of consistency was selected and analyzed.

The three selected vibration reducing gloves had a neoprene closed cell foam padding at palm side of fingers with “Eureka Impact Vibration Amplitude” being thickest and “Eureka 15-1 Transient Vibration” being thinnest.

The 3D acceleration data from the measurements have been aggregated into 1/3 octave bands and presented per frequency band and weighted by the standard ISO 5349 or by the “finger weighting” curve from NIOSH/HELD.

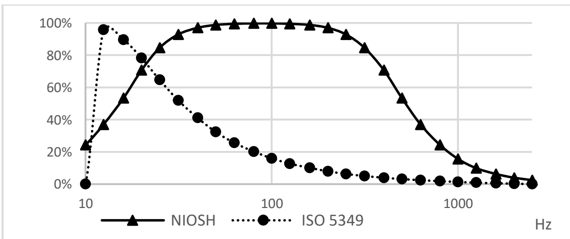

Figure 1. Applied frequency weighting curves

The measurements on the handle of the grinders were taken approximately 5cm apart from the location of the finger measurements. The difference in acceleration between these locations has not been compensated for in this study.

Results

The acceleration over the frequency spectrum was influenced whether the grinder was running free or when the operator was cutting into the cast iron disc. The cutting caused significant vibrations at frequencies above 400 Hz as well a minor reduction and widening the peak at the motor frequency.

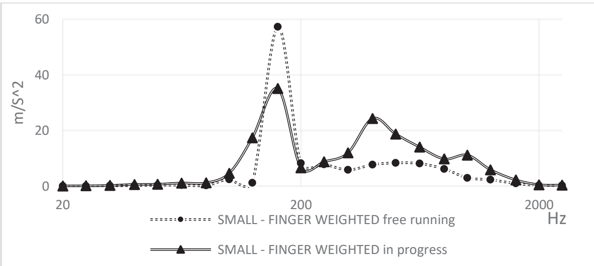

Figure 2. The small angle grinder acceleration spectrum free running and in progress of cutting cast iron

The frequency weighting also had a very big influence on the acceleration spectrum, this is visualized in figure2.

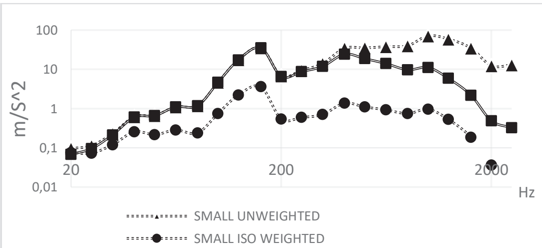

Figure 3. The small angle grinder acceleration spectrum in progress of cutting iron. Unweighted, ISO 5349 weighting and NIOSH/HELD finger weighting.

Table 2. Acceleration for each task and grinder by weighting method

	Unweighted acc. 12,5-1250Hz (m/s^2)	ISO 5349 weighted acc. (m/s^2)	Finger weighted acc. (m/s^2)
Small grinder free	77,0	6,0	60,9
Small grinder cutting	126,3	5,1	56,1
Big grinder free	154,3	10,5	85,3
Big grinder cutting	220,1	9,3	82,8

There were significant differences between the heavy grinder and the smaller faster grinder. The difference in motor frequency is shown clearly as the first peak in figure 4. The larger grinder surprisingly showed higher accelerations at higher frequencies too.

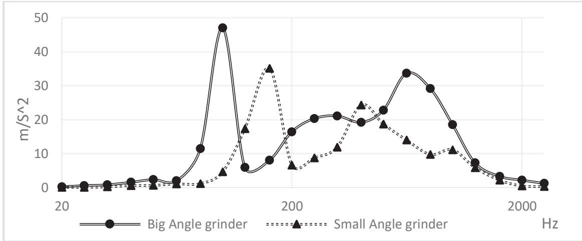

Figure 4. The NIOSH finger weighting acceleration spectrum for the angle grinders cutting iron.

The finger transmissibility was measured while cutting iron with the small grinder. Calculated transmission values at low frequencies where the tool acceleration is low are more uncertain as well as at very high frequencies that are prone to resonance is small substructures. To counter the uncertainties transmission values at frequencies below 20Hz has been neglected.

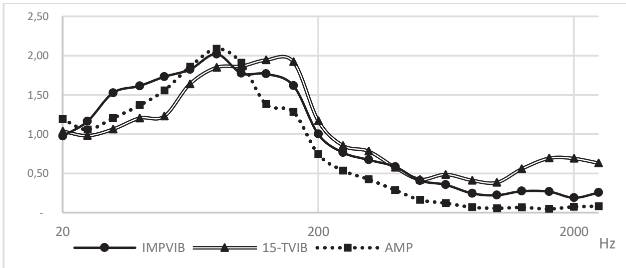

Figure 5. Glove finger transmissibility using 3 different vibration reducing gloves while cutting iron with the small grinder.

The application of different weighting curves provide different average transmission for each glove and weighting curve.

Table 3. Small grinder cutting iron, fingertip transmission values per glove, grinder and weighting method

Small angle grinder cutting	IMP VIB AMP	IMP VIB	15-1 TVIB
T(Unweighted 20-1250Hz)	0,41	0,57	0,80
T(Finger weighted)	0,91	1,07	1,46
T(ISO 5349)	1,15	1,37	1,69

Discussion

Measurements in the study were taken at distal phalanx rather than middle, while the NIOSH/HELD weighting curve for the entire finger was used. This is expected to increase the reported transmission values in the report.

The weighted vibration exposure from angle grinders is highly dependent on the grinder motor speed, work task performed and the selection of frequency weighting curve.

Weighting curves that emphasize vibrations at higher frequencies will yield a lower finger transmission for the VR gloves. The exposures and transmissions based on ISO 5349 gives a substantially different result and conclusion compared to the NIOSH/HELD finger weighting curve.

The use of finger measurements and associated weighting curve could be used as complement to traditional methods for on site evaluation of tools and VR gloves under different working conditions.

Conclusion

In this study only the most extreme vibration reducing glove (Imp Vib Amp) could achieve attenuation at the fingers for the small and fast angle grinder. The other gloves could not compensate for the resonance and high transmission values around the motor frequency despite the attenuation at high frequencies.

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Predicting the Occurrence of Vibration-Induced White Finger Using ISO Technical Report 18570:2017

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Introduction

A recent technical report published by the International Organization for Standardization has proposed an alternative frequency weighting to acount for the relative hazard posed by vibration coupled to the hand at different frequencies [1]. The supplementary frequency weighting, termed W_p, is distinguished from the frequency weighting in ISO 5349-1:2001, W_h [2], by the increase in weight given to frequencies above 20 Hz, as can be seen from Figure 1.

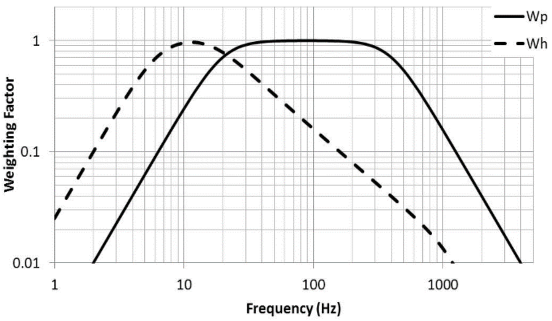

Figure1: Frequency weightings W_p and W_h

W_p is based on a meta-analysis of epidemiologic studies conducted by Tominaga [3], a model for predicting the absorption of energy in components of the hand-arm system [4], and a model for comparing health risks for pairs of population groups with similar health outcomes resulting from operating power tools with markedly different acceleration spectra [5].

The ISO report contains an annex that includes an estimate for the least daily exposures at which vibration-induced white finger (VWF) may be expected to develop when assessed using W_p. The purpose of this paper is to derive the exposure thresholds proposed in ISO/TR 18570:2017 and suggest their precision.

Methods

The three studies used to derive W_p employed different methods for estimating the hazard posed by vibration at different frequencies yet produced similar results. However, only the study that considered pairs of population groups lends itself to estimating the *minimum* exposure necessary for the onset of white fingers [5].

To compare health risks for population groups operating power tools or machines with markedly different acceleration spectra, studies had to be identified in which: 1) each population group operated near-daily a single type of power tool or machine throughout the workday, and: 2) the groups experienced similar prevalence and latency of VWF. These requirements imposed severe restrictions on the epidemiologic studies that could be included in the analysis. Two studies so identified involved exposures close to the threshold for the onset of VWF, that is, the prevalence of finger blanching was only marginally above that believed to be representative of a control group of persons performing similar work but not exposed to vibration. The characteristics of the two population groups are summarized in Table 1, where N is the number of exposed persons, P(%) is the reported prevalence, a_{hw} is the measured dominant single-axis, root-mean-square (r.m.s.) acceleration on the handle, frequency weighted according to ISO 5349-1:2001 (i.e., by W_h), and T is the reported daily exposure duration. The exposure data in Table 1 are for postmen who travelled comparatively short distances delivering mail on motorcycles, and for gas workers who operated pavement breakers. As the latter have been reported elsewhere to develop white fingers [6], the least time using pavement breakers in the original study is listed as it is considered closest to that applicable to an exposure threshold for VWF [7].

Confidence that the exposures were close to the threshold for the onset of VWF results, in part, from the population groups possessing large numbers of exposed persons. For example, it has been estimated for groups of ~400 exposed persons that a difference in prevalence of 0.1% could be detected with 95% confidence [5].

Frequency spectra for these machines are only available for the dominant single-axis accelerations. An estimate for the exposure threshold applicable to multi-axis accelerations can be obtained by applying the ratio a_{hv} / a_{hw}, where a_{hv} is the vibration total value. Values of the ratio when both a_{hv} and a_{hw} are frequency weighted by W_h can be obtained from the United Kingdom Health and Safety Executive database containing 917 types of vibrating power tools and machines [8].

Table 1: Data for pavement breakers in the gas industry and postmen riding motorcycles with almost the same prevalence of VWF as controls [5]

Population Group	N	P(%) Exposed	P(%) Controls	a_{hw} (ms^{-2})	T (h)
Pavement Breakers	895	9.6	9.5	17.9	0.5
Motorcycles	8773	1.9	0.9 - 1.7	2.1	3.1

Results

ISO/TR 18570:2017 recommends that the potential for developing VWF be assessed by the daily vibration exposure, $E_{p,d}$, which is dependent on the r.m.s. acceleration coupled to the hand and the square root of the duration of exposure. Procedures are also provided for calculating $E_{p,d}$ when different power tools and machines are used during a workday.

An estimate for the least daily exposure at which finger blanching may be expected to occur can be obtained from the experiences of the population groups in Table 1 when the dominant single-axis accelerations are weighted by W_p. The values of the daily vibration exposure are then:

For pavement breakers: $E_{p,d}$ = 1150 $ms^{-1.5}$, and:

For motorcycles: $E_{p,d}$ = 1140 $ms^{-1.5}$.

As expected from the analysis that resulted in the selection of the population groups in Table 1, the values of $E_{p,d}$ are essentially the same and define an exposure threshold (e.g., $E_{p,d(min)}$ = 1150 $ms^{-1.5}$). This daily exposure for the onset of finger blanching is applicable to situations in which it is not possible to obtain vibration total values, and exposures have to be constructed from dominant single-axis accelerations.

The corresponding daily exposure when vibration is measured in three coordinate axes may be estimated using a_{hv} / a_{hw}. Values of the ratio when both a_{hv} and a_{hw} are frequency weighted by W_h, as values of the ratio calculated using W_p are not available, yields for the 5 and 95 percentiles [8]:

$$1.04 \leq a_{hv} / a_{hw} \leq 1.53 \qquad (1)$$

Applying the upper value of this ratio to the exposure threshold for single-axis accelerations leads to estimated thresholds for the onset of VWF for daily exposures constructed from single- and multi-axis accelerations:

$$E_{p,d(min)} = (1150 - 1750)\ ms^{-1.5} \qquad (2)$$

where accelerations have been weighted by W_p, and values have been rounded to the nearest 50 $ms^{-1.5}$.

Almost all values in equation (2) are expected to apply to exposures evaluated using vibration total values, while only values close to the lower end of the range are expected to apply to exposures evaluated by dominant single-axis accelerations. It should be noted that the estimates are applicable to population groups and not to individuals, who possess unknown susceptibility to developing VWF and usually unknown work practices.

Discussion and Conclusions

In contrast to ISO 5349-1:2001, where a dose-response relationship is proposed that allows for the consequences of any exposure to vibration to be predicted, only a threshold above which finger blanching is predicted to occur is proposed in ISO/TR 18570:2017. Thus, no prediction for the rate of development of VWF at exposures above the threshold is provided.

The derivation of the dominant single-axis threshold is a by-product of the derivation of W_p in [5]. In that analysis, the relative risk of developing VWF by operating one of two power tools or machines was calculated for acceleration frequency spectra in bandwidths that were adjusted by one-third octave bands, which was the resolution of the frequency data. The corresponding resolution in relative risk was ~10%, which, together with the rounding of estimates, are believed to represent the precision of $E_{p,d(min)}$. The accuracy of $E_{p,d(min)}$ will also depend on the full potential of an exposure causing VWF in a population group to have been captured at the time of the epidemiologic study. It will also depend on the accuracy of the vibration exposure measurements, and the accuracy with which W_p expresses the potential for vibration at different frequencies to cause VWF.

The accuracy and precision of thresholds predicted for exposures constructed from multi-axis accelerations will also include uncertainty in the applicability of the upper value for a_{hv} / a_{hw} in equation (1). As it is not expected that the range will differ substantially when calculated using W_p, it is believed this uncertainty will be contained within the uncertainties already identified. Hence the (rounded) overall precision of the lower value in equation (2) is estimated to be ± 150 $ms^{-1.5}$, and the precision of the upper value is estimated to be ± 200 $ms^{-1.5}$.

It is beyond the scope of this paper to apply the exposure thresholds to arbitrary vibration-exposed populations. It is noted, however, that application of ISO/TR 18570:2017 to two population groups experiencing either near-continuous vibration during the workday (from chain saws and brush saws) or repeated shocks as well as near-continuous vibration (from air hammers, grinders and polishers) found that the observed occurrence of VWF was consistent with that predicted by equation (2) for multi-axis accelerations [9].

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International Consensus Criteria for Diagnosing and Staging Hand-Arm Vibration Syndrome

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Keywords: Hand-arm vibration syndrome; HAVS; Delphi method; classification; staging; diagnosis

Introduction

It has been 30 years since the Stockholm Workshop Scale (SWS) was published for the classification of hand-arm vibration syndrome (HAVS) [1,2]. Since then concern has been expressed about its use of subjective terms; the combination of frequency of attacks with extent of blanching and the variable ways in which a loss of sensory perception or tactile discrimination are being determined and interpreted.

Methods

Seven clinically active experts who have had papers published on HAVS in the last 10 years took part in a four round Delphi method to improve the diagnosis and classification of HAVS. Experts were asked to provide evidence from the literature or data from research to support their opinions. CJMP acted as a facilitator but took no part in voting. Consensus was set as 5/7 (72%) of experts in agreement. After each round the experts were given the group's results and in the light of this could change their opinion about an issue. To answer some of the questions, existing data were re-analysed to ascertain the relationship between frequency and extent of blanching; for the selection of sensory modalities for testing and to determine limit values.

Results

Consensus was achieved on most of the questions put to experts from four countries. The frequency and extent of blanching were found to be weakly correlated (rho = 0.42 dominant and 0.31 non-dominant hands) with no particular pattern on a scatter plot. The use of a blanching score from photographs taken during vasospastic attacks was recommended in place of self-recall and frequency. Thermal and vibration perception tests and Semmes-Weinstein monofilaments (SWM) were thought to have the best evidence base for determining sensory perception in digits. Limit values for SWM and the Purdue pegboard test in heavy manual workers not exposed to vibration were determined. The following classification was arrived at by consensus:

HAVS Vascular Component

ICC Stage	Description
0V	No attacks of blanching
1V	Digit blanching score 1-4
2V	Digit blanching score 5-12
3V	Digit blanching score>12

HAVS Neurological Component

ICC Stage	Description
0N	No numbness or tingling of digits
1N	Intermittent numbness and /or tingling of digits
2N	As in stage 1 but with sensory perception loss in two or more digits as evidenced by two or more validated methods such as monofilaments, thermal aesthesiometry and vibrotactile thresholds
3N	As in stage 2 but with symptoms of impaired dexterity and objective evidence of impaired dexterity by the Purdue pegboard test

Discussion

It is recommended that photographs are used to confirm that blanching of the digits is of the Raynaud type and for calculating a blanching score. No test could be recommended to reliably distinguish primary Raynaud's phenomenon from vascular HAVS which is the main vascular differential diagnosis. Caution was expressed about misattributing thick or hard skin, or neuropathy proximal to the hand, to neuropathy in the digits. Tactile discrimination was dropped from the scale as there is no standardised method for measuring it and no comparative normative data to determine limit values. It is recommended that dexterity is determined by the Purdue pegboard test, which is a well validated technique with normative data. Consensus could not be achieved on how blanching of the digits with an abnormal Allen's test should be investigated. Neither could consensus be obtained as to whether an occluded artery in the hand should affect vascular staging because of uncertainty over whether its cause was likely to be congenital or acquired.

Conclusion

We recommend that this new and more objective classification replaces the SWS for the clinico-pathological staging of HAVS [3].

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Requirements for PPE in the European Union

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Abstract

The requirements for PPE in the European Union layed down by European regulations and directives are presented.

Keywords:

Personal protetive equipment, anti-vibration gloves

Introduction

The European "REGULATION (EU) 2016/425 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 9 March 2016 on personal protective equipment" [1] lays down requirements for the design and manufacture of personal protective equipment (PPE) which is to be made available on the European market, in order to ensure protection of the health and safety of users and establish rules on the free movement of PPE in the European Union ([1], Article 1). In addition the European Council Directive 89/656/EEC [2] lays down minimum requirements for personal protective equipment (PPE) used by workers at work. This Directive is addressed to employers who have to select PPE, provide PPE to their employees and may have to perform maintenance measures on PPE.

Methods

Article 4 of [1] specifies, that PPE shall only be made available on the European market if, where properly maintained and used for its intended purpose, it complies with the Regulation [1] and does not endanger the health or safety of persons, domestic animals or property. Article 3 "Definitions "of [1] explains: " 'making available on the market' means any supply of PPE for distribution or use on the Union market in the course of a commercial activity, whether in return for payment or free of charge". Article 5 of [1] requires: "PPE shall meet the essential health and safety requirements (EHSR) set out in Annex II which apply to it." For anti-vibrations gloves EHSR 3.1.3 "Mechanical vibration" of Annex II, [1] applies: "PPE designed to prevent the effects of mechanical vibrations must be capable of ensuring adequate attenuation of harmful vibration components for the part of the body at risk."

The 'New Approach' developed in 1985 restricted the content of legislation to 'essential requirements' leaving the technical details to European 'harmonised standards'. This in turn led to the development of European standardisation policy to support this legislation. 'Harmonised standard' means a European standard adopted on the basis of a request made by the European Commission for the application of European Union harmonisation legislation [3].

Article 14 of [1] specifies that "PPE which is in conformity with harmonised standards or parts thereof the references of which have been published in the Official Journal of the European Union shall be presumed to be in conformity with the EHSR set out in Annex II covered by those standards or parts thereof." On 15th of June 2018 'EN ISO 10819:2013, Mechanical vibration and shock — Hand-arm vibration — Measurement and evaluation of the vibration transmissibility of gloves at the palm of the hand (ISO 10819:2013)' was published in the Official Journal of the European Union [4].

Instead of harmonised standards 'technical specification' may be used which means a document that prescribes technical requirements to be fulfilled by PPE. In these cases the manufacturer does not benefit from the presumption of conformity, but has to demonstrate the conformity himself. This implies that he demonstrates, in the technical file of a relevant product, in a more detailed manner how the technical specifications he uses provide conformity with the EHSR.

The 'New Legislative Framework' [5], which was adopted in July 2008 and built on the New Approach, completed the overall legislative framework with all the necessary elements for effective conformity assessment, accreditation and market surveillance including the control of products from outside the Union.

Annex I of [1] specifies three categories of risk against which PPE is intended to protect users. [6] states that "all PPE designed and manufactured to protect the wearer against vibrations" are PPE to protect against a risk of category 2.
For PPE to protect against risks of category 2 Article 19 of [1] requires to carry out the EU type-examination (module B) set out in Annex V of [1]. The EU type-examination is the part of a conformity assessment procedure in which a notified body examines the technical design of PPE through examination of the technical documentation, plus examination of a specimen, representative of the production envisaged, of the complete PPE (production type). The notified body verifies and attests that the technical design of the PPE meets the requirements of the Regulation [1] that apply to it (Annex V of [1], 1. and 2.).

For notification a conformity assessment body shall submit an application to the notifying authority of the Member State in which it is established (article 27 of [1]).

The EU Member State's notifying authority may notify to the EU Commission only conformity assessment bodies which have satisfied the requirements laid down in Article 24 of [1] (article 28 of [1]). In case notification procedures were successfully completed the conformity assessment body notified is listed in the NANDO databank of "Notified Bodies":

http://ec.europa.eu/growth/tools-databases/nando/index.cfm?fuseaction=directive.notifiedbody&dir_id=155501

Only PPE which fulfills the requirements of [1] are allowed to be placed and to be made availble on the EU market. For anti-vibration gloves this means that amongst others a declaration of conformity, an EU-type examination certificate issued by a notified body, an user information accompanying each product in the language specified by the Member State where it will be offered shall be available and a CE marking shall be affixed to each PPE.

Obligations of economic operators, Notified Bodies, notifying authorities, market surveillance authorities, Member States and the EU Commissions are specified in [1].

Requirements on the use of PPE at workplaces are specified in an European Directive [2]; i.e. that EU Member States may lay down stricter requirements for the use of PPE at workplaces in their Member State.

Results

Use of standards developped by standardisation bodies provides the possibility to all stakeholders to participate in the process of specifying technical details for the application of European Union harmonisation legislation. The reference numbers of standards which are adopted within specified EU procedures are published in the Official Journal of the European Union. Only those 'hamonised standards' provide a presumption of conformity with the EHSR of [1] specified in the standard's Annex 'ZA'. Using harmonised standards is the easier way of two alternatives to demonstrate conformity with the essential requirements of [1]. As specified in [1] Notified Bodies are required to participate or at least be aware of relevant standardisation activities and the activities of the notified body coordination group (called "Horizontal Committee of Notified Bodies – PPE") established under Article 36 [1] and shall apply as general guidance the administrative decisions and documents produced as a result of the work of that group. These decisisons and documents (called "Recommendations of Use - RfUs") are published on the PPE-Website of the EU Commission: http://ec.europa.eu/growth/sectors/mechanical-engineering/personal-protective-equipment/ .

The requirements for manufacturers and Notified Bodies specified by EU product regulations and directives such as [1] may consolidate users' confidence in products and manufacturers' confidence in the EU market. Minimum requirements which are applied to all products and Notified Bodies being indipendent third parties guarantee fair competition. Because only one request for development of a standard to become a harmonised standrad can be made by the European Commission only one standard may provide presumtion of conformity. This ensures the predictibility of legal decissions.

Discussion

The procedures required for placing and making available of products on the EU market aim at having available only save products in the EU. For the enforcement market surveillance bodies of the EU Member States monitor and may block making available products on the EU market. Information concerning dangerous products found on EU/EEA markets by national authorities are send to the European Commission by PAPEX (Rapid Exchange of Information System) and ICSMS (Information and Communication System on Market Surveillance). Public information on dangerous products are available via: https://ec.europa.eu/growth/single-market/goods/building-blocks/icsms_en . ICSMS may be used by users/consumers to notify dangerous products to national authorities responsible.

Conclusion

The free movement of PPE within the EU market is enabled by the Regulation (EU) 2016/425 [1]; all EU Member States apply the same rules on PPE as specified by [1]. Limit exposure levels and PPE performance levels required for specific exposure levels may differ from Member State to Member State because they may tighten requirements refering to the selection and use of PPE at workplaces specified by EU directives.

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Encouraging the use of vibration efficient tools – a regulatory perspective

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Abstract

The declaration of powered hand tool vibration has been based on the use of Harmonised standards for the testing of vibration magnitudes. This has resulted in the production of data which, while useful for ensuring measurement repeatability and reproducibility, is not necessarily representative of the vibration of the tool in use. Research has demonstrated that some harmonised standards under predict typical in use vibration magnitudes while others over predict. The HSE has also seen an increase in the use of third party consultancy services to provide companies with in-use data of their power tools. However when this data is scrutinised it is often found that the test procedures were not representative of the actual tool usage. With hand-arm vibration becoming a well know industrial risk, many tool manufacturers have responded by producing a new generation of tools which are either significantly more efficient, thereby limiting the duration of use, or incorporate vibration reduction technologies. With tool users incorrectly focusing their concerns on measurement and monitoring these developments in tooling, improvements in processes and technique have been missed. The HSE therefore wants to re-focus tool users attention on finding vibration efficient tools. This paper will detail the proposed method the HSE hopes to adopt to help identify and promote vibration efficient tools and provide a methodology for the assessment and inclusion of vibration efficient tools within the possible scheme.

Introduction

In 2016 Hand-Arm Vibration Syndrome (HAVS) accounted for 46% of all ill-health RIDDOR Reports in Great Britain. The Noise and Vibration team at HSE is keen to see industry activity that could help reduce this figure. One way that has been identified to address this issue is to provide an open discussion forum for tool suppliers and tool users. It is hoped that this could lead to cross industry work within the UK which could develop a method of more easily identifying vibration efficient tools.

The two key reasons the HSE wishes to develop a vibration efficient tools scheme are:

1. Obtaining suitable in use vibration magnitude data is key to shifting duty holder focus onto control
2. Shifting focus on to control (so knowing what vibration efficient tools and practices look like is imperative)

Background

Where the use of power-tools cannot be avoided, choosing vibration efficient power-tools is one of the most effective ways of reducing operator hand-arm vibration exposures. These lower vibration or higher efficiency tools will be described as “vibration efficient tools”. It is also clear from discussions with HSE across industry that power-tool manufacturers would like to make known their vibration efficient products and employers would like to purchase those vibration efficient products. This is in response to the improvements made in standard power tool design, the development of new power systems (e.g. battery) and the increasing range of entirely new tools entering the market.

A workshop was held in February 2018 at HSE Buxton to explore support for development of a self-funding scheme that publicises the in use vibration magnitudes of specific makes and models of powered hand-tool and especially those that have demonstrably lower in use vibration magnitudes than those suggested as a recommended initial value on HSE’s website. The workshop was an opportunity for tool manufacturers, tool suppliers and tool users to discuss the problem of hand-arm vibration exposure. The key outcomes of the workshop were as follows;

1. Industry would be interested in an HSE approval mark that allows vibration efficient tools to be identified
2. Promotion of the scheme should be clearly identified as HSE approved (web link/logo)
3. Focus on correct tool selection should be accompanied with suitable processes and adequate training

A scheme that could potentially meet these criteria is being developed and is outlined in this paper for discussion.

Promoting Vibration Efficient Tools - Proposal

The following is an outline of how a registration scheme could work.

PROPOSAL - HSE are looking for partners to develop an independently hosted portal or website that is freely accessible to all. The portal or website must reinforce the HSE message of elimination, substitution and control of hand-arm vibration. Therefore, there is an interest in identifying;

- Processes which eliminate the need for vibrating tools to be used.

- Alternative Tools which can achieve the same result without exposing the user to vibration.
- Lower vibration tools
- Highly efficient vibrating tools

Any scheme that is produced should aim to:
- Provide advice and information to help with hand-arm vibration risk assessment and control.
- Promote alternatives working practices which limit exposure to hand-arm vibration.
- Act as a shopfront for choosing the best performing vibration efficient power tools.
- Provide advice on best operating practice for different power tool types.

The portal or website might be established by an independent host and reached by direct link from the HSE website or from any partner website.

PARTNERS - To achieve a suitable outcome the HSE need partners to work with us to develop content material and information including:
- Details of alternative processes to those involving vibration exposure where available.
- Information on best practice use of different power tool types.
- Identification of those power tools that are amongst the lowest in the category in terms of vibration magnitude or total vibration exposure by task.
- Identification of consumables which provide lower levels of vibration or which make tasks quicker.
- Advisory training or good practice information that the end user can access.

APPROACH - HSE believes that the best way to deal with the vast array of information will be to divide the work by industry group. We therefore propose to run three pilot schemes in industries where there are significant numbers of HAVS cases reported each year. Within each area, we propose to investigate a small number of power tool types. The proposed industries and power tools are:
- Construction and Utilities - Trench rammers, plate compactors, breakers, cut-off saws
- Horticulture - Mowers, strimmers, brush cutters, chainsaws, hedge trimmers
- Motor Vehicle Repair – Pneumatic chisels/zip guns, sanders, polishers, angle grinders, reciprocating saws.

In addition to these key industries and tools we also anticipate that alternative tooling for the tasks most closely associated with these industries would also be assessed.

VALIDATON – The second function of the scheme will be to determine how best to validate the acceptability of:
- Existing tool data that could contribute to evaluation of any tool or process.
- New tool data gathered in support of the validation of a tool or process.
- Comparison of vibration exposures between common processes and tools and newer processes and tools.

The potential means of achieving the validation process, and which are open for discussion are as follows:

- A directorate is set up, with approval from HSE, whose purpose is to assess and validate data supplied by stakeholders. Once validated this tool data can be promoted as vibration efficient tools and carry an **approval mark**
- The data would be approved via an online web-portal linked to the HSE (as per the Sound Solutions Model). This web-portal will host the information and allow for links to tool manufactures sites
- Users of the site will select the tool type that they are interested in. The in use vibration magnitude data will be displayed as will a selection of credible alternative tools. The most vibration efficient options will appear at the top of any list
- Alternative methods of working will be validated by the directorate and where possible can also carry an **approval mark**
- Information such as the most suitable consumable and links to training content on how to use the tools will be provided when a user selects a tool
- Validity of suitable consumables or training content would be undertaken by the Directorate and also carry the **approval mark**
- Where updated models of existing vibration efficient tools are brought to the market the approval mark can be transferred to the updated product assuming the changes do not substantially change the in use vibration magnitude of the tool
- There is an agreed validation method for the consumables and training information
- HSE will retain the right to review the continuation of the scheme on a 5 year cycle An executive board would provide internal oversight and would be made up of regulators, tool suppliers and tool users

Conclusion

The full scope of the scheme is yet to be determined but there is a clear desire to improve tool users understanding of how they can limit their exposure to hand-arm vibration through the careful selection of processes, tools and consumables. Correct training is also seen as a key element of the overall hand-arm vibration control process.

The overall aim is to move companies who expose their workers to hand-arm vibration away from their focus on measurement and monitoring and towards actively looking for opportunities to reduce vibration exposure. Having an industry agreed methodology and approval scheme to identify vibration efficient tools is expected to be the most credible way for tool manufactuerers to demonstrate that their products are vibration efficient. As the scheme will only focus on vibration efficient tools industry should not be burdened with having to develop testing and approval for all tools.

Methods for estimating vibration exposure without measurement

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Abstract (optional)

According to the European Physical Agents Directive (vibration) 2002/44/EC, employers are required to estimate the daily exposure of employees exposed to hand arm or whole body vibration. This communication reports different simple methods for helping employers to comply with the law.

Keywords:
vibration exposure, database

Introduction

The methods for estimating vibration exposure described in this communication are based on the requirements and guidance given in ISO 2631 or EN ISO 5349 but instead of measuring the vibration magnitudes at the specific workplaces, these methods use existing vibration values from other sources of information such as:

a) Those provided by the manufacturers of the machinery according to the requirements of the Machinery Directive 2006/42/EC. They are known as the manufacturer's declared vibration emission.
b) Those provided by public data bases on vibration immission measured at workplace.

Methods

a) CEN TC231 has elaborated a technical report (TR 15350) which specifies guideline for the assessment of exposure to hand-transmitted vibration using available information including that provided by manufacturers of machinery. It gives guidance on how to estimate the exposure duration and the daily vibration exposure as defined in EN ISO 5349-1. It also offers a simple method for estimating the daily vibration exposure by means of a table which indicates the vibration exposure as a function of the equivalent vibration total value and the associated exposure duration. Both methods can be used even in cases of multiple exposures on the same day.
b) Depending on their content, vibration date bases are dedicated to research, risk assessment, market surveillance, compensation cases and performance of seat suspension systems … A new technical report is being prepared within CEN TC231 to define the basic requirements for quality databases. There are different ways to use these data. Thus in Italy and Spain employers have a direct access to national data bases. They can read vibration magnitude obtained under real conditions on tools or mobile machines similar to those they are using. In France two applications named OSEV were developed respectively to cover whole body and hand arm vibration. For a given family of mobile machines or tools, the users will be asked the way he is using the machines and the daily duration of exposure. The application will propose him an estimation of A(8) value calculated from statistics based on all vibration measurements obtained for this family at work.

Results

Both CEN technical reports are presently circulating for national votes and should be published within a year.

Today they are half a dozen public databases on hand-arm and whole-body vibration in Germany, Italy, Spain, Sweden…

OSEV “corps entier” and OSEV “main bras” are on INRS web site under excel format.

Discussion

Confidence in the data is based on the qualification of the measurers, the quality procedure follows, the number of measurements done for each machine, the measurement protocol, the representativeness of the operator using the machine. The source of data should be clearly identified.

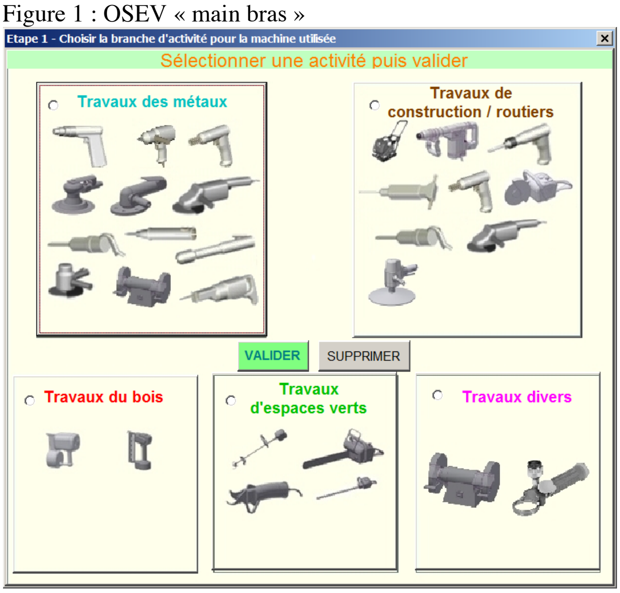
It is why annexes of TR 15350 explains limits for the use of the vibration declaration when estimating the vibration magnitude. This is also the reason why the technical report on data base provides a method for classifying the quality of vibration data and lists precautions to take.

Conclusion

Vibration values deduced from these simple methods are only estimations. When exposure are over legal values, it is recommanded to make vibration measurements especially when actions to reduce the vibration magnitude are carried out as recommended by the European Directive (vibration) 2002/44/EC.

Figure 1: OSEV

Figure 1 : OSEV « main bras »



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[3] http://www.inrs.fr/media.html?refINRS=outil59 “OSEVmainbras_ A simplified tool for the assessment of hand arm vibration”

[4] http://www.inrs.fr/media.html?refINRS=outil39 “OSEVCE_ A simplified tool for the assessment of whole body vibration”

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Can we prevent HAVS by using Declared Vibration Emission Value ?

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Abstract

This study reports the results of an investigation into A(8) based on tool vibration values and the effects of hand-transmitted vibration on temporary threshold shifts of vibratory sensation on the finger. The results suggest that the A(8) method based on tool declared values of vibration in accordance with ISO 5349-1 and ISO 28927 series does not readily predict the TTS of a group of individuals after hand-transmitted vibration exposure with different working postures.

Keywords:

Hand-transmitted vibration, Tool Vibration Declaration Value, Manufactuered's Tool Emission Data

Introduction

In July 2002 the European Union published the Directive 2002/44/EC the Physical Agents (Vibration) Directive (PA(V)D) [1]. It outlines new guidelines for exposure to vibration in the workplace. It sets action and limit values for vibration exposure and it describes the employer's obligations to manage the risk from exposure to vibration. This directive is intended as a guide for the employer who has employees using vibrating hand-held power tools and gives practical tips regarding what can be done to reduce vibration exposure from hand-held power tools. The Physical Agents (Vibration) Directive was developed from an original proposal made by the European Commission in 1993. This proposal was revised, amended and eventually agreed by Member States and the European Parliament and came into force on 6 July 2002. The Directive lays down the minimum standards for the health and safety of workers exposed to hand-arm vibration and supports the general requirements for improving health and safety that are outlined in the Framework Directive (2006/42/EC) [2]. For prevention of the industrial disease HAVS, the consideration of A(8) is introduced as a risk assessment method. The A(8) is a combination of the vibration magnitude (calculated as a frequency-weighted r.m.s. of acceleration) and the daily Exposure Times. In the work places, the managers of the vibration tool users must consider the risk of the tool works to the employers before real works according to the consideration of A(8). So, the managers need the vibration magnitude of the individual tool which is appropriate for the use of the tool in the way it will be used by the tool operator. As a consequence of the EU Directive, the manufacturers have to declare the magnitude of the individual tool according to the test protocols (ISO 28927 series)[3]. This purpose of the test protocols was intended that the results be used to compare different models of the same type of machine. However due to the difficulties in carrying out a measurement of vibration magnitude to the accepted standards in the actual work place, employers are estimating workplace risk by calculating A(8) with the estimated work time and tool manufacturer's declared emission value based on the test protocols of ISO 28927 series.

Figure 1. Test Protocol of ISO 28927-5 standard.

As shown in Figure 1, the tool manufacturer's declared emission value is obtained based on highly controlled laboratory conditions. In the worksite, employers are using this value for evaluating the A(8) for the purpose of preventing the development of HAVS within their workforce. In this evaluation, the employers are using the one value from the test protocol result. However, in the real work site, many tool workers are using tools with different kind of tool usages as shown in Figure 2.

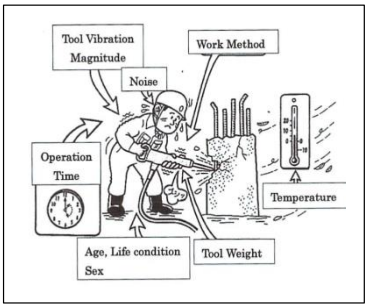


Figure 2. Factors likely to influence the effects of human exposure the hand-transmitted vibration in the working conditions of Annex D of the ISO 5349-1 standard.

It is not clear whether the tool manufacturer's declared emission value based on standards such as ISO 28927 series are appropriate to be used to evaluate the vibration exposure in the real worksite, given the many factors which impact the tools' hand transmitted vibration.

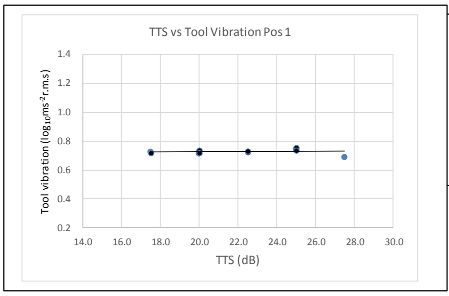
Therefore, in the present study, an experiment was designed to assess whether a Tool's Vibration Declared Values determined using tool vibration measurement standards can assess the risk from the real tool work vibration exposure.

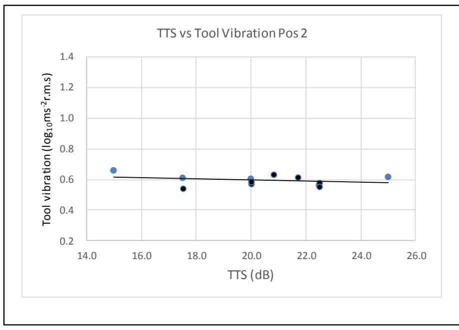
Methods

To study the TTS in fingertip vibratory sensation, the vibratory sensation threshold was measured before and after subjects (male n=12) were exposed to hand-transmitted vibration. The experiment was carried out in a sound-proof room. The room temperature was held at approximately 22℃. Vibration was applied to the right hand through a handle of the electric tool. Three working postures were considered to reflect working practice. These included (1) vertical downwards (single handed) which the same posture of the test protocol of ISO 28927-5 standard, (2) horizontal (tool held in front of subject with both hands) and (3) vertically upwards (overhead, single handed). All subjects performed separate tests with each of the nine possible combinations of tool and posture configuration. The subjects were instructed to clasp the handle tightly and constantly with part of the palm and fingers with a real grip force in the appointed posture. The exposure time was 2 minutes. The threshold of 125 Hz vibratory sensation was measured at the index finger of the right hand. Vibration thresholds were determined with the vibrotactile sensation meter (RION type AU-02A). Vibrotactile thresholds were determined by the method of adjustment. In this method, the measurement was performed three times. Thresholds were calculated by the mean values of three measurements obtained less than 30 seconds after the end of the vibration exposure. The TTS was defined as the difference (in decibels) of the vibrotactile thresholds before and after vibration exposure.

Results

The Figure 3 shows the results the relationship between TTS and the vibration magnitude on the tool handle of each subject when using the same impact drill with different postures. The tool vibration magnitude is in accordance with the tool test protocol such as ISO 28927-5 for a horizontal posture. From this Figure 3, although the TTS value of each subject is changing, the vibration magnitude is constant. Previous research has identified a strong linear correlation between vibration magnitude and TTS. From these evidences, on the Figure 3, when the TTS value is increasing, the hand transmitted vibration might be increasing. However, the tool vibration magnitude shows little change. From these results, although the tool vibration magnitude is the same, the TTS is increasing. This means that the hand transmitted vibration magnitude is increasing. So, the tool vibration declared value is not suited for the risk assessment for the workers





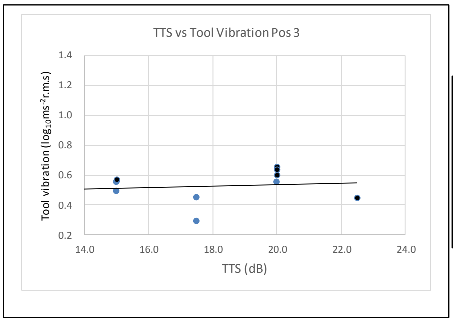


Figure 3. *Results the relationship between TTS and the vibration magnitude on the tool handle of each subject.*

Discussion

From this experiment, although many countries are using the tool vibration declared values based on the ISO 28927 series for the prupose of preventing HAVS, it is clear that the values from the test protocol are not appropriate for all factors in the real work conditions. Also, from the results of Figure 3, the ISO 5349-1 vibration measurement on the tool handle has similar limitations.

Conclusion

Many countries are using the tool vibration declared values based on the ISO 28927 series or following ISO5349 for preventing HAVS. It is clear that the values from these test protocols do not consider all factors in real work conditions. These results indicate that a new evaluation method or equipment is needed to provide a more realistic and practical assessment of HAV exposure. It seems unrealistic to consider HAVS prevention without more realistic assessments. For many years, the factors outlined within Annex D of ISO 5349-1 have not been adequately captured when making an assessment of hand-transmitted vibration exposure for the purposes of prevention of HAVS in real work environments. A desire by employers to adhere strictly to the ISO 5349-1 standard may be contributing to inaccurate dose assessments and inferior outcomes for the worker.

References

[1] EU Directive. 2002/44/EC.

[2] EU Directive. 2006/42/EC.

[3] ISO 29827 Series.

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