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National Hazard Exposure Worker Surveillance:

Vibration exposure and the provision of vibration control measures in Australian workplaces

June 2010

National Hazard Exposure Worker Surveillance – Exposure to vibration and the provision of vibration control measures in Australian workplaces

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Foreword

The Australian Safety and Compensation Council (ASCC) (now Safe Work Australia) requested the development and fielding of the National Hazard Exposure Worker Surveillance (NHEWS) Survey in 2008 to determine the current nature and extent of Australian workers' exposure to selected occupational disease causing hazards. The survey also collected information from workers about the controls that were provided to eliminate or reduce these hazards. The results from the NHEWS survey will be used to develop estimates of where workplace exposures exist that may contribute to the onset of one or more of the priority occupational diseases. These are; occupational cancer, respiratory diseases, noise induced hearing loss, musculoskeletal disorders, mental disorders, cardiovascular disease, infectious and parasitic diseases and contact dermatitis.

The NHEWS survey was developed by the ASCC in collaboration with Australian occupational health and safety regulators and a panel of experts. These included Dr Tim Driscoll, Associate Professor Anthony LaMontagne, Associate Professor Wendy Macdonald, Dr Rosemary Nixon, Professor Malcolm Sim and Dr Warwick Williams. The NHEWS survey was the first national survey on exposure to workplace hazards in Australia.

In 2008, Sweeney Research was commissioned to conduct the NHEWS survey using computer assisted telephone interviews (CATI). The data they collected from 4500 workers forms a nationally representative data set of occupational exposures across all seventeen Australian industries. The survey was conducted in two stages. The first stage (n=1900) focussed on the five national priority industries: *Manufacturing*, *Transport and storage*, *Construction*, *Health and community services* and *Agriculture, forestry and fishing*. The second stage (n = 2600) placed no restrictions on industry.

An initial report on the results of the NHEWS survey can be found on the Safe Work Australia website[1]. It contains a descriptive overview of the prevalence of exposure to all the occupational hazards within industries and the provision of the various hazard control measures.

This report focuses on the exposure of Australian workers to vibration and the control measures that are provided in workplaces that eliminate, reduce or control worker exposure to vibration. The aims of this report are threefold. The first aim is to describe patterns of exposure to vibration in conjunction with patterns of vibration control provisions with respect to industry, occupation and other relevant demographic and employment variables. The second aim is to make recommendations, where possible, for the development of work health and safety and workers compensation policy. The final aim of this report is to provide researchers in this field with clear and constructive directions for future research.

[1] http://www.safeworkaustralia.gov.au/swa/AboutUs/Publications/2008ResearchReports.htm

Contents

Glossary

ACGIH	American Conference of Governmental Industrial Hygienists
AMSRS	Australian Market and Social Research Society
ASCC	Australian Safety and Compensation Council
CATI	Computer Assisted Telephone Interviews
EU	European Union
EWCS	European Working Conditions Surveys
NHEWS	National Hazard Exposure Worker Surveillance
OSHA	Occupational Safety and Health Administration
PPE	Personal Protective Equipment
TLV	Threshold Limit Value
TOOCS	Type of Occurrence Classification System

Summary

Occupational exposure to hazardous levels of vibration is associated with a range of adverse health outcomes, including vibration white finger, carpal tunnel syndrome, musculoskeletal disorders and neurological disorders. In 2008, the National Hazard Exposure Worker Surveillance (NHEWS) survey gathered self reported data on the exposure of Australian workers to vibration and, for workers who reported exposure to vibration, data on the provision of control measures for vibration in the workplace. The purpose of this survey was to identify the workers who are at risk from adverse vibration related health effects. This will inform policy and potential regulation development and enable better targeting of work health and safety information, awareness and education campaigns relating to occupational exposure to vibration. It is hoped that these initiatives will lead to a decline and, ultimately, the elimination of occupational vibration related injury or disease.

This report describes the demographic and employment characteristics of the workers who reported they were exposed to vibration in the workplace. In addition, the report describes the employment and vibration exposure characteristics that affected the provision of vibration control measures in exposed workers' workplaces. The analyses in this report focus on the five national priority industries: *Manufacturing, Transport and storage, Construction, Agriculture, forestry and fishing,* and *Health and community services*.

It was beyond the scope of the NHEWS survey and this research to measure the actual exposures of workers to vibration in the workplace. Therefore, it is important to note that data contained in this report cannot be used to assess the risk the reported exposures to vibration pose for workers' health, or whether or not the control measures provided in the workplace were appropriate for the vibration exposures involved.

Summary of the main findings of the report

- Approximately 24% of Australian workers were exposed to vibration in their workplace.
- Young workers were more likely to report vibration exposure than older workers.
- The industries where workers had the highest likelihood of reporting exposure to vibration were *Agriculture, forestry and fishing*, *Transport and storage* and *Construction*.
- The occupations in which workers had the highest likelihood of reporting exposure to vibration were *Machinery operators and drivers, Technicians and trades workers* and *Labourers.*
- 43% of vibration-exposed workers were exposed to hand-arm vibration only, 38% were exposed to whole body vibration only and 17% were exposed to both hand-arm and whole body vibration.
- 41% of vibration-exposed workers reported they were exposed for up to a quarter of their time at work, while 21% reported they were exposed for between a quarter and half of their time at work, 15% reported they were exposed for between half and three quarters of their time at work, and 24% reported they were exposed for more than three quarters of their time at work.
- 23% of vibration-exposed workers reported that none of the surveyed control measures were provided in their workplace.
- Only 27% of vibration-exposed workers reported they received training.
- Large percentages of vibration-exposed workers in smaller workplaces reported they were not provided with any vibration control measures.

Main findings

1. Approximately 24% of Australian workers were exposed to vibration in their workplace.
2. Worker gender, age, income, education, occupation and industry affected the likelihood that a worker reported exposure to vibration:
    - Males were more likely than females to report exposure to vibration.
    - Younger workers were more likely to report exposure to vibration than older workers.
    - Workers with lower incomes were more likely to report exposure to vibration than workers with higher incomes.
    - Workers with a trade certificate/TAFE qualifications were more likely to report exposure to vibration than workers with a bachelor's degree or higher.
    - The occupations in which workers had the greatest odds of reporting exposure to vibration were *Machinery operators and drivers, Technicians and trades workers* and *Labourers.*
    - The industries in which workers had the highest likelihood of reporting exposure to vibration were *Agriculture, forestry and fishing, Transport and storage* and *Construction*.
3. Of the workers who reported they were exposed to vibration in the NHEWS survey:
    - 43% were determined to be exposed to only hand-arm vibration
    - 38% were determined to be exposed to only whole body vibration
    - 17% were determined to be exposed to both hand-arm and whole body vibration, and
    - 3% of workers reported exposures where the vibration type could not be determined.
4. Worker gender, age, income, education, workplace size, occupation and industry affected the likelihood that a worker reported exposure to the types (only hand-arm vibration, only whole body vibration or both hand-arm and whole body vibration) of vibration:
    - Males were over three times more likely than females to report they were exposed to both hand-arm and whole body vibration.
    - Generally, younger workers were more likely to report they were exposed to each type of vibration than older workers.
    - Workers in smaller workplaces were more likely to report they were exposed to only hand-arm vibration than workers in the largest workplaces.
    - *Machinery operators and drivers* were over nine times more likely to report they were exposed to only whole body vibration and *Technicians and trades workers* were 47 times more likely to report they were exposed to only hand-arm vibration than *Clerical and administrative workers* and *Sales workers*.
    - Workers in the *Agricultural, forestry and fishing industry* were over eight times more likely to report they were exposed to both hand-arm and

whole body vibration than workers in the *Health and community services* industry.

5. Of the workers who reported the duration they were exposed to vibration:
    - 41% of workers reported they were exposed for up to a quarter of their time at work
    - 21% of workers reported they were exposed for between a quarter and half of their time at work
    - 15% of workers reported they were exposed for between half and three quarters of their time at work, and
    - 24% of workers reported they were exposed for more than three quarters of their time at work.
6. The duration of exposure to vibration was associated with industry, workplace size, income, type of exposure, occupation and education:
    - Workers in the *Transport and storage* industry were most likely to report they were exposed to vibration for more than three quarters of their time at work, while workers in the *Health and community services* industry were most likely to report they were exposed for up to a quarter of their time at work.
    - *Machinery operators and drivers* were most likely to report they were exposed to vibration for more than three quarters of their time at work, while *Professionals* were most likely to report they were exposed for up to a quarter of their time at work.
7. Training on how to prevent the health problems associated with vibration appears to be under provided in workplaces:
    - Only 27% of workers who reported they were exposed to vibration also reported receiving training.
    - 18% of workers who reported exposure to vibration in workplaces with less than five employees reported receiving training compared to 41% of workers in larger workplaces (200 or more employees).
    - The *Construction* industry had the largest percentage of exposed workers (30%) who reported that training was provided compared to the other priority industries, while the *Agriculture, fishing and forestry* industry had the lowest percentage of exposed workers (17%) who reported that training was provided.
8. 23% of workers who reported they were exposed to vibration also reported that none of the surveyed control measures were provided in their workplace:
    - Of the industries, the *Health and community services* industry had the greatest percentage (47%) of workers who reported they were not provided with any of the control measures surveyed.
    - *Professionals* and *Community and personal service workers* had the highest percentages of workers who reported they were not provided with any of the control measures surveyed (47% and 44% respectively).
9. Of the workers who reported they were exposed to vibration, 43% reported they were provided with at least one of the following vibration controls; Elimination/substitution, Engineering or Administrative controls, in addition to being provided with Personal protective equipment (PPE). This level of control

provision was classified as *vibration control measures and PPE* and was the most commonly reported level of control provision amongst exposed workers.

10. Worker occupation, industry, workplace size and type of exposure affected the likelihood of particular combinations of vibration control measures being provided in the workplace:

    - Workers in workplaces with fewer than 200 employees were less likely to report they were provided with *vibration control measures and PPE* (as opposed to *no control measures*) than workers in workplaces with 200 or more employees.
    - Workers exposed to only whole body vibration or both hand-arm and whole body vibration, were more likely to report they were provided with *vibration control measures other than PPE* (as opposed to *no control measures*) than workers who reported exposure to only hand-arm vibration.
    - Workers exposed to both hand-arm and whole body vibration were more likely to report they were provided with *vibration control measures and PPE* and *PPE only* (as opposed to *no control measures*) than workers who reported they were exposed to only hand-arm vibration.

Policy implications

1. Currently, none of the jurisdictions in Australia have specific regulations for vibration exposures in workplaces. However vibration is mentioned to varying degrees in their general regulations, codes of practice and guidance material. This is in contrast to the European Union (EU), where a Directive on the minimum health and safety requirements for workers exposed to vibration was introduced in 2002[2]. An investigation about whether or not it would be beneficial for Australia to adopt the minimum health and safety requirements of the EU Directive on vibration in regulations or codes of practice should be undertaken. Furthermore, it should be investigated whether or not plant design standards/regulations should include specific requirements for vibration.
2. Younger workers were more likely to report they were exposed to vibration than older workers but workers' compensation data show that it is older workers who make workers' compensation claims for vibration related injury and disease. This could be due, in part, to the long latency of some vibration related conditions but vibration exposure also causes short latency conditions such as sprains and strains. Further, some cohorts of workers (e.g. young workers) may be suffering adverse health consequences of vibration exposure but, for a variety of reasons, may be unwilling to claim workers' compensation. It is important to reduce the exposure of young workers to vibration and to investigate why workers' compensation claim rates differ between older and younger workers. Exposure to vibration could be reduced in the short term, by raising awareness of the adverse health effects caused by exposure to vibration in younger workers.
3. Smaller workplaces were associated with large percentages of exposed workers reporting they were not provided with any vibration control measures and large percentages of exposed workers reporting they were not provided with training. Small workplaces were also less likely to provide *vibration control measures and*

[2] Member states were required to comply by 6 July 2005. However, a maximum transition period of five years from 6 July 2005 was agreed for non-compliant work equipment provided to workers before 6 July 2007. An additional four years applies to equipment used in the agriculture and forestry sectors.

PPE (as opposed to *no control measures*) than large workplaces. Although more research is required into the actual vibration exposure of all workers and into the factors that affect the provision of vibration controls in all workplaces, this should be undertaken as a priority in smaller workplaces where workers appear to be comparatively less well protected.

4. *Professionals*, *Community and personal service workers*, and *Clerical and administrative workers and Sales workers* occupations, and workers in the *Health and community services* industry each recorded large percentages of exposed workers who reported they were not provided with any vibration control measures in the workplace. Further investigation is required to determine whether or not these workers' exposures to vibration are hazardous and to identify the barriers and enablers to vibration control provision for these workers. In addition, education and awareness campaigns should target these cohorts of workers in order to reduce exposure to vibration hazards.
5. Only 27% of workers' who reported exposure to vibration also reported that training on how to prevent the health problems associated with vibration was provided in their workplace. Greater emphasis should be placed on ensuring training is provided to all workers exposed (or likely to be exposed) to vibration in their workplaces.

Future research considerations

1. Research on the prevalence of exposure to vibration in the workplace that is based on self-reported data must be linked to measurements of actual exposures to vibration to validate the information collected and to determine whether self-reported vibration exposure levels are hazardous.
2. Self-reported data on the provision of vibration control measures should be supplemented with an assessment by a qualified work health and safety worker of the exposure and the adequacy and suitability of the control measures provided and used in the workplace. This would enable researchers to determine whether or not the reported vibration exposures are hazardous.
3. Surveillance research would also benefit from the collection of health status information from vibration-exposed workers. Such information could be used to determine whether or not exposures to vibration are causing or contributing to worker injury or disease.

Introduction

Between 2000-01 and 2007-08, there were approximately 400 workers' compensation claims per year for injuries or illness that resulted from exposure to vibration[3]. These amounted to approximately $61 million in workers' compensation payments over the eight years and had an estimated total economic cost of $48 million annually[4] (Safe Work Australia 2009). Of the workers' compensation claims made over this period, over 70% were classified as 'sprains and strains of joints and adjacent muscles', which are short term injuries. However, many of the adverse health conditions caused by exposure to vibration have long latency periods (Brammer & Taylor 1982). For example, the latency period for the 'blanching' stage of vibration white finger can vary from two to 16 years and the 'numbness' stage from two to 12 years (Brammer & Taylor 1982; Contant 2009). Unfortunately workers' compensation data do not adequately capture health conditions with long latency periods because many of these conditions are multi-factorial in nature and it can be difficult to prove that an occupational exposure caused the adverse health condition. Also, workers who are self-employed are not covered by workers' compensation data and are therefore not included in the workers' compensation database. Self employed workers include many tradespersons, farmers and drivers, which are occupations known to be exposed to high levels of vibration. This is supported by the findings of the European Working Conditions Surveys (EWCS) (Parent-Thirion et al. 2007), which found that self-employed persons reported a higher rate of exposure to vibration than employees (27.1% and 23.9%, respectively). Therefore, it is likely that workers' compensation claims significantly underestimate the prevalence of the adverse health effects related to vibration exposure in the workplace. This highlights the importance of using alternative information sources, in addition to workers' compensation data, for the development of policy and regulations on occupational hazards. One such information source is hazard exposure data.

There are two main types of vibration that workers are exposed to: Hand-arm vibration refers to vibration that is transmitted through the hand-arm system – generally from hand held or guided power tools such as angle grinders, drills, jackhammers and chainsaws. Whole body vibration refers to vibration that is transmitted through the entire body – generally from the floor or a seat. Directive 2002/44/EC of the European Parliament and the Council of the European Union defines the terms as:

> *'hand-arm vibration': the mechanical vibration that, when transmitted to the human hand-arm system, entails risks to the health and safety of workers, in particular vascular, bone or joint, neurological or muscular disorders;*
>
> *'whole-body vibration': the mechanical vibration that, when transmitted to the whole body, entails risks to the health and safety of workers, in particular lower-back morbidity and trauma of the spine.*

There is an extensive body of evidence demonstrating that exposure to these types of vibration can pose substantial risks to worker's health (VIBRISKS 2007). For instance, there are numerous adverse health conditions caused by exposure to

[3] These statistics include all workers' compensation claims, not just 'serious' claims as presented in Safe Work Australia's workers' compensation publications and available in the online statistics (NOSI) on the Safe Work Australia website.

[4] The total economic costs were derived using the same methodology in the Safe Work Australia report titled *The cost of work related injury and illness for Australian employers, workers and the community 2005-06*.

hand-arm vibration (Hagberg 2002; Bovenzi 2005; Griffin 2006a; 2006b). Latency periods for these conditions vary from less than a year to over 10 years of exposure depending on the pattern of exposure, level of vibration, pre-existing conditions and other factors (Griffin 1990). These conditions include:

- ***Vibration-induced white finger:*** A form of Raynaud's disease where the blood vessels and nerves in the hands and fingers are damaged causing blanching, numbness, tingling, pain, loss of grip strength and reduced sensation touch.
- ***Carpal tunnel syndrome:*** A medical condition where the median nerve is compressed at the wrist. Causes pain, tingling, muscle weakness and numbness in the forearm and hand.
- ***Musculoskeletal disorders:*** Bone, joint and soft tissue damage, pain in the hands and arms, and reduced muscular strength.
- ***Neurological disorders:*** Tingling and numbness of the fingers and hands, leading to reduced sensory perception and loss of dexterity.

The combination of these disorders derived from exposure to hand-arm vibration is commonly referred to as hand-arm vibration syndrome (Hagberg 2002; Bovenzi 2005; Griffin 2006b; 2006a).

In relation to whole body vibration, the main adverse health effects are disorders of the lumbar spine and the connected nervous system (Seidel & Heide 1986; Griffin 1990; P. Bernard (editor) 1997; Bovenzi & Hulshof 1999; Griffin 2006b). Other adverse health effects include disorders of the neck and shoulder, the gastrointestinal system, the female reproductive organs, the peripheral veins and the cochleo-vestibular system (Seidel & Heide 1986; Griffin 2006b). However there is weak epidemiological support for health effects caused by exposure to whole body vibration other than those of the lower back (Seidel & Heide 1986; Bovenzi 2005; VIBRISKS 2007).

The development of the symptoms related to the adverse health effects of exposure to vibration depends on factors such as the level of vibration, the duration of exposure, the cumulative exposure to date, environmental conditions, the exposed individual's current health, pattern of exposure, latency periods of disorders, an individual's susceptibility to vibration, other diseases or agents that may be present, grip force (hand-arm), method of tool handling or style of driving vehicles and the posture and body position during exposure (Australian Standards 1988; Bovenzi 2005; Contant 2009).

Vibration standards, regulation, codes of practice and guidance material

Australian Standards has developed exposure standards relating to both whole body and hand-arm vibration. For whole body vibration, Australian Standards has developed *AS 2670.1-2001 – Evaluation of human exposure to whole body vibration*. This standard is identical to the International Standards Organisation *ISO 2631-1:1997, Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration*. For hand-arm vibration, Australian Standards has developed *AS 2763-1988 – Vibration and shock – Hand-transmitted vibration – Guidelines for measurement and assessment of human exposure*. *AS 2763-1988* is aligned with the International Standards Organisation *ISO 5349:1986, Mechanical vibration – Guidelines for the measurement and the assessment of human exposure to hand-transmitted vibration*. These Australian Standards do not define what the safe limits

of exposure to vibration are. However, they provide guidance on how to evaluate exposure to vibration (Australian Standards 1988; 2001).

Unlike in the United Kingdom, where there is a specific regulation for vibration (*The Control of Vibration at Work Regulations* (2005)), in Australia there are no specific vibration regulations in any of the jurisdictions. However, seven jurisdictions (Victoria, New South Wales, Queensland, South Australia, Western Australia, Northern Territory and the Commonwealth) mention vibration within their work health and safety regulations. Within these, vibration is usually mentioned within some definitions, risk management and in some hazardous work. The Commonwealth *Occupational Health and Safety Code of Practice 2008* has a specific section on vibration, which provides guidance for duty holders to meet the duties of care they owe under the Act[5]. Similarly, some jurisdictions mention vibration in Codes of Practice and guidance material[6].

The Commonwealth *Occupational Health and Safety Code of Practice 2008* prescribes a process for controlling the risks of vibration exposure congruent with the hierarchy of controls. It also states that where hazardous vibration has been identified, employers must measure the vibration levels in accordance with the following Australian Standards: *AS.2670.1:2001 – Evaluation of human exposure to whole body vibration* and *AS 2763: 1988 – Vibration and shock – Hand transmitted vibration – guidelines for measurement and assessment of human exposure*. Further, it recommends that employers should regularly monitor and review the exposure levels of workers, assess the control measures in place and undertake regular medical checks of workers.

In Europe, the European Union (EU) Directive states that employers are required to take action to control vibration exposures that exceed a prescribed level of vibration (the action value) and state the maximum vibration exposure (exposure limit) that a worker can be exposed to (Table 1). Exposures above these limits are considered to pose unacceptable risks to worker health.

Table 1 EU daily exposure action values and daily exposure limit values

Average daily vibration exposure A(8) (1)	Hand-arm vibration	Whole body vibration
Action value	$2.5ms^{-2}$	$0.5ms^{-2}$ or $9.1ms^{-1.75}$ (VDV) (2)
Exposure limit	$5ms^{-2}$	$1.15ms^{-2}$ or $21ms^{-1.75}$ (VDV) (2)

(1) Standardised to eight-hour energy equivalent frequency weighted acceleration magnitude
(2) Vibration dose value

Like Australia, the United States of America's Occupational Safety and Health Administration (OSHA) has not developed standards for occupational exposure to vibration (OSHA 2008). However, the American Conference of Governmental Industrial Hygienists (ACGIH) has developed threshold limit values (TLVs) for vibration exposure (Table 2) (ACGIH 2010). The ACGIH is not a policy making organisation and the TLVs they recommend are not enforceable or a form of regulation in America.

[5] Part 5: Vibration *Occupational Health and Safety Code of Practice 2008 (Cwth)*

[6] The Australian Capital Territory mentions vibration in their manual handling code of practice. The Northern Territory has published a paper on whole body vibration. In Queensland vibration is mentioned in the noise code, plant code, sugar industry code of practice and the manual tasks code of practice. In Western Australia guidance material on vibration has been produced by the SafetyLine Institute and in Victoria vibration is mentioned in the code of practice for manual handling.

Table 2 ACGIH Threshold Limit Values

ACGIH TLVs				
Hand-arm vibration (1)		**Whole body vibration** (2) (3)		
Four hours and less than eight hours	$4ms^{-2}$	Eight hours	$0.315ms^{-2}$ (longitudinal direction)	$0.224ms^{-2}$ (transverse direction)
Two hours and less than four hours	$6ms^{-2}$	Four hours	$0.53ms^{-2}$ (longitudinal direction)	$0.355ms^{-2}$ (transverse direction)
One hour and less than two hours	$8ms^{-2}$	One hour	$1.18ms^{-2}$ (longitudinal direction)	$0.85ms^{-2}$ (transverse direction)
Less than one hour	$12ms^{-2}$	16 minutes	$2.12ms^{-2}$ (longitudinal direction)	$1.50ms^{-2}$ (transverse direction)

(1) Frequency weighted
(2) Refers to a frequency range of four to eight Hz for vibration in the longitudinal direction
(3) Refers to a frequency range of one to two Hz for vibration in the transverse direction

Vibration exposure estimates

Estimates of vibration exposure have been developed in Europe through the EWCS (Parent-Thirion et al. 2007). The most recent (4^{th}) EWCS found that 24% of persons interviewed reported exposure to vibration in the workplace. Specific surveys have also been conducted in Britain to obtain this information (Palmer et al. 2000b; 2000a). Palmer et al. 2000a estimated that 20% of men (4.2 million) and 3% of women (667,000), who are of working age, were exposed to hand-arm vibration at work, of which 5.8% of men (1.2 million) and 0.3% of women (44,000), who are of working age, are exposed to levels above the Health and Safety Executive (HSE) suggested action level of $2.8ms^{-2}$ (eight hour equivalent). It should be noted that the action value has since been revised to $2.5ms^{-2}$ in *The Control of Vibration at Work Regulations* (2005). Palmer et al. 2000b estimated that 7.2 million men and 1.8 million women are exposed to whole body vibration, although on 374,000 men and 9000 women were exposed to vibration above equivalent estimated dose of vibration of 15 $ms^{-1.75}$, as set out in the British Standard (*BS 6841:1987*). Although the British study provided estimates of workers exposed above the vibration limits, in reality neither the British nor the EWCS surveys measured actual levels of vibration in the workplace.

In Australia, little is known about the actual vibration exposure levels of Australian workers or which workers (as identified by employment and demographic characteristics) are exposed to vibration. The substantial costs and difficulties involved with collecting such information are major contributing factors to this paucity of information, however modern instrumentation make this more practicable. This lack of information on Australian workers' vibration exposure impinges on the ability of work health and safety organisations to develop policy and target information and awareness campaigns to reduce the incidence of the adverse health effects associated with vibration.

With this in mind, the National Hazard Exposure Workers Surveillance (NHEWS) survey (2008) was developed to improve our knowledge of the exposure of Australian workers to vibration hazards. Survey participants were asked to estimate how long (hours per day or hours per week) they worked with tools, equipment or in vehicles that vibrate. Furthermore, they were asked if particular vibration controls were provided in their workplaces. Unfortunately, it was beyond the scope of the survey to obtain measured exposures to vibration and it is therefore impossible to determine whether or not the reported vibration exposures are hazardous. This would have required the collection of the following additional information (at a minimum); the magnitude of vibration (acceleration), and the frequency of vibration (the number

of times per second the vibrating body moves back and forth). These data require *in situ* measured exposures to vibration.

Although this survey could not assess the health risks associated with the self reported vibration exposures, it is likely that the self-reported sources (i.e. vibrating equipment used) of exposure and therefore the type (hand-arm / whole body) of vibration received are reliable. An assessment of self reported exposures to vibration in Britain found that workers reasonably accurately (97% for hand-arm and 93% for whole body) reported the source of exposure to vibration, although the use of cars in the workplace was substantially over reported (Palmer et al. 2000c). However, it should be noted that this same study found that durations of exposure to hand-arm vibration were systematically overestimated by workers, especially when the exposure was intermittent (Palmer et al. 2000c).

Vibration control measures

A variety of vibration control measures are available that can be implemented in the workplace in order to reduce/eliminate a worker's exposure to vibration. Not all types of vibration control measures are appropriate or suitable for all workplaces. The suitability of a vibration control measure will depend on the characteristics of the vibration exposure (e.g. magnitude of vibration, source of vibration and whether the vibration is intermittent or constant) and the characteristics of the workplace.

In the NHEWS survey, information regarding the provision of control measures for vibration was collected from workers who reported exposure to vibration. Survey participants were asked to specify whether or not their employers provided particular control measures to prevent the health problems associated with vibration[7]. The options were phrased in such a way that participants were not asked whether or not they personally utilised the control measure, but simply whether or not the control measure was provided in their workplace. As such, the data collected are only appropriate for determining the likelihood of a control being provided and not for the use of controls for vibration exposure. Also, because the NHEWS survey did not collect information on the actual vibration levels that workers were exposed to, it is difficult to determine whether or not the control measures provided were appropriate for the exposure concerned.

Research objectives

This research has three main objectives. The first objective is to determine the percentage of Australian workers who were exposed to vibration in their workplace and to determine what employment and demographic characteristics distinguished workers who reported exposure to vibration. The second objective is to determine what employment and vibration exposure characteristics affected the provision of vibration control measures in workplaces where workers reported they were exposed to vibration. The information obtained from the first two research objectives will be used to make recommendations for work health and safety and workers' compensation policy on vibration. It is hoped that these initiatives will, over time, lead to a reduction in the incidence of adverse health conditions associated with vibration exposure.

The third objective of this research is to inform the development and design of future studies of vibration exposure in Australia and elsewhere. While the results of the NHEWS survey have increased our understanding of vibration exposure in Australian workplaces, considerable research in this field is required in order to fill the remaining

[7] See Appendix A for full details of the survey question.

gaps. Recommendations in this report highlight what information is required to further develop our understanding of Australian workers' exposures to vibration.

Overview of the survey methodology

The NHEWS survey collected vibration exposure data from 4500 Australian workers using computer assisted telephone interviews (CATI). Survey participants were asked to estimate the duration (hours per day or hours per week) they were exposed to vibration. Workers who reported they were exposed to vibration were asked what the main vibrating tools, equipment or vehicles were that they used. This information was used to determine the type of vibration exposure (hand-arm and/or whole body) a worker received.

Workers who reported that they were exposed to vibration were also asked about the vibration control measures provided in their workplace. Specifically, they were asked to indicate whether a range of specific vibration control measures, such as gloves, vibration dampeners, vibration absorbing seats, purchasing of products with less vibration, or training on how to prevent the health problems caused by vibration were provided or undertaken in their workplace.

The data collected in the NHEWS survey were analysed using multinomial logistic regression models. These models describe the odds of reporting exposure to vibration and the odds of exposed workers being provided with particular types of vibration control measures with respect to the employment and demographic characteristics of the workers. Only workers in the national priority industries (*Manufacturing, Construction, Transport and storage, Agriculture forestry and fishing* and *Health and community services*) (n = 3033) were included in the multinomial logistic regression models. This was due to small sample sizes in the remaining industries rather than any expectation concerning vibration exposure. Therefore, some industries (e.g. *Mining*) with high vibration exposure have not been included in these analyses. This means that the results of this report do not describe the complete picture of occupational vibration exposure for Australian workers. Future research should endeavour to obtain larger samples of workers in the excluded industries.

With the exception of the estimate of the percentage of Australian workers who are exposed to vibration during the course of their work, the data presented in this report are unweighted and are therefore only representative of the survey sample.

Full details of the survey design, fielding methodology and the data analysis methodology can be found in Appendix A of this report.

Results

This section provides an overview of the main results of the NHEWS survey in relation to vibration exposure and the provision of control measures. Detailed statistical information such as model output, test statistics and *p*-values are presented in Appendix B. All the results presented here are supported by formal statistical analyses and are statistically significant at the 0.05 level. Except where otherwise stated (with 'all workers'), the data presented here pertain only to workers in the five national priority industries; *Manufacturing, Construction, Transport and storage, Agriculture forestry and fishing* and *Health and community services*. A descriptive overview of the results for the remaining industries is published on the Safe Work Australia website[8].

Exposure to vibration in Australian workplaces

The estimates of Australian workers' exposure to vibration were calculated using the data from all survey participants who reported exposure to vibration, irrespective of the length of the exposure. Approximately 30% of the workers surveyed reported they were exposed to vibration in the workplace. However, when the data were weighted to reflect the Australian working population, the data indicated that in 2008, approximately 24% of Australian workers were exposed to vibration in their workplace.

Table 3 shows the breakdown of the types of vibration that workers reported they were exposed to. The type of vibration exposure was determined from information provided by workers on the sources (see below) of their vibration exposure in the survey. Hand-arm vibration was the most common type of vibration reported. Hand-arm only vibration was reported by 43% of workers and a further 17% of workers reported they were exposed to hand-arm and whole body vibration. Whole body vibration only was reported by 38% of the workers who reported exposure to vibration.

Table 3 All Workers: The percentage of workers who reported they were exposed to each type of vibration

Type of vibration	Number of reported cases	Percentage of all workers exposed to vibration
Hand-arm only	578	43%
Whole body only	513	38%
Both hand-arm and whole body	228	17%
Vibration type not determined	39	3%
Total	**1358**	**100%**

Sources of vibration reported by Australian workers

Workers who reported that they were exposed to vibration were asked what the main vibrating tools, equipment or vehicles used were. Worker responses were classified using the Type of Occurrence Classification System (TOOCS) (NOHSC 2002). This classification system was developed to code details of workers' compensation claims.

Table 4 shows that the most commonly reported source of exposure to vibration was *Workshop and worksite tools and equipment* (488 reported instances). *Road transport* (326 reported instances), *Other mobile plant* (190 reported instances), *Conveyors and lifting plant* (166 reported instances), *Cutting, slicing, sawing*

[8] http://www.safeworkaustralia.gov.au/swa/AboutUs/Publications/2008ResearchReports.htm

machinery (161 reported instances) and *Semi-portable plant* (154 reported instances) were also commonly reported sources of exposure to vibration.

Table 4 Sources of vibration exposure (all workers): 2nd and 3rd digit TOOCS classification of agency of injury or disease by the number and percentage of workers who reported exposure to vibration who specified each source of vibration exposure, and the percentage of exposures accounted for by selected 3rd digit agencies within the 2nd digit agency classification.

TOOCS CLASSIFICATION Left aligned are 2nd digit classifications. Right aligned are selected 3rd digit categories within the 2nd digit classification.	Number and percentage of exposed workers who reported exposure to each source of vibration	The percentage of exposures accounted for by 3rd digit agencies within the 2nd digit agency classification
Workshop and worksite tools and equipment (2)	488 (36%)	
Abrasive, planing, cutting powered tools		44%
Electric drills		55%
Industrial guns		14%
Road transport	326 (24%)	
Trucks, semi-trailers, lorries		40%
Cars, station wagons, vans, utilities		53%
Other mobile plant	190 (14%)	
Tractors, agricultural or otherwise		69%
Conveyors and lifting plant	166 (12%)	
Forklifts		75%
Cutting, slicing, sawing machinery (2)	161 (12%)	
Saws		59%
Semi-portable plant	154 (11%)	
Pneumatic tools		73%
Self-propelled plant	106 (8%)	
Non-powered hand tools, appliances and equipment (1)	85 (6%)	
Other plant and machinery	74 (5%)	
Excavators, backhoes, other digging plant		27%
Front-end loaders, log-handling plant, other loading plant		42%
Road rollers compactors		15%
Garden and outdoor equipment	72 (5%)	
Chainsaws		69%
Kitchen and domestic equipment	37 (3%)	
Crushing, pressing, rolling machinery	19 (1%)	
Office and electronic equipment	16 (1%)	
Electrical installation	10 (1%)	
Other powered equipment, tools and appliances	10 (1%)	
Rail transport	10 (1%)	
Other (a)	27 (2%)	

(a) Includes TOOCS 2 digit level classifications with less than 10 cases.
(1) TOOCS coding at the one digit level.
(2) 'Grinders' are classified as either 'cutting, slicing, sawing machinery' or 'workshop and worksite tools and equipment' depending on whether they are a fixed piece of machinery or a hand held tool. There were instances when it was difficult to determine the appropriate classification of a 'Grinder'. The NHEWS verbatim was used to classify the information.

Within the 2nd digit agency classifications, 55% of reported exposures to W*orkshop and worksite tools and equipment* were for *Electric drills*, while 44% were for *Abrasive, planing and cutting powered tools*. Within *Road transport*, *Cars, station wagons, van, utilities* accounted for 53% of the reported exposures while *Trucks, semi-trailers, lorries* accounted for a further 40% of exposures. The main source of exposure to vibration within *Other plant and machinery* was *Tractors, agricultural or otherwise* (69% of exposures). *Front-end loaders, log handling plant or other loading*

plant was the main source of exposure to vibration, with 42% of reported exposures, within *Other plant and machinery*.

Employment and demographic characteristics of Australian workers who reported they were exposed to vibration

In order to determine what employment and demographic characteristics of workers predict exposure to vibration a multinomial logistic regression model, restricted to the five national priority industries, was undertaken. The demographic and employment characteristics found to significantly predict exposure to vibration were gender, age, education, income, occupation and industry (Table 5). The full model output can be found in Appendix B, Table 13.

Table 5 The likelihood of a worker reporting an exposure to vibration. Parameter estimates of the multinomial logistic model[9].

MODEL FACTORS The reference group in the model is 'not exposed to vibration'	The odds of reporting exposure to vibration (as opposed to not reporting exposure) were…	…by a factor of (Odds ratio) relative to the model factor reference group
Gender		
Male	Increased	2.597
Female	**Reference group**	
Age		
15-24 years	Increased	2.923
25-34 years	Increased	2.026
35-44 years	Increased	1.384
45-54 years	Increased	1.537
55+ years	**Reference group**	
Income		
Under $50 000	Increased	1.475
$50 000 to $99 999	Increased	1.686
$100 000+	**Reference group**	
Education		
Year 12 not completed	-	-
Year 12 completed	-	-
Trade certificate/TAFE qualification	Increased	1.482
Bachelor's degree or higher	**Reference group**	
Occupation		
Machinery operators & drivers	Increased	8.011
Technicians & trades workers	Increased	6.502
Labourers	Increased	5.938
Managers	Increased	2.878
Community & personal service workers	Increased	2.260
Professionals		-
Clerical & administrative workers and Sales workers	**Reference group**	
Industry		
Agriculture, forestry & fishing	Increased	4.651
Transport & storage	Increased	2.435
Construction	Increased	2.352
Manufacturing	Increased	1.924
Health & community services	**Reference group**	

Male workers were more likely to report they were exposed to vibration than female workers. Male workers accounted for approximately 85% of the workers in the priority industries who reported an exposure to vibration. Or, expressed another way, 53% of

[9] Only statistically significant results are presented.

all the male workers in the priority industries reported they were exposed to vibration compared to just 15% of the female workers. These findings are reflected in the Australian workers' compensation statistics, which show that male workers make more compensation claims for vibration related injury and disease than female workers. In fact, between 2000-01 and 2007-08, over 90% of serious workers' compensation claims[10] for vibration related conditions were made by male workers. The difference between the sexes is probably largely attributable to the male domination of jobs where workers are more likely to be exposed to vibration, such as *Construction*, *Transport and storage*, and *Agriculture, forestry and fishing*.

Age also affected the odds that a worker reported they were exposed to vibration. The younger a worker was, the more likely they were to report an exposure to vibration relative to older workers (Table 5). Workers in the 15-24 year age group were almost three times more likely than workers in the 55+ age group to report being exposed to vibration. In contrast to the exposure pattern evident in the NHEWS survey data, from 2000-01 to 2007-08 the Australian workers' compensation statistics show that workers in the 35-44 years and 45-54 years age groups had the highest incidence rates of vibration related compensation claims (5.8 and 5.7 per 100 000 workers respectively). This compares to 1.5 claims per 100 000 workers amongst the 15-24 year age group. Some of the difference between the reported exposure by worker age in NHEWS and the incidence rate of workers' compensation claims by age is likely to be due to the long latency of vibration related injury / illness. However, a large proportion of workers' compensation claims where the mechanism of injury or disease is vibration are sprains and strains of joints and adjacent muscles, which do not have a long latency period. This raises the possibility that young workers may not claim workers' compensation for their vibration related injuries and/or that 35-54 years olds are more likely to suffer sprains and strains as a result of vibration exposure than younger workers.

The odds of reporting exposure to vibration were increased for workers earning less than $100 000 per year relative to those earning more than $100 000 per year. Workers earning less than $50 000 were nearly 1.5 times more likely to report an exposure to vibration relative to workers earning more than $100 000. Workers earning between $50 000 to $99 999 were more than 1.6 times more likely to report an exposure to vibration relative to those earning more than $100 000.

Occupation affected the likelihood a worker reported they were exposed to vibration (Table 5). All occupations, except *Professionals,* had increased odds of reporting exposure to vibration relative to *Clerical and administrative and Sales workers*. *Machinery operators and drivers*, *Technicians and trades workers*, and *Labourers* had the highest odds of reporting an exposure to vibration when compared to *Clerical and administrative and Sales workers.* Unfortunately, it is not possible to make a direct comparison of the NHEWS data with the Australian workers' compensation statistics because the occupation categorisations used in the NHEWS survey differ from those currently used in the compensation data set[11]. However, in the workers' compensation data set *Intermediate production and transport workers*, *Trades persons and related workers* and *Labourers and related workers* accounted for the vast majority of vibration related claims, which is similar to the occupational groupings in the NHEWS data on vibration exposure. Furthermore, although also not

[10] Serious compensation claims are those that involve either a death; a permanent incapacity; or a temporary incapacity requiring an absence from work of one working week or more.

[11] The NHEWS survey used the ANZSCO first edition classification of occupations whereas the National Data Set for Compensation Based Statistics (NDS) uses ASCO 2nd edition.

strictly comparable, occupations with high levels of vibration exposure in the EWCS also had high levels of exposure in the NHEWS survey cohort (Parent-Thirion et al. 2007).

Table 5 shows that workers in the *Agriculture, forestry and fishing* industry were 4.5 times more likely to report exposure to vibration than workers in the *Health and community services* industry. This was followed by the *Transport and storage*, *Construction* and *Manufacturing* industries, where workers were 2.4, 2.3 and 1.9 times respectively more likely to report exposure to vibration than workers in the *Health and community services* industry. These finding are broadly consistent with the Australian workers' compensation data, which shows that the *Transport and storage* (12.7 claims per 100 000 workers), *Construction* (9.0 claims per 100 000 workers)*, Manufacturing* (5.9 claims per 100 000 workers) and *Agriculture, forestry and fishing* (5.2 claims per 100 000 workers) industries had considerably higher incidence rates of vibration related injury or disease than the *Health and community services industry* (0.5 claims per 100 000 workers). However, in the compensation data, *Agriculture, forestry and fishing* had the lowest incidence rate of these four industries. The difference between NHEWS survey findings and the workers' compensation data may be due to the fact that many workers in the *Agriculture, forestry and fishing* are not captured in the workers' compensation data because they are not covered by any of the workers' compensation schemes. The vibration exposure pattern revealed in the NHEWS survey is also broadly consistent with the findings of the EWCS. However in the EWCS the *Construction* industry reported the highest incidence of exposure to vibration (63%) (Parent-Thirion et al. 2007).

What employment and demographic factors affected the type of vibration workers reported exposure to?

As described earlier, the NHEWS survey data were also coded with respect to the type of vibration (whether or not a worker was exposed to hand-arm vibration, whole body vibration or both types of vibration) they were exposed to (Table 3). A multinomial logistic regression model was developed to determine the demographic and employment characteristics that predicted whether or not a worker reported a particular type of vibration. The types of vibration examined were hand-arm, whole body, both hand-arm and whole body and vibration type not determined, with the reference group being not exposed to vibration. The demographic and employment characteristics found to be significant predictors were gender, age, income, education, workplace size, occupation and industry (Table 6). The full model output can be found in Appendix B, Table 15.

Not surprisingly, the demographic and employment factors that were found to have a significant effect on the type of vibration exposure were the same as those found to have a significant effect on exposure to vibration generally. However, an additional factor, workplace size (the number of employees working at the workplace) also affected the type of vibration a worker was exposed to. In the model, the odds of being exposed to each type of vibration (hand, whole body or both) were compared with the odds of not reporting any exposure to vibration.

Table 6 The likelihood of reporting an exposure to each type of vibration. Parameter estimates of multinomial logistic model[12].

MODEL FACTORS The reference group in the model is 'not exposed to vibration'	The odds of reporting exposure to hand-arm vibration only (as opposed to not reporting exposure) were…	…by a factor of (Odds ratio) relative to the model factor reference group	The odds of reporting exposure to whole body vibration only (as opposed to not reporting exposure) were…	…by a factor of (Odds ratio) relative to the model factor reference group	The odds of reporting exposure to both hand-arm and whole body vibration (as opposed to not reporting exposure) were…	…by a factor of (Odds ratio) relative to the model factor reference group	The odds of reporting exposure to vibration types that could not be determined (as opposed to not reporting exposure) were…	…by a factor of (Odds ratio) relative to the model factor reference group
	Hand-arm vibration		Whole body vibration		Both hand-arm and whole body vibration		Vibration type not determined	
Gender								
Male	Increased	2.734	Increased	2.511	Increased	3.581	-	-
Female	**Reference group**		**Reference group**		**Reference group**		**Reference group**	
Age								
15-24 years	Increased	3.262	-	-	Increased	4.940	-	-
25-34 years	Increased	2.663	Increased	1.619	Increased	2.523	-	-
35-44 years	Increased	1.726	-	-	-	-	-	-
45-54 years	Increased	1.801	Increased	1.461	-	-	-	-
55+ years	**Reference group**		**Reference group**		**Reference group**		**Reference group**	
Income								
Under $50 000	Increased	1.848	-	-	-	-	-	-
$50 000 to $99 999	Increased	1.892	-	-	-	-	-	-
$100 000+	**Reference group**		**Reference group**		**Reference group**		**Reference group**	
Education								
Year 12 not completed	-	-	-	-	-	-	-	-
Year 12 completed	-	-	-	-	-	-	-	-
Trade certificate/TAFE	-	-	-	-	Increased	2.392	-	-
Bachelor's degree or higher	**Reference group**		**Reference group**		**Reference group**		**Reference group**	

Table continued on next page

[12] Only statistically significant results are presented.

MODEL FACTORS The reference group in the model is 'not exposed to vibration'	The odds of reporting exposure to hand-arm vibration only (as opposed to not reporting exposure) were…	…by a factor of (Odds ratio) relative to the model factor reference group	The odds of reporting exposure to whole body vibration only (as opposed to not reporting exposure) were…	…by a factor of (Odds ratio) relative to the model factor reference group	The odds of reporting exposure to both hand-arm and whole body vibration (as opposed to not reporting exposure) were…	…by a factor of (Odds ratio) relative to the model factor reference group	The odds of reporting exposure to vibration types that could not be determined (as opposed to not reporting exposure) were…	…by a factor of (Odds ratio) relative to the model factor reference group
	Hand-arm vibration		Whole body vibration		Both hand-arm and whole body vibration		Vibration type not determined	
Workplace size								
Less than five	Increased	1.901	-	-	-	-	-	-
Five to 19	Increased	1.900	-	-	-	-	-	-
20 to 199	-	-	-	-	-	-	-	-
200 or more	**Reference group**		**Reference group**		**Reference group**		**Reference group**	
Occupation								
Managers	Increased	11.726	Increased	1.825	Increased	3.194	-	-
Professionals	Increased	6.917	-	-	-	-	-	-
Technicians & trades workers	Increased	47.637	-	-	Increased	7.412	-	-
Community & personal services workers	Increased	5.151	Increased	2.322	-	-	-	-
Labourers	Increased	34.834	Increased	3.300	Increased	6.553	-	-
Machinery operators & drivers	Increased	9.874	Increased	9.461	Increased	6.587	-	-
Clerical & administrative workers & Sales workers	**Reference group**		**Reference group**		**Reference group**		**Reference group**	
Industry								
Manufacturing	Increased	2.108	-	-	Increased	4.235	-	-
Transport & storage	Increased	2.042	Increased	2.886	-	-	-	-
Construction	Increased	2.226	-	-	Increased	4.386	-	-
Agriculture, forestry & fishing	-	-	Increased	7.637	Increased	8.512	-	-
Health & community services	**Reference group**		**Reference group**		**Reference group**		**Reference group**	

The likelihood of reporting an exposure to each type of vibration varied considerably for workers in the *Manufacturing* and the *Construction* industries. Compared with workers in the *Health and community services* industry, workers in the *Manufacturing* and the *Construction* industries were more than four times more likely to report vibration exposures that affected both the hand-arm and whole body and were over twice as likely to report an hand-arm vibration only, (when both types of vibration were opposed to reporting no exposure). However *Manufacturing* and *Construction* industry workers had similar odds of reporting whole body vibration (as opposed to no exposure) to workers in the *Health and community services* industry.

The likelihood of reporting an exposure to each type of vibration also varied for workers in the *Agriculture, forestry and fishing* industry. Workers in the *Agriculture, forestry and fishing* industry were over eight times more likely to report an exposure to both hand-arm and whole body vibration (rather than no exposure) and over seven times more likely to report an exposure to whole body vibration (rather than no exposure), than workers in the *Health and community services* industry. However there was no difference in the likelihoods of *Agriculture, forestry and fishing* and *Health and community service* workers reporting exposure to hand-arm vibration (rather than no vibration exposure).

The odds of reporting exposure to hand-arm vibration or whole body vibration, as opposed to not reporting exposure to vibration, were more than doubled by working in the *Transport and storage* industry in comparison to the *Health and community services* industry. There was no statistical difference in the odds of reporting exposure to both hand-arm and whole body vibration between the *Transport and storage* industry and the *Health and community services* industry.

There were major differences in the odds of reporting exposure to the different types of vibration between occupations. For example, *Technicians and trades* workers were 47 times more likely to report an exposure to hand-arm vibration (as opposed to no exposure to vibration) and over seven times more likely to report exposure to both hand-arm and whole body vibration (as opposed to no exposure to vibration), than *Clerical and administrative workers and Sales workers*. However there was no difference between these two occupations in terms of the odds of reporting exposure to whole body vibration, as opposed to not reporting exposure.

Similarly, the odds of reporting exposure to hand-arm vibration, whole body vibration or both hand-arm and whole body vibration (as opposed to not reporting exposure to vibration) were increased by factors of 34, three and six respectively by being a *Labourer* rather than a *Clerical and administrative workers* and *Sales workers*. *Managers* also had increased odds of reporting exposure to each type of vibration (relative to reporting no exposure) compared to *Clerical and administrative workers* and *Sales workers.*

The likelihood an exposure to hand-arm vibration was increased for those workers in smaller workplaces relative to larger workplaces of 200 or more workers. Workplaces of five or fewer workers and those with between five to 19 workers were almost twice as likely to be exposed to hand-arm vibration relative to workers in workplaces of 200 or more workers. The size of the workplace did not have a significant effect on the likelihood of a worker reporting exposure to whole body vibration or both hand-arm and whole body vibration.

The likelihood of reporting an exposure to hand-arm vibration was increased for those workers with lower incomes relative to workers with higher incomes. Workers earning less than $50 000 and those earning $50 000 to $99 999 were almost twice as likely to be exposed to hand-arm vibration relative to workers earning over $100 000. Workers income did not have a significant effect on the likelihood of a

worker reporting exposure to whole body vibration or both hand-arm and whole body vibration.

Workers whose highest education level was a trade or TAFE certificate were more than twice as likely to be exposed to both hand-arm and whole body vibration as those workers whose highest education level was a bachelor's degree or higher.

There were no significant differences between factor levels in terms of the odds of reporting exposure to vibration (as opposed to not reporting exposure to vibration) when the vibration type could not be determined.

Duration of exposure to vibration

In the NHEWS survey, workers were asked to estimate how many hours per day or per week they were exposed to vibration. This information was used to determine the proportion of time at work a worker was exposed to vibration. These proportions were then categorised into quartiles of exposure (refer to Figure 1) similar to the measure of exposure used in the EWCS. Refer to Appendix A for methodology.

Figure 1 shows that of those workers who reported they were exposed to vibration, 41% reported being exposed for up to a quarter of their time at work, 21% were exposed for more than a quarter of their time but less than or equal to half their time at work, 15% were exposed for more than half their time but less than or equal to three quarters of their time at work and 24% were exposed to vibration for more than three quarters of their time at work.

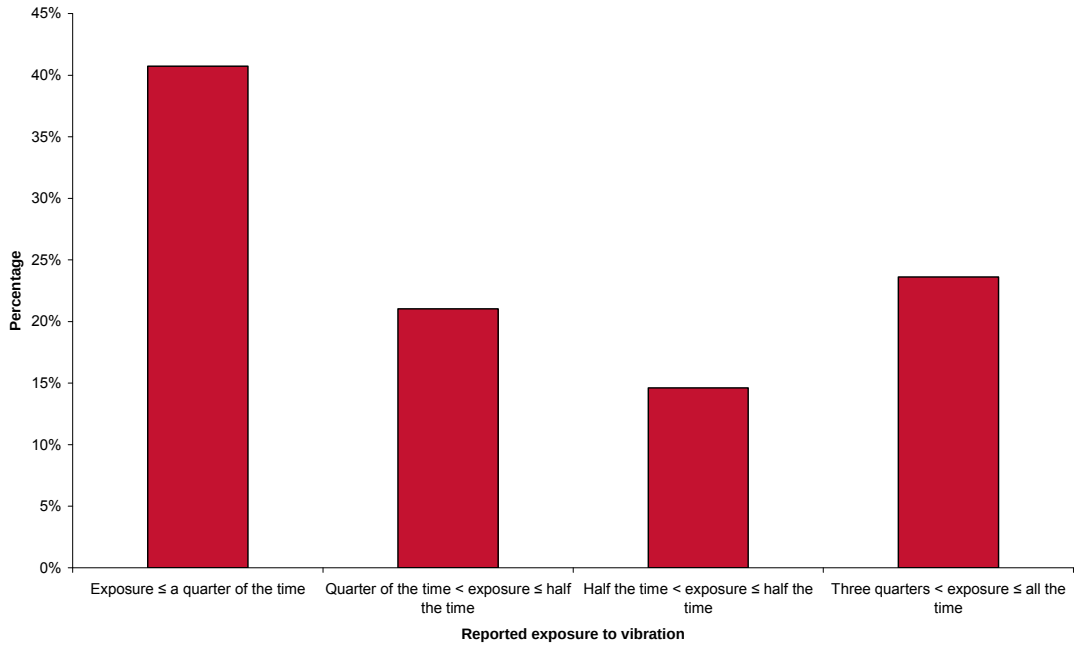


Figure 1 All Workers: The percentage of workers who reported exposure to vibration by quartiles of reported duration of exposure

A direct comparison of the NHEWS and EWCS surveys is not possible because of slight differences in the exposure categories. However, the fourth EWCS found that 11% of workers were almost never exposed to vibration, 7% of workers were exposed for around one quarter of their time at work, 4% of workers for around half the time, nearly 3% of workers were exposed for three quarters of the time, 5% of workers were exposed almost all the time and nearly 6% of workers were exposed to vibration all the time they were at work (Donati et al. 2008). Workers who were

exposed for one quarter or more of their time were considered exposed to vibration in the EWCS and this amounted to a weighted estimate of 24% of workers.

In the NHEWS study, all reported exposures were considered valid exposures to vibration. The comparable, but unweighted percentages of workers exposed to vibration for each duration of exposure from the NHEWS study are as follows: 12% of workers were exposed to vibration for up to a quarter of the time, 6% for more than a quarter of the time to half the time, 4% for more than half the time to three quarters of the time and 7% for more than three quarters to all the time. The data from this Australian study indicate that larger percentages of Australian workers were exposed to vibration for less than half their time at work than in Europe. This is partially because the NHEWS study includes all reported exposures to vibration rather than excluding the workers who are almost never exposed to vibration.

Demographic and employment factors that were associated with the duration of exposure to vibration

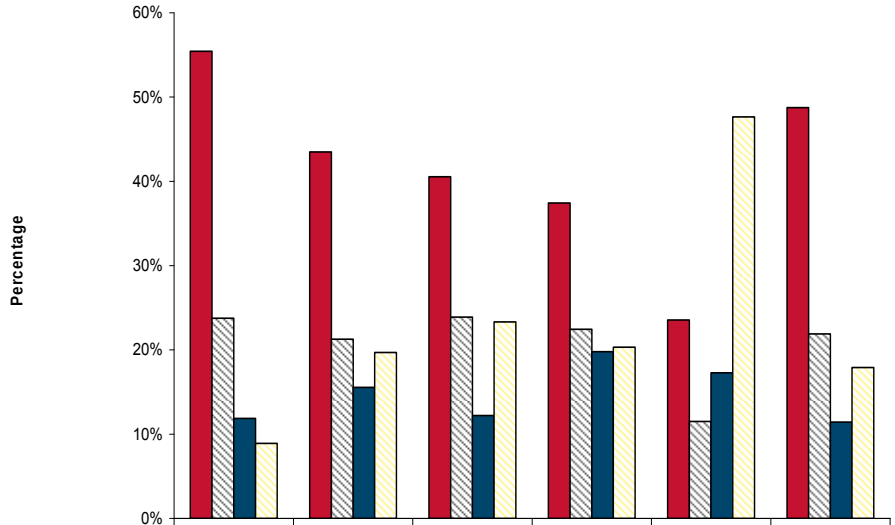
Chi-square tests were used to determine what demographic and employment factors were associated with the duration of exposure to vibration. The factors examined in these analyses were gender, industry, type of employment, workplace size, age, occupation, education, type of exposure, worked at night and income. Of these, the following factors were found to have a significant association with duration of exposure to vibration; industry, workplace size, income, type of exposure, occupation and education (Table 7).

Table 7 All Workers exposed to vibration: Factors associated with the duration of exposure to vibration

Factors affecting duration of exposure	Chi-square	*df*	*P*
Industry	145.805	42	0.000
Workplace size	17.426	9	0.042
Income	15.701	6	0.015
Type of exposure	66.482	9	0.000
Occupation	207.628	21	0.000
Education	76.054	12	0.000

Workers were most commonly exposed to vibration for up to a quarter of their time at work in all industries except *Transport and storage* (Figure 2). In this latter industry, the most commonly reported duration of exposure to vibration was more than three quarters to all the time (48% of exposures within the industry). This finding is not unexpected because of the nature of the work in this industry. Work in this industry often involves driving vehicles (i.e. trucking bulk haulage) for most/all of a shift, where the vehicle is the source of exposure to vibration.

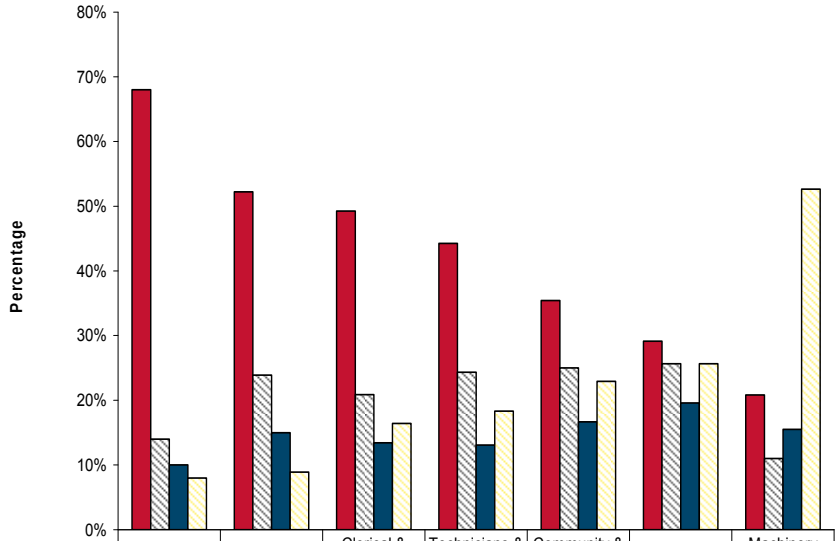
With the exception of *Machinery operators and drivers*, within each occupation workers most commonly reported they were exposed to vibration for up to one quarter of their time at work (Figure 3). For *Machinery operators and drivers,* the majority of workers reported they were exposed to vibration for more than three quarters to all the time at work (53%). *Labourers* also differed from the other occupations in that more than 20% of workers reported each of the durations of exposure. *Professionals* recorded the lowest percentage (8%) of workers who reported being exposed for more than three quarters to all of their time at work.



	Health & community services	Manufacturing	Construction	Agriculture, forestry & fishing	Transport & storage	Other industries
Exposure ≤ a quarter of the time	55%	43%	41%	37%	24%	49%
Quarter of the time < exposure ≤ half the time	24%	21%	24%	22%	12%	22%
Half the time < exposure ≤ half the time	12%	16%	12%	20%	17%	11%
Three quarters < exposure ≤ all the time	9%	20%	23%	20%	48%	18%

Industry

Figure 2 All workers who reported exposure to vibration: the percentage of workers within each quartile of duration of exposure by industry



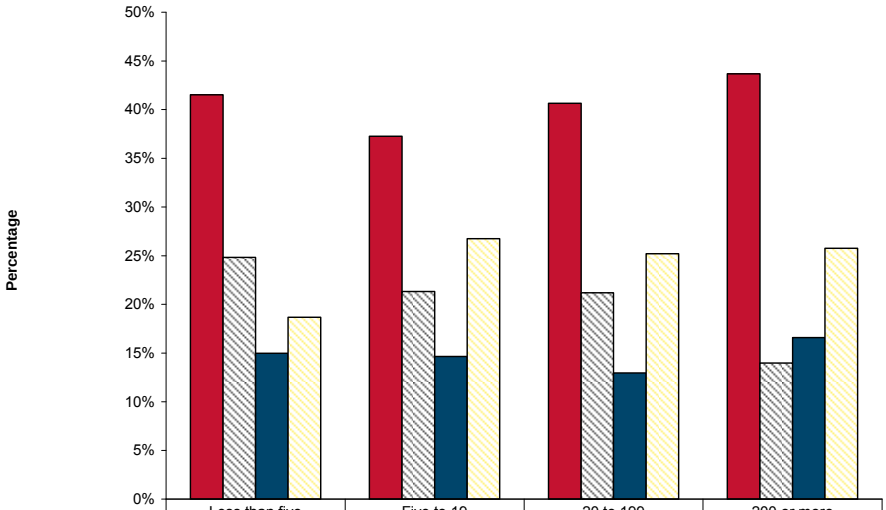
	Professionals	Managers	Clerical & administrative and Sales	Technicians & trades workers	Community & personal service	Labourers	Machinery operators & drivers
Exposure ≤ a quarter of the time	68%	52%	49%	44%	35%	29%	21%
Quarter of the time < exposure ≤ half the time	14%	24%	21%	24%	25%	26%	11%
Half the time < exposure ≤ half the time	10%	15%	13%	13%	17%	20%	16%
Three quarters < exposure ≤ all the time	8%	9%	16%	18%	23%	26%	53%

Occupation

Figure 3 All workers who reported exposure to vibration: the percentage of workers within each quartile of duration of exposure by occupation[13]

[13] Workers who did not know their occupation are not shown in this graph.

As can be seen in Figure 4, as workplaces get larger the percentage of workers exposed to vibration for more than a quarter to half of their time at work declines and, with the exception of workplaces with fewer than five workers, the percentage of workers exposed to vibration for up to a quarter of the time increases. There were little differences between the workplaces in terms of the percentage of workers who were exposed to vibration for more than half their time but less than or equal to three quarters of their time at work.



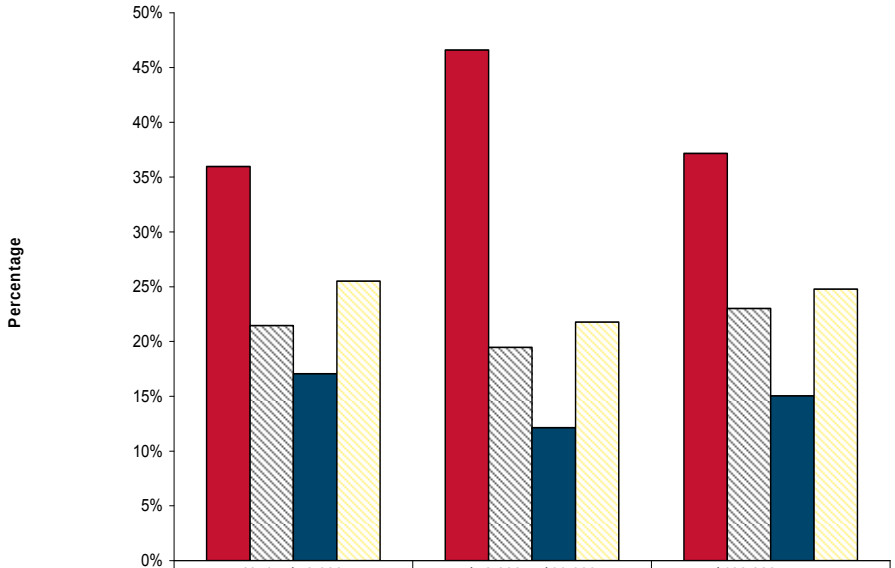
	Less than five	Five to 19	20 to 199	200 or more
Exposure ≤ a quarter of the time	42%	37%	41%	44%
Quarter of the time < exposure ≤ half the time	25%	21%	21%	14%
Half the time < exposure ≤ half the time	15%	15%	13%	17%
Three quarters < exposure ≤ all the time	19%	27%	25%	26%

Workplace size

Figure 4 All workers who reported exposure to vibration: the percentage of workers within each quartile of duration of exposure by workplace size

Figure 5 shows the duration of exposure to vibration by income. Workers earning less than $50 000 had both the highest incidence of reporting being exposed to vibration for more than three quarters to all of their time at work (26%) and the lowest incidence of being exposed for up to a quarter of the time (36%).The reverse was true for workers earning between $50 000 to $99 999. In addition this earning bracket recorded the smallest percentages of workers exposed to vibration for more than a quarter of the time but less than or equal to half their time at work (19%) and more than half the time but less than or equal to three quarters of the time at work (12%).

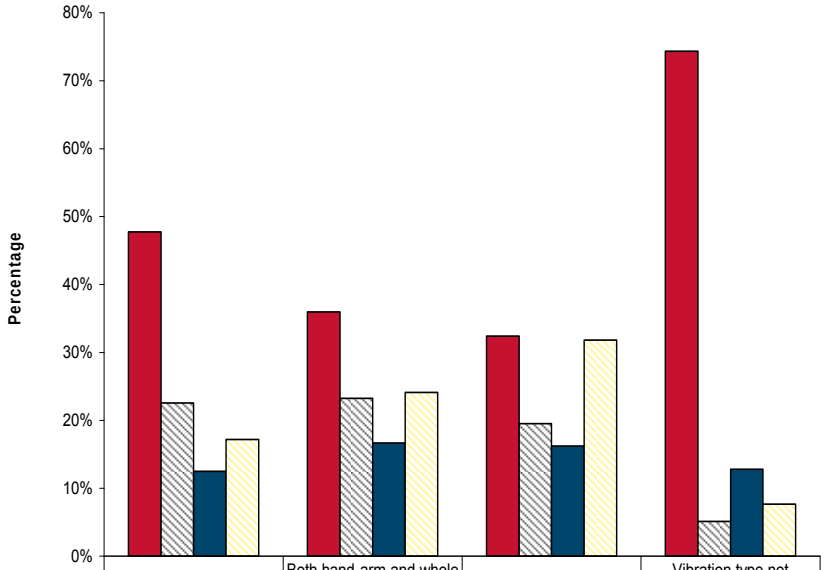
As can be seen in Figure 6, the type of vibration had a significant impact on the duration of exposure to vibration reported by workers. Workers exposed to hand-arm vibration were more likely to be exposed for up to one quarter of their time (48%) than those workers exposed to either whole body vibration (32%) or both hand-arm and whole body vibration (36%). Workers exposed to whole body vibration were more likely to report they were exposed for more than three quarters to all their time at work (32%) than workers exposed to hand-arm vibration (17%) and both hand-arm and whole body vibration (24%). More than 70% of the workers for whom the type of vibration could not be determined reported they were exposed to vibration for up to one quarter of their time at work.



	Under $50 000	$50 000 to $99 999	$100 000 or over
Exposure ≤ a quarter of the time	36%	47%	37%
Quarter of the time < exposure ≤ half the time	21%	19%	23%
Half the time < exposure ≤ half the time	17%	12%	15%
Three quarters < exposure ≤ all the time	26%	22%	25%

Income

Figure 5 All workers who reported exposure to vibration: the percentage of workers within each quartile of duration of exposure by income

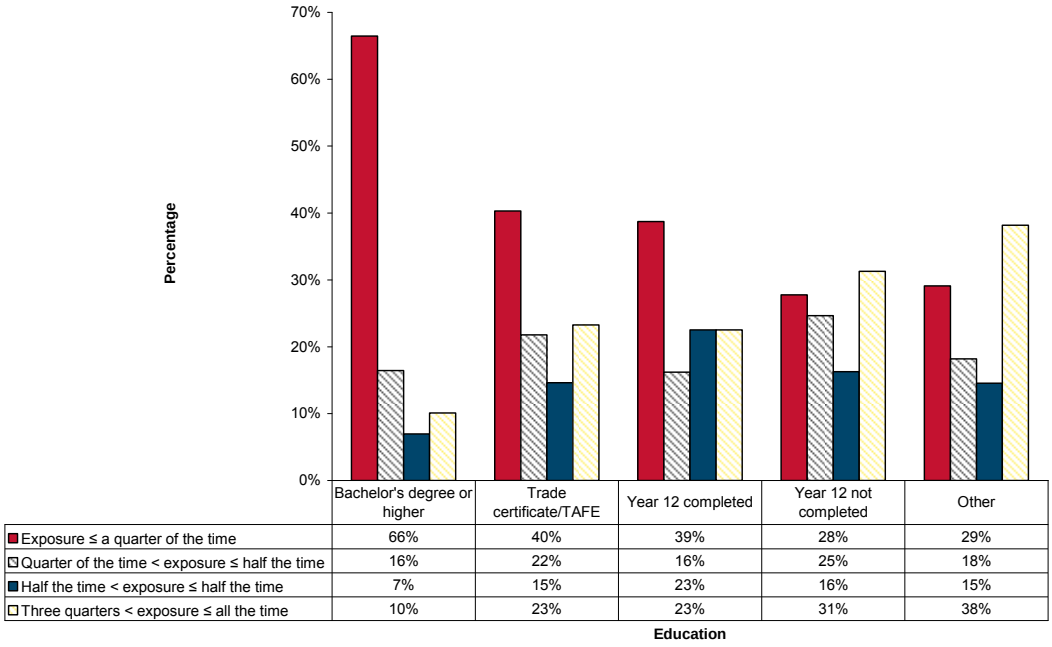


	Hand-arm	Both hand-arm and whole body	Whole body	Vibration type not determined
Exposure ≤ a quarter of the time	48%	36%	32%	74%
Quarter of the time < exposure ≤ half the time	23%	23%	20%	5%
Half the time < exposure ≤ half the time	13%	17%	16%	13%
Three quarters < exposure ≤ all the time	17%	24%	32%	8%

Type of vibration

Figure 6 All workers who reported exposure to vibration: the percentage of workers within quartile of duration by type of exposure

As can be seen in Figure 7, the higher the workers' education level the shorter their duration of exposure to vibration. Of the workers who were exposed to vibration, 66% of those with a Bachelor's degree or higher were exposed for up to one quarter of their time at work, while 28% of workers who did not complete year 12 reported being exposed to vibration for the same duration. In contrast, 31% of workers who had not completed year 12 reported they were exposed to vibration for more than three quarters to all of their time at work. Of workers whose education level was Other 38% were exposed for more than three quarters of their time at work. However it should be noted that the Other education category consisted of only 55 workers and should therefore be interpreted with caution.



	Bachelor's degree or higher	Trade certificate/TAFE	Year 12 completed	Year 12 not completed	Other
Exposure ≤ a quarter of the time	66%	40%	39%	28%	29%
Quarter of the time < exposure ≤ half the time	16%	22%	16%	25%	18%
Half the time < exposure ≤ half the time	7%	15%	23%	16%	15%
Three quarters < exposure ≤ all the time	10%	23%	23%	31%	38%

Figure 7 All workers who reported exposure to vibration: the percentage of workers within each quartile of duration of exposure by education

Vibration control measures provided in the workplace

The NHEWS survey asked all workers who reported an exposure to vibration about the vibration control measures that were provided in their workplace by their employer (or themselves, if they were self employed). Workers who did not report an exposure to vibration were not asked about the vibration controls provided in their workplace. Therefore, it is possible that workers for whom controls have eliminated vibration may not be included in this aspect of the survey because they may not be exposed to vibration as a result, or aware their employer has taken measures to eliminate vibration in the workplace. As such, the following data analyses on vibration control measures could be biased towards workplaces where vibration has not been eliminated and therefore it may be underestimating control provisions, especially the purchasing of products with less or no vibration, in Australian workplaces. Unfortunately it is not possible to estimate how biased the data are with the information currently available. This problem could be partially addressed in future surveys by asking all workers (including those who did not report exposure to vibration) about the use of vibration control measures in the workplace.

The NHEWS survey questionnaire specifically asked workers whether or not particular vibration control measures were provided in their workplaces. It did not ask whether or not the vibration control measures provided were used by the worker. Therefore it is possible workers reported the provision of vibration control measures that they did not personally use when performing their duties.

Table 8 shows that 22% (296) of the workers who reported they were exposed to vibration also reported they were not provided with any of the vibration control measures surveyed in their workplace. The control measure most commonly provided was gloves, with 65% (884) of workers reporting they were provided in their workplaces. Approximately 31% of workers reported that products with less vibration were purchased, 30% of workers said vibration absorbing seats were provided and 27% of workers said that they had received training on how to prevent health problems caused by vibration. Providing vibration dampeners was reported by only 20% of those workers exposed to vibration.

Table 8 also shows the breakdown of vibration control measures provided in workplaces by the hierarchy of controls, the number of controls provided and the types of controls provided relative to the provision of personal protective equipment (PPE). It should be noted that multiple responses were allowed when the hierarchy of controls data were collated. A large percentage (65%) of workers who were exposed to vibration reported they were provided with PPE. In comparison, engineering controls, the next largest group, were provided in only 37% of exposed workers' workplaces. Of the workers who were provided with PPE, one third (or 22% of all vibration exposed workers) were solely provided with PPE as a control measure to prevent the health problems associated with vibration.

Most workers (43%) were provided with vibration controls and PPE. Approximately 11% of workers were provided with vibration control measures other than PPE and 22% were provided with only PPE.

As can be seen in Table 8, 30% of exposed workers reported that only one vibration control measure was provided in their workplace. However, 47% of workers were provided with two, three, four or five vibration controls. Most commonly, workers were provided with two or three controls (19% and 14% of exposed workers respectively).

Table 8 All Workers: Vibration exposure control measures reported by respondents who reported an exposure to vibration, frequencies and percentages of those exposed to vibration by methods of categorising vibration exposure control measures[14]

Vibration control measures surveyed (multiple responses allowed)	Number of workers who reported control provided	% of workers exposed to vibration
Provide gloves	884	65%
Use vibration dampeners	265	20%
Provide vibration absorbing seats	410	30%
Purchase products with less vibration	425	31%
Provide training on how to prevent health problems caused by vibration	360	27%
Nothing	296	22%
Don't know	7	1%
Refused	1	0%
Vibration control measure categories following the hierarchy of controls (multiple responses allowed)	**Number of workers who reported control provided**	**% of workers exposed to vibration**
Eliminate or substitute (1)	425	31%
Engineering (2)	504	37%
Administrative (3)	360	27%
PPE (4)	884	65%
No control measures (5)	296	22%
Number of control measures in place	**Number of workers who reported control provided**	**% of workers exposed to vibration**
Zero control measures (a)	318	23%
One control measure	401	30%
Two control measures	253	19%
Three control measures	190	14%
Four control measures	113	8%
Five control measures	83	6%
Total	**1358**	**100%**
Control measures with respect to the provision of PPE	**Number of workers who reported control provided**	**% of workers exposed to vibration**
No control measures (b)	318	23%
Vibration control measures other than PPE	156	11%
Vibration control measures and PPE	584	43%
PPE only	300	22%
Total	**1358**	**100%**

(a) 'Other' responses have not been included as the interviewer did not prompt for 'other' response but recorded them if they were given voluntarily. One response of 'Not applicable' was also not included.
(b) Includes cases where workers gave no response, only 'other', 'N/A', 'don't know' and 'nothing' responses.
(1) Includes survey responses of 'purchase products with less vibration'.
(2) Includes survey responses of 'use vibration dampeners' or 'provide vibration absorbing seats'.
(3) Includes survey responses of 'provide training on how to prevent health problems caused by vibration'.
(4) Includes survey responses of 'provide gloves'.
(5) Includes survey responses of 'nothing'.

Table 9 shows the breakdown, by industry and occupation, of all workers who reported they were not provided with any of the surveyed vibration control measures despite being exposed to vibration. Vibration controls were not provided to 47% of

[14] Not all control measures recorded in the survey were included in the analysis. Those respondents who only reported an 'other' control measure were excluded because this option was not prompted by the interviewer. As a result, the number of workers who reported zero control measures has increased because it includes those workers who stated that each of the surveyed items were not provided but who provided alternative, non-surveyed control measures.

workers in the *Health and community services* industry, 23% of workers in the *Transport and storage* industry and 22% of *Construction* industry workers. Of concern is the high percentage of workers who were not provided with vibration controls in industries outside of the national priority industries (in addition to the high percentage of workers without controls in *Health and community services*).

Reflecting the pattern by industry, 44% of *Community and personal service workers* and 47% of *Professionals* were not provided with any vibration control measures. These occupations make up a large percentage of workers in the *Health and community services industry*. Over 40% of *Clerical, administrative and sales workers* were also not provided with any controls for their vibration exposures.

It should be noted that while high percentages of exposed workers were not provided with vibration controls, only small percentages of workers in this industry / these occupations reported exposure to vibration (Table 9). Furthermore, it is not possible to determine whether or not the vibration exposures were hazardous. Indeed, a commonly reported source of vibration exposure for these workers was cars and vans, the occupational use of which was shown to be over-reported in a British study (Palmer et al. 2000c).

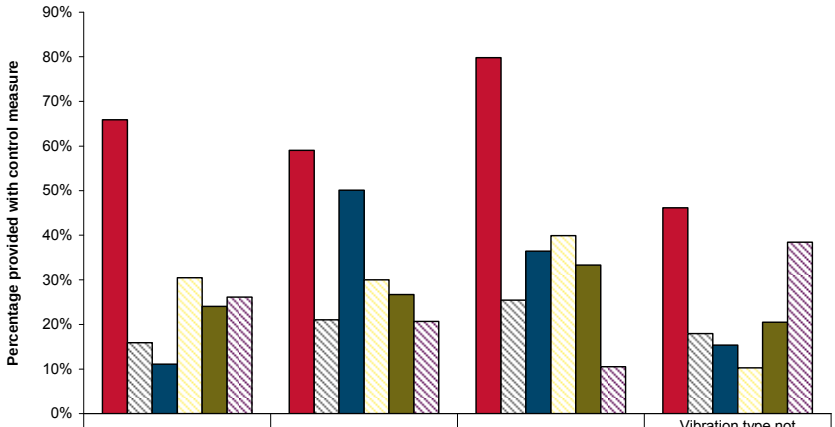
Table 9 All Workers: The percentage of workers within each industry / occupation who reported that no control measures for vibration were provided in their workplaces[15] and the percentage of workers within each industry / occupation who reported they were exposed to vibration

Industry	% of workers within the industry with no control measures	% of workers within the industry who reported being exposed to vibration
Health and community services	47%	11%
Transport and storage	23%	49%
Construction	22%	55%
Agriculture, forestry and fishing	16%	60%
Manufacturing	14%	44%
Other industries	37%	14%
Occupation	**% of workers within the occupation with no control measures**	**% of workers within occupation who reported being exposed to vibration**
Professionals	47%	10%
Community and personal service workers	44%	13%
Clerical and administrative workers and Sales workers	42%	9%
Technicians and trades workers	23%	60%
Labourers	19%	49%
Machinery operators and drivers	15%	68%
Managers	15%	31%
Don't know	21%	18%

Figure 8 shows the control measures provided in workplaces by the type (hand-arm and/or whole body) of vibration workers reported they were exposed to. Gloves were the most commonly provided vibration control measure for all types of exposure. Caution should be taken when interpreting these results because the question was phrased in terms of what control measures were provided in the workplace and not what control measures were used by the respondent. Therefore, it is plausible that an

[15]Includes cases where workers gave no response, only an 'other', 'N/A', 'don't know' and 'nothing' responses.

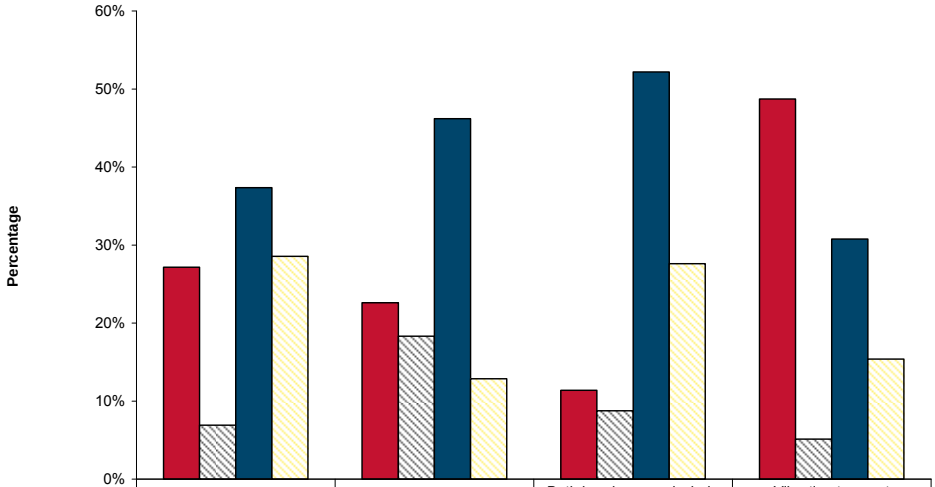
employer could provide a particular control measure in the workplace that is not used by the worker. Furthermore, workers may have reported the provision of controls for exposures to vibration that did not occur during the reference week in the survey. Only the exposure questions related to a reference week, while the control questions were not time specific. Future iterations of this survey must ensure that vibration exposures and control provision and use are matched by careful phrasing of these questions.



	Hand-arm	Whole body	Both	Vibration type not determined
Providing gloves	66%	59%	80%	46%
Use vibration dampeners	16%	21%	25%	18%
Provide vibration absorbing seats	11%	50%	36%	15%
Purchase products with less vibration	30%	30%	40%	10%
Provide training on how to prevent health problems	24%	27%	33%	21%
Nothing	26%	21%	11%	38%

Figure 8 All workers who reported exposure to vibration: Control measures provided for each type of vibration

Figure 9 shows the vibration control measures provided in workplaces according to the type of vibration workers reported they were exposed to. Workers whose type of vibration could not be determined reported the highest incidence of being provided with no control measures (49%). Of the types that could be determined, workers exposed to hand-arm vibration recorded the greatest percentage of workers who reported they were provided with no control measures (27%). Workers exposed to both hand-arm and whole body vibration recorded the greatest percentage of workers who reported they were provided with *vibration control measures and PPE* (52%). *PPE only* was provided to 29% of workers exposed to hand-arm vibration only and 28% of workers exposed to both hand-arm and whole body vibration. The provision of *vibration control measures other than PPE* was most common for workers exposed to whole body vibration only.



	Hand-arm	Whole body	Both hand-arm and whole body	Vibration type not determined
No control measures	27%	23%	11%	49%
Control measures other than PPE	7%	18%	9%	5%
Control measures and PPE	37%	46%	52%	31%
PPE only	29%	13%	28%	15%

Type of vibration

Figure 9 All workers who reported exposure to vibration: Combinations of vibration control measures that were provided within each type of vibration

What employment and exposure characteristics predicted the provision of vibration control measures in the workplace?

The provision of the individual types of vibration control measures were modelled using logistic regression analyses. Only the model examining the provision of gloves produced reliable results. The failure of the other models was due to either the model assumptions regarding the goodness of fit being violated or the models explaining very little of the variation in the data. This implies that the vibration exposure and employment factors included in the models were not good predictors of the provision of controls. Other factors, not surveyed, may be better predictors of control provision, or control provision may be inherently random and not consistently explained by any demographic, employment or exposure factors. However, given that the NHEWS data did not effectively link exposure and control provision or usage data, it remains a strong possibility that employment and exposure factors may explain vibration control provision. Future iterations of this survey, with better designed exposure and control questions may improve these relationships.

Provision of combinations of vibration control measures relative to no control measures

Despite the failure of the regressions examining the provision of the individual control measures against vibration, a multinomial logistic regression model examining the provision of various combinations of vibration control measures proved robust and a reasonable predictor of the provision of vibration controls in the national priority industries. The following combinations of vibration control measures were modelled: *vibration control measures other than PPE*, *vibration control measures and PPE*, and *PPE only* relative to the provision of *no control measures*[16]. The following factors had a statistically significant effect on the provision of the combinations of vibration

[16] Control measures refers to the use of vibration dampeners, vibration absorbing seats, the purchasing of products with less vibration and the provision of training to prevent the health problems associated with vibration. PPE refers to the provision of gloves.

control measures; occupation, industry, workplace size and type of exposure. The effect of levels within individual factors on the provision of controls was relative to the factor reference group. The parameter estimates of the model are presented in Table 10 and the full model output can be found in Appendix B, Table 17.

The odds of being provided with *vibration control measures other than PPE*, as opposed to being provided with *no control measures*, were increased by a factor of 3.6 for workers who worked in the *Agriculture, forestry and fishing* industry relative to those who worked in the *Health and community services* industry. The odds of being provided with *vibration control measures other than PPE* were also increased by factors of more than 3.5 for workers who were exposed to either whole body vibration or both hand-arm and whole body vibration in comparison to those workers who were exposed to hand-arm vibration only.

Managers were more than five times more likely than *Clerical and administrative workers and Sales workers* to report that they were provided with *control measures and PPE*, as opposed to being provided with *no control measures*. This was the only occupation associated with increased odds of *providing control measures and PPE* when compared with *Clerical and administrative workers and Sales workers*.

Compared to workers in the *Health and community services* industry, workers in the *Manufacturing* industry were more than six times more likely to be provided with *control measures and PPE* as opposed to being provided with *no vibration controls*. This was followed by the *Construction* (more than four times more likely), *Agriculture, forestry and fishing* (approximately four times more likely) and *Transport and storage* (approximately three times more likely) industries.

Smaller workplaces were less likely than larger workplaces to provide *control measures and PPE*. For example, the odds that *vibration control measures and PPE* were provided in workplaces with less than five workers were decreased by a factor of 0.263 relative to workplaces with 200 or more employees.

The likelihood of a worker being provided with *vibration control measures and PPE* increased by more than a factor of three for those workers who reported they were exposed to both hand-arm and whole body vibration relative to those only exposed to hand-arm vibration. There was no significant difference in the odds of being provided with *vibration control measures and PPE* between workers exposed to whole body vibration and those exposed to hand arm vibration.

The likelihood of being provided with *PPE only*, as opposed to *no vibration controls*, was increased for workers who were *Managers* and *Labourers* relative to workers in the *Clerical and administrative workers* and *Sales workers*. *Managers* were more than eight times more likely and *Labourers* were more than four times more likely to report *PPE only* was provided.

The odds of a worker reporting that PPE was the only vibration control measure provided in the workplace, as opposed to being provided with no controls, were increased for workers in the *Manufacturing* industry relative to workers in the *Health and community services* industry. There were no significant differences between the remaining priority industries and the *Health and community services* industry in terms of the likelihood of being provided with *PPE only*.

The odds of being provided with *PPE only*, as opposed to *no vibration controls*, were significantly decreased for smaller workplaces in comparison to the largest workplaces, with 200 or more employees.

The likelihood of being provided with *PPE only*, as opposed to *no vibration controls*, was significantly increased for workers exposed to both hand-arm and whole body vibration relative to workers who were only exposed to hand-arm vibration.

Table 10 The parameter estimates of the multinomial logistic regression model examining the provision of various combinations of vibration control measures relative to the provision of no control measures. Only statistically significant differences in odds ratios are presented.

MODEL FACTORS The reference group in the model is 'no control measures'	The odds of reporting vibration control measures other than PPE were provided (as opposed to no control measures) were…	…by a factor of (Odds ratio) relative to the model factor reference group	The odds of reporting vibration control measures and PPE were provided (as opposed to no control measures) were…	…by a factor of (Odds ratio) relative to the model factor reference group	The odds of reporting PPE only were provided (as opposed to no control measures) were…	…by a factor of (Odds ratio) relative to the model factor reference group
	Vibration control measures other than PPE		Vibration control measures and PPE		PPE only	
Occupation						
Managers	-	-	Increased	5.694	Increased	8.126
Professionals	-	-	-	-	-	-
Technicians & trades workers	-	-	-	-	-	-
Community & personal services workers	-	-	-	-	-	-
Labourers	-	-	-	-	Increased	4.198
Machinery operators & drivers	-	-	-	-	-	-
Clerical & administrative workers and Sales workers	**Reference group**		**Reference group**		**Reference group**	
Industry						
Manufacturing	-	-	Increased	6.208	Increased	3.793
Transport & storage	-	-	Increased	3.043	-	-
Construction	-	-	Increased	4.494	-	-
Agriculture, forestry & fishing	Increased	3.555	Increased	4.004	-	-
Health & community services	**Reference group**		**Reference group**		**Reference group**	
Workplace size						
Less than five	-	-	Decreased	0.263	Decreased	0.350
Five to 19	-	-	Decreased	0.277	Decreased	0.372
20 to 199	-	-	Decreased	0.468	-	-
200 or more	**Reference group**		**Reference group**		**Reference group**	
Type of exposure						
Vibration type not determined	-	-	-	-	-	-
Whole body vibration	Increased	3.593	-	-	-	-
Both hand-arm & whole body vibration	Increased	3.650	Increased	3.280	Increased	2.529
Hand-arm vibration	**Reference group**		**Reference group**		**Reference group**	

Policy implications

Vibration standards and regulation

No Australian jurisdiction currently has specific vibration regulations. However many jurisdictions in Australia mention vibration to varying degrees in their general regulations, codes of practices and guidance material. This differs to the situation in Europe where the European Parliament and the Council of the European Union has issued a Directive[17] regarding the minimum health and safety requirements for workers exposed to vibration (2002/44/EC 2002). The regulations (e.g. the United Kingdom *Control of Vibration at Work Regulations 2005)* arising from this directive were implemented in 2005.

Unfortunately it is not possible to determine if the different approaches to the regulation of vibration in Australia, Europe and the United Kingdom have resulted in different outcomes in terms of vibration exposure for several reasons. Firstly, the British national surveys on whole body vibration and hand-arm vibration were undertaken before 2005 and the EWCS data was collected in 2005, which is the year the *Control of Vibration at Work Regulations 2005* were implemented. Secondly, it is not possible, in any of the datasets, to determine if workers' exposures to vibration were hazardous because the levels of vibration are not known. Thirdly, the employment demographics vary between Australia, Europe and the United Kingdom. Finally, the surveys collected data on vibration exposure in different ways. However, despite these limitations some general comparisons can be made.

The NHEWS found that 30% of workers in the survey reported they were exposed to vibration. When weighted to reflect the Australian working population, these data suggested approximately 24% of Australian workers were exposed. The fourth EWCS found that 24% of workers in the EU27 and 23% of workers in the EU15 were exposed to vibration in the workplace and 15% of workers in the United Kingdom were exposed to vibration. Compared to the third EWCS (run in 2000), vibration exposure for workers in the EU15 has fallen from 24% and for workers in the United Kingdom from 18%[18] (Paoli & Merllié 2001; EWCO 2007). This raises the possibility that the 2002 European Directive on vibration had an impact on vibration exposure in the UK before the regulations came into force in 2005. The fifth EWCS has just been completed and the results will be published within the next 12 months. It will be interesting to see how exposure levels to vibration have changed since 2005, particularly when examining exposure levels concurrently with health data as most of the adverse health effects from vibration exposure occur over the long term. These findings could be an important mandate for introducing regulations on vibration exposure in Australia.

With this in mind, it is recommended that an official investigation be undertaken on whether or not it would be beneficial for Australia to adopt the minimum health and safety requirements for vibration determined in the EU directive in regulations or

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[17] "*An EU Directive is a legislative act of the EU, which requires member states to achieve a particular result without dictating the means of achieving that result. It can be distinguished from EU Regulations which are self-executing and do not require any implementing measures"* CEN (2010) *FAQs*. Retrieved 11 May 2010, from http://www.cen.eu/cen/Pages/FAQ.aspx#14.

[18] The third EWCS was undertaken prior to the expansion of the EU, thus EU27 figures are not determined. Vibration exposure for the United Kingdom has been determined using data from the third EWCS where workers who reported being exposed to vibration for at least a quarter of the time are considered to be exposed to vibration. This is consistent with the methodology used in the EWCS.

codes of practice. This study could also investigate whether or not plant design standards/regulations should include specific requirements for vibration. Furthermore, Australian Standards should consider revisiting *AS 2763-1988 – Vibration and Shock – Hand-transmitted vibration – Guidelines for the measurement and assessment of human exposure* as it is based on the 1986 version of *ISO 5349*, which was revised in 2001.

Young workers

Data from the NHEWS survey shows that young workers are more likely to be exposed to vibration than older workers. This is consistent with the findings of the EWCS where respondents younger than 24 years old reported the highest percentage of exposure to vibration (26%) (Parent-Thirion et al. 2007). However, workers' compensation data shows that young workers make fewer claims for vibration related injuries/disease than older workers.

There are a number of possible explanations for the difference observed between the NHEWS exposure data and the workers' compensation statistics. First, many conditions and diseases associated with exposure to vibration have long latency periods. This means that workers may not be aware of their condition until they are older. Second, young workers may be more reluctant than older workers to make workers' compensation claims for their injuries out of concern for their future employment. Third, younger workers may move out of occupations where they are exposed to vibration and never make a compensation claim for vibration related condition or disease that developed while being exposed to vibration.

Greater emphasis should be placed on making younger people aware of the possible conditions and diseases that can develop from exposure to vibration. Measures for early detection of deleterious health effects associated with vibration exposure, such as regular health checks of exposed workers, should also be implemented to prevent young people from aggravating these conditions further. Indeed, health surveillance is a recommendation in the Australian Standard for hand-arm vibration (Australian Standards 1988).

Workplace size

The analysis of the NHEWS data showed that smaller workplaces, in which workers were more than twice as likely to report exposure to hand-arm vibration than larger workplaces, were less likely than larger workplaces to have comprehensive vibration control measures in place (that is, elimination/substitution/engineering/training vibration control measures and PPE). This finding is supported by those of the European Agency for Safety and Health at Work's pilot study on the state of occupational health and safety in the EU, where comments from participating countries suggested that smaller businesses were at greater risk from the health effects caused from exposure to vibration because of the use of older machines, and lack of awareness of the problem and lack of resources to address the problem (OSHA 2000).

Smaller work places were also more likely than larger workplaces to provide no vibration control measures. Therefore, workers in smaller workplaces may be at greater risk of developing adverse health conditions and diseases associated with exposure to vibration. Efforts need to be made to ensure that workers in smaller workplaces as a priority, and all workplaces in general, understand the health consequences of vibration exposure and that all workplaces meet their obligations for worker health and safety.

Training

These analyses have shown that only a small percentage (27%) of workers who reported they were exposed to vibration also reported that they had received training on how to prevent or recognise the health problems associated with vibration. These findings imply that there is a considerable lack of awareness in the working community of the consequences of vibration exposure in addition to a lack of knowledge about how to minimise vibration exposure and prevent the health problems associated with exposure. All workers who are exposed to vibration hazards (or likely to be exposed to vibration) should receive training on this matter and efforts must be made to ensure that training occurs.

Industry

Analysis of the NHEWS data shows that workers in industries with a highly likelihood of reporting exposure to vibration in the workplace (e.g. *Agriculture, forestry and fishing* and *Construction)* also have high odds of being provided with comprehensive types of vibration controls. The combination of elimination, substitution, engineering or administrative controls in conjunction with PPE is considered to be comprehensive. However, the provision of vibration *control measures other than PPE* is also satisfactory provided that the control measures adequately control vibration levels. Therefore, as long as the control measures are appropriate for the situation and they are used properly, then the workers in these industries are more likely to be appropriately protected and therefore at a lower risk of risk of developing any adverse health effects associated with vibration exposure. Unfortunately, we were unable to assess the adequacy of the control measures provided to vibration exposed workers in this study.

The analysis of the NHEWS data showed that of the five priority industries, workers in the *Health and community services industry* reported the lowest rates of exposure to vibration (11%). However, of the workers within this industry who reported being exposed to vibration, 47% were provided with no control measures. This highlights that it is important that authorities ensure that awareness campaigns do not just target industries with high vibration exposure rates. Furthermore, more research is required within the *Health and community services* industry to determine whether or not vibration exposures pose health risks to workers and whether or not the exposures are controlled appropriately.

It is important to keep in mind that these analyses were restricted to the priority industries and that the priority industries were used for these analyses because of sample size rather than any expectations concerning vibration exposure. Therefore, workers from some industries, such as the *Mining* industry*,* in which workers were exposed to numerous sources of vibration, have not been included despite large percentages of workers in this industry (61%) reporting they were exposed to vibration. It is important that this industry in particular and the other non priority industries in general, must not be overlooked either in terms of policy initiatives or future research.

Occupations

This study has revealed that high percentages of workers who were *Technicians and trade workers*, *Machinery operators and drivers* and *Labourers* reported exposure to vibration (60%, 68% and 49% respectively). However, none of these occupations had a higher likelihood of being provided with *vibration control measures and PPE* or *vibration control measures other than PPE* (relative to the provision of no controls) compared to *Clerical and administrative workers and Sales workers*. Only *Labourers* and *Managers* were more likely to be provided with *PPE only* compared to *Clerical*

and administrative workers and Sales workers. This raises the possibility that these high exposure occupations are poorly provided with vibration control measures. However, the risks these vibration exposures pose for worker health need to be quantified before drawing any firm conclusions on the adequacy of control provision. In the meantime, education and awareness campaigns on the risk of vibration in the workplace should be targeted toward these occupations where workers are potentially at risk.

Of the workers who reported being exposed to vibration in the workplace, *Professionals*, *Community and personal service workers* and *Clerical and administrative workers and Sales workers* recorded the highest percentages of exposed workers who were not provided with vibration control measures (47%, 44% and 42% respectively). However again, further research is required within these occupations to determine whether or not vibration exposure levels are hazardous. Also more research on the barriers and enablers to the provision of vibration control measures would benefit policy makers.

Future research

Although the NHEWS data are subject to various limitations outlined earlier in this report, the survey has provided one of the only national estimates of workers' exposure to vibration in the workplace by key demographic and employment characteristics.

Obtaining regular updates of vibration exposure surveillance data is important for work health and safety and workers' compensation policy. It enables interventions to be focussed effectively, before the workers develop any adverse health effects related to vibration exposure. Although the data on vibration exposures could be improved and expanded in a number of ways (some of which are outlined in the next section of this report) it is recommended that the surveillance is continued. Furthermore, it would be beneficial if measurements of actual vibration exposures in the workplace were undertaken (i.e. duration of exposure and level of vibration for each source of exposure in the workplace) and matched to the self reported exposure data. This would improve the scope of the analyses undertaken and conclusions drawn from surveillance research. Similar outcomes could also be achieved by matching vibration exposure sources to databases of source vibration levels. For example, the Hand-Arm Vibration Test Centre (HAVTEC) have established a register that provides information on hand-arm vibration exposure levels of a variety of hand-held power tools (OPERC 2010).

Recommendations for future research

Although the NHEWS survey provided a needed insight into Australian workers exposure to vibration, the survey had several limitations. The following additions to the NHEWS survey are recommended for future research into vibration exposure in Australia:

1. In addition to asking respondents to report the main vibrating tools, equipment and vehicles they are exposed to, the duration of exposure and vibration level for each tool, piece of equipment or vehicle should also be obtained. This will allow researchers to better determine an estimate of the respondent's actual level of vibration exposure and whether their level of vibration exposure is hazardous.
2. Only one time scale (hours per day or hours per week) should be used to collect information on how long the respondents worked with tools, equipment or vehicles that vibrate. This will eliminate the issues related to the conversion of two scales into one common scale. However, issues related to determining the pattern of vibration exposure (consistent or intermittent) will still be present. These issues could be partially addressed by asking a further question on their normal pattern of exposure for each reported source of vibration exposure.
3. Both vibration exposed and not exposed respondents should be asked about the vibration control measures provided in their workplace. In addition, all workers should be prompted about whether 'other' control measures not specifically surveyed are provided in their workplace. Further, respondents should be asked if they used each of the control measures provided and which control measure/s they used for each source of exposure.
4. A question on whether the respondent experiences any adverse health effects during or after being exposed to vibration should be asked. Such information would be useful in determining any patterns between vibration exposure, control measures and adverse health effects.
5. A question (or series of questions) about what the respondents' attitudes are towards their exposure to vibration in the workplace and what they think their employers attitudes towards vibration exposure, would provide valuable information to policy makers and regulators.

In addition to collection of self-reported data on vibration exposure in the workplace, measured exposures to vibration and the use of vibration control measures from a representative sample of Australian workers should ideally be undertaken. Not only can the measured exposures and use of vibration control measures be used to validate the self reported data on vibration, but they can provide a more comprehensive description of vibration exposure in all Australian workplaces.

The NHEWS survey has highlighted a variety of areas where research is required to further our understanding of vibration exposure in Australia. These include:

1. Research to determine the barriers and enablers of the provision of vibration control measures should be conducted. Particular attention should be given to smaller workplaces as the NHEWS data showed that of the workers who reported they were exposed to vibration in the workplace, those in smaller workplaces were less likely to be provided with comprehensive vibration control measures and more likely to be provided with no control measures than larger workplaces.
2. A large percentage of workers in the *Health and community services* industry who reported they were exposed to vibration also reported they were not provided with any vibration control measures. Assessments of vibration exposure in this industry should be undertaken to determine if the exposure levels are

hazardous to the workers health. Research on the barriers to the provision of vibration control measures should also be conducted for this industry as well as other industries (i.e. *Mining*) that are known to have rate of exposure to vibration.

3. Similar research should be undertaken on workers in the occupations of *Professionals*, *Community and personal service workers* and *Clerical and administrative workers and Sales workers* in addition to occupations that are known to have high rates of exposure to vibration, since large percentages of workers in these occupations reported they were not provided with any vibration control measures.

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Appendix A. NHEWS survey methodology

Survey design

The purpose of the NHEWS survey was to gather information to guide decision makers in developing prevention initiatives that ultimately lead to a reduction in occupational disease. Therefore, the survey was designed to collect demographic (e.g. sex, age, educational qualifications) and employment information (occupation, industry, employment conditions, size of workplace) in addition to worker exposure to a variety of different occupational hazards and information about the hazard controls provided in the workplace.

The design and wording of the survey was undertaken by the ASCC in consultation with Australian occupational health and safety regulators and a panel of experts. It was based on existing Australian and international hazard exposure survey instruments. For example, these included the EWCS, the National Exposures at Work Survey (NIOSH, USA), the Swedish Workplace and Environment Survey and the Victorian WorkCover Authority Worker Survey amongst others.

A draft of the survey was reviewed by Dr Rebbecca Lilley, Preventative and Social Medicine, Injury Prevention and Research Unit, University of Otago, New Zealand who is an expert on occupational hazard exposure. Comments and feedback from her review were incorporated into the survey instrument.

Skirmish testing (undertaken on ASCC staff) and cognitive testing on eleven workers, who were of a low literacy or non-English speaking background, and worked in several industries, was undertaken in face to face interviews.

The survey was piloted by the Victorian WorkCover Authority on 160 workers using programming issues.

Feedback from the cognitive and pilot testing was incorporated into the final survey instrument. Of particular relevance to the vibration data was the recommendation that vibration exposure be collected on two different scales (hours per day and hours per week) since many workers had difficulty describing a typical day at work.

The NHEWS research design and survey instrument were submitted to the University of Sydney Human Research Ethics Committee. The approval reference number is: 02-2008/10506. The research design and instrument met the National Statistical Clearing House guidelines. The research design and instrument were also in accordance with the Australian Market and Social Research Society (AMSRS) guidelines and the research company that undertook the CATI is a member of the AMRSRS and met all privacy and other guidelines.

More information, including the full survey instrument for all occupational hazards and their controls, can be found in the National Hazard Exposure Worker Surveillance (NHEWS): Survey Handbook and the National Hazard Exposure Worker Surveillance (NHEWS) Survey: 2008 Results, which are published on the Safe Work Australia website[19].

19 http://www.safeworkaustralia.gov.au/swa/AboutUs/Publications/2008ResearchReports.htm

Vibration exposure and vibration exposure control measures questions

The specific questions relating to exposure to vibration were as follows:

1. On a typical day at work last week, how long (hours per day/hours per week) did you work with tools, equipment or in vehicles that vibrate?
2. What were the main vibrating tools, equipment or vehicles you used?
3. Does your employer (or, in the case of self employed/contractors etc, *do you*) do any of the following to prevent health problems caused by working with vibrating equipment or in vehicles that vibrate?
    a. Provide gloves
    b. Use vibration dampeners
    c. Provide vibration absorbing seats
    d. Purchase products with less vibration
    e. Provide training on how to prevent health problems caused by vibration
    f. Other
    g. Nothing
    h. Don't know
    i. Refused

Vibration was not defined in the survey. All questions (except screening and demographics) related to the respondent's main job, which was the job in which the respondent worked the most hours.

Survey fielding

The NHEWS survey was conducted by Sweeney Research using CATI. The survey obtained an Australia-wide representative sample of 4500 workers across all seventeen Australian industries. Households were randomly selected using the desktop marketing systems (DTMS) database, which collects its information from directories such as the White / Yellow pages. To be eligible for the research, respondents were required to have worked in the last week and to have earned money from the work. Where more than one individual was eligible for the research, the person whose birthday came next was selected. Overall, the survey achieved a 42.3% response rate.

The sampling scheme for the NHEWS can be considered as two stages with three waves of data collection. The first wave resulted in 1900 completed interviews which met quotas by sex within industry (five national priority industries: *Manufacturing*, *Transport and storage, Construction, Health and community services* and *Agriculture, forestry and fishing*) within state (1300 interviews), plus an additional sample coming from state contributions (600 interviews).

The second and third waves of the survey (n_{total} = 2600) placed no restrictions on industry and differed only in that some additional questions were asked. The second wave involved recontacting those households that had not been interviewed in the first wave due to being out of scope (e.g. had no persons working in the priority industries) or quotas already being met, and had given permission to be recontacted for further studies. This wave resulted in 485 completed interviews. The third wave (n=2115) resulted in the balance of the 4500 interviews, meeting sex within state quotas.

For reporting purposes the following industries were collapsed into two integrated industries: 1) *Wholesale and Retail trade* and 2) *Cultural and recreational services and Personal and other services*.

Data analyses

The data were analysed using SPSS 18.0. All data were inspected prior to formal analysis for missing cases or unusual values. The original data received from Sweeney Research on the source of vibration was recoded to conform to the TOOCS. The data presented in this report therefore differ from the preliminary results report published in 2008 on the Safe Work Australia website.

In addition, a new variable describing the bodily location of the vibration (type of vibration) was created using the recoded vibration source data. The types of vibration in the new variable were hand-arm vibration, whole body vibration, both hand-arm and whole body vibration or vibration type not determined. In some cases it was difficult to determine the type of vibration exposure a worker would have experienced and in these cases a best guess was made based on the source of vibration and any other job description information that was recorded in the verbatim from the survey.

Duration of exposure data

The analysis of the duration of exposure data was complicated by the fact that workers reported their exposure to vibration either in terms of hours per day (n=807) or in terms of hours per week (n=551). Conversion of these two scales of measurement to one common scale was not straightforward owing to probable differences in the patterns of vibration exposure between those workers who reported daily durations of exposure and those who reported weekly patterns of exposure. People with consistent exposure to vibration may have reported their duration of exposure in hours per day while people with highly variable durations of exposure may have reported their duration of exposure in hours per week.

In order to address this problem and to be consistent with the approach of the EWCS, the proportion of time a worker was exposed to vibration in the workplace was calculated. For workers who reported their exposure to vibration in hours per day, the formula below was used:

$$PE = RE_{day} / HW_{day} \qquad \text{where: } HW_{day} = TH_{week} / DW$$

where PE is the proportion of time a worker is exposed to vibration in the workplace, RE_{day} is the reported hours exposed to vibration per day, HW_{day} is the hours worked per day, TH_{week} is the total hours worked per week and DW is the number of days worked per week. Any value for proportion exposed per day greater than one was recoded to one to ensure that workers could not be exposed to occupational vibration more hours than they worked.

For workers who reported their exposure to vibration in hours per week, the formula below was used:

$$PE = RE_{week} / TH_{week}$$

where PE is the proportion of time a worker is exposed to vibration in the workplace, RE_{week} is the reported hours exposed to vibration per week and TH_{week} is the total hours worked per week. Any value for proportion exposed per day greater than one was recoded to one.

To simplify the duration data, the proportion of workers exposed to vibration in the workplace was then categorised into four quartiles of exposure (exposed up to a quarter of the time, exposed between a quarter of the time and half the time, exposed between half the time and three quarters of the time and exposed between three

quarters of the time and all the time) based on the proportion of time a worker was exposed to vibration in the workplace. The limitation of this method, which is also used by the European Foundation for the Improvement of Living and Working Conditions in their EWCS (Parent-Thirion et al. 2007), is that it does not reflect the actual length of exposure to vibration. For example a worker who is exposed to vibration for 10 hours of a 20 hour working week has the same proportional exposure as a worker who is exposed to vibration for 20 hours of a 40 hour working week. This is a problem because the length of exposure to vibration has important consequences for worker health.

Vibration exposure controls data

The vibration control measures that were provided in the workplace were categorised in several different ways. The first way reflected the hierarchy of controls. The categories are as follows 1) Eliminate or substitute; 2) Engineering; 3) Administrative; and 4) PPE. Other methods of categorising the control measures were to sum the number of control measures used in the workplace, to simplify the data to either the presence or absence of control measures or to describe various combination of control provision relative to the provision of PPE. All of these methods have been used in the data analyses.

Exposure to vibration logistic regression model

The data were analysed with respect to the likelihood of reporting exposure to vibration by undertaking a multinomial logistic regression that examined the impact of various demographic and employment factors. The data were restricted to only those workers in the five priority industries for modelling simplicity and owing to the very small sample sizes in some of the other industries. Furthermore, two occupation groups, *Clerical and administrative workers* and *Sales workers* were pooled due to the small sample size of *Sales workers* captured in the survey. A small number of workers did not know their occupation and were excluded from the analysis. Further, those workers who gave an 'other' response for highest education qualifications were also excluded from the analysis.

The dependent variable was binary and it encoded whether or not the workers reported an exposure to vibration. All reported exposures to vibration, irrespective of duration, were assumed to be non-trivial and considered as a valid report of exposure to vibration. Factors included in the model were gender, age, highest education qualification, income, type of employment (permanent, casual, fixed term), industry, occupational skill level, workplace size, whether of not they worked at night, whether or not a language other than English was spoken at home and occupation.

Non significant factors were removed from the model following a backward stepwise deletion until the minimal model remained. Also occupational skill level was removed because it was found to be correlated with occupation. The significant factors were gender, age, income, highest education qualification, occupation and industry. The reference group in the model was no reported vibration exposure. As such, the results of the analysis are therefore expressed in the following manner: the odds of reporting exposure to vibration rather than not reporting an exposure increased/decreased by a factor of *x* as a result of being employed in *y* industry/occupation/demographic as opposed to *z* industry/occupation/demographic, while controlling for the effects of other variables.

Exposure to different types of vibration logistic regression model

The data was analysed with respect to the likelihood of reporting exposure to different types of vibration (no vibration exposure, vibration type not determined, hand-arm vibration only, whole body vibration only and both hand-arm and whole body vibration) by undertaking a multinomial logistic regression that examined the impact of various demographic and employment factors on the type of vibration exposure. The data was restricted to only those workers in the five priority industries for modelling simplicity and owing to the very small sample sizes in some of the other industries. Furthermore, two occupation groups, *Clerical and administrative workers* and *Sales workers* were pooled due to the small sample size of *Sales workers* captured in the survey. A small number of workers did not know their occupation and were excluded from the analysis. Further, those workers who gave an 'other' response for highest education qualifications were also excluded from the analysis.

The dependent variable had five mutually exclusive levels (no vibration exposure, vibration type not determined, hand-arm vibration only, whole body vibration only and both hand-arm and whole body vibration. All reported exposures to vibration, irrespective of duration, were assumed to be non-trivial and considered as a valid report of exposure to vibration. Factors examined in the model were gender, age, highest education qualification, income, type of employment (permanent, casual, fixed term), industry, occupational skill level, workplace size, whether of not they worked at night, whether or not a language other than English was spoken at home and occupation.

Non significant factors were removed from the model using backward stepwise deletion until the minimal model remained. Also occupational skill level was removed because it was found to be correlated with occupation. The significant factors were gender, age income, workplace size, highest education qualification, industry and occupation. The reference group in the model was 'not exposed to vibration'. As such, the results of the analysis are therefore expressed in the following manner: the odds of reporting exposure to *w* type of vibration rather than not being exposed to vibration increased/decreased by a factor of *x* (odds ratio) as a result of being employed in *y* industry/occupation/demographic as opposed to *z* industry/occupation/demographic, while controlling for the effects of other variables.

The provision of vibration controls measures logistic regression model

The data was analysed with respect to the likelihood of providing control measures for vibration by undertaking a multinomial logistic regression that examined the impact of various employment and exposure factors on the provision of various combinations of vibration control measures. Only employment and exposure factors were considered because the question related to controls that were provided in the workplace rather than specific workers. The data were restricted to only those workers in the five priority industries for modelling simplicity and owing to the very small sample sizes in some of the other industries. Two occupation groups, *Clerical and administrative workers* and *Sales workers* were pooled due to the small sample size of *Sales workers* captured in the survey. A small number of workers did not know their occupation and were excluded from the analysis.

The dependent variable had four levels; *no vibration control measures provided*, *vibration control measures other than PPE, vibration control measures and PPE*, and *PPE only*. Factors included in the model were type of employment (permanent, casual, fixed term), industry, workplace size, occupational skill level, whether of not they worked at night, occupation, duration of exposure and type of exposure.

Non-significant terms were removed from the model following backward stepwise deletion until the minimal model remained. Factors that were statistically significant predictors of vibration control provision included occupation, industry, workplace size, type of exposure and duration of exposure. However, inclusion of duration of exposure caused the model assumptions about goodness of fit to be violated. This factor was therefore excluded from the final model. The reference group in the model was no control measures provided.

The results of the analysis are expressed in the following manner: the odds of reporting *w* vibration control measure rather than no vibration control measures were increased/decreased by a factor of *x* as a result of being employed in *y* employment factor as opposed to *z* employment factor, while controlling for the effects of other variables.

Appendix B. Results: statistical analyses and model output

Appendix B presents the statistical output of the various models and data analyses that underpin the findings of this report.

Table 11 Vibration exposure control measures by demographic, employment and exposure characteristics

	Percentage of exposed workers within each category who were provided gloves in the workplace	Percentage of exposed workers within each category who were provided with vibration dampeners in the workplace	Percentage of exposed workers within each category who were provided with vibration absorbing seats in the workplace	Percentage of exposed workers within each category where products with less vibration were purchased in the workplace	Percentage of exposed workers within each category who were provided with training on how to prevent the health problems associated with vibration in the workplace	Percentage of workers within each category who reported being exposed to vibration
Gender						
Male	69%	21%	32%	34%	28%	45%
Female	46%	13%	20%	17%	18%	11%
Age						
15-24	68%	12%	16%	24%	26%	44%
25-34	67%	19%	26%	29%	20%	35%
35-44	65%	21%	34%	29%	23%	29%
45-54	63%	22%	31%	39%	32%	30%
55+	67%	18%	34%	26%	27%	25%
Income						
Under $50,000	63%	17%	26%	28%	22%	29%
$50,000 to $99,999	68%	20%	33%	33%	29%	34%
$100,000 or over	71%	28%	42%	43%	39%	26%
Education						
Year 12 not completed	64%	17%	33%	30%	22%	34%
Year 12 completed	65%	19%	32%	27%	23%	26%
Trade certificate/TAFE	69%	21%	29%	33%	29%	40%
Bachelor's degree or higher	49%	14%	24%	25%	18%	13%
Other	65%	29%	45%	45%	38%	39%
Workplace size						
Less than five employees	59%	17%	27%	33%	18%	42%
five to 19 employees	61%	18%	28%	30%	27%	33%
20 to 199 employees	68%	18%	30%	28%	27%	27%
200 or more employees	76%	28%	39%	35%	41%	22%

	Percentage of exposed workers within each category who were provided gloves in the workplace	Percentage of exposed workers within each category who were provided with vibration dampeners in the workplace	Percentage of exposed workers within each category who were provided with vibration absorbing seats in the workplace	Percentage of exposed workers within each category where products with less vibration were purchased in the workplace	Percentage of exposed workers within each category who were provided with training on how to prevent the health problems associated with vibration in the workplace	Percentage of workers within each category who reported being exposed to vibration
Type of Exposure						
Hand-arm	66%	16%	11%	30%	24%	N/A
Whole body	59%	21%	50%	30%	27%	N/A
Both hand-arm & whole body	80%	25%	36%	40%	33%	N/A
Not determined	46%	18%	15%	10%	21%	N/A
Industry						
Manufacturing	82%	21%	24%	36%	28%	44%
Transport & storage	58%	20%	49%	27%	27%	49%
Construction	68%	22%	24%	33%	30%	55%
Agriculture, forestry & fishing	64%	21%	48%	40%	17%	60%
Health & community services	44%	6%	16%	15%	20%	11%
Other industries	52%	17%	23%	26%	28%	14%
Occupation						
Don't know	79%	21%	53%	42%	47%	18%
Managers	69%	19%	45%	43%	24%	31%
Professionals	42%	10%	15%	17%	24%	10%
Technicians & trades workers	70%	18%	18%	32%	26%	60%
Community & personal service workers	46%	13%	27%	19%	19%	13%
Labourers	70%	26%	25%	30%	28%	49%
Machinery operators & drivers	68%	24%	54%	32%	29%	68%
Clerical & administrative and Sales workers	39%	15%	33%	25%	24%	9%

Demographic and employment characteristics of Australian workers exposed to vibration

Multinomial logistic regression for exposure to vibration

Table 12 Likelihood ratio tests of the multinomial logistic regression: the factors that had a significant impact on the likelihood of reporting exposure to vibration[20]

Likelihood ratio tests			
Model Factors	**Chi-square**	**df**	***P***
Gender	50.620	1	0.000
Age	30.903	4	0.000
Occupation	155.740	6	0.000
Industry	54.961	4	0.000
Education	16.048	3	0.001
Income	9.633	2	0.008
Minimal model	**907.503**	**20**	**0.000**
Goodness of fit (Pearson)	**920.501**	**913**	**0.424**
Nagelkerke Pseudo R-square	**0.393**		

[20] The variable for occupational skill level was also found to be significant, however further testing found it was correlated with education (Two tailed Pearson Correlation = -0.435). As such it was excluded from the model. This is also the case for the model examining the types of vibration reported and presented in Table 14.

Table 13 The parameter estimates of the minimal multinomial logistic model exploring the likelihood of reporting exposure to vibration

Whether or not a worker reported exposure to vibration[a]	Parameter estimates					
Model factors	**B**	**Std. Error**	**Wald**	**df**	***P***	**Odds ratio Exp(B)**
Gender						
Male	0.954	0.135	50.197	1	0.000	2.597
Female	0[(b)]	.	.	0	.	.
Age						
15-24 years	1.073	0.240	19.975	1	0.000	2.923
25-34 years	0.706	0.166	18.042	1	0.000	2.026
35-44 years	0.325	0.141	5.284	1	0.022	1.384
45-54 years	0.430	0.135	10.110	1	0.001	1.537
55+ years	0[(b)]	.	.	0	.	.
Income						
Under $50 000	0.389	0.182	4.572	1	0.032	1.475
$50 000 to $99 999	0.522	0.172	9.264	1	0.002	1.686
$100 000+	0[(b)]	.	.	0	.	.
Education						
Year 12 not completed	0.154	0.195	0.628	1	0.428	1.167
Year 12 completed	-0.195	0.220	0.788	1	0.375	0.823
Trade certificate/TAFE	0.393	0.160	6.059	1	0.014	1.482
Bachelor's degree or higher	0[(b)]	.	.	0	.	.
Occupation						
Managers	1.057	0.234	20.341	1	0.000	2.878
Professionals	0.358	0.257	1.929	1	0.165	1.430
Technicians & trades workers	1.872	0.217	74.220	1	0.000	6.502
Community & personal services workers	0.815	0.299	7.424	1	0.006	2.260
Labourers	1.781	0.230	60.073	1	0.000	5.938
Machinery operators & drivers	2.081	0.232	80.252	1	0.000	8.011
Clerical & administrative workers and Sales workers	0[(b)]	.	.	0	.	.
Industry						
Manufacturing	0.655	0.196	11.201	1	0.001	1.924
Transport & storage	0.890	0.220	16.417	1	0.000	2.435
Construction	0.855	0.202	17.953	1	0.000	2.352
Agriculture, forestry & fishing	1.537	0.219	49.299	1	0.000	4.651
Health & community services	0[(b)]	.	.	0	.	.
Intercept	-4.085	0.326	157.461	1	0.000	.

a. The reference category is: no reported exposure to vibration.
b. This parameter is set to zero because it is redundant.

Multinomial logistic regression for exposure to different types of vibration

Table 14 Likelihood ratio tests of the multinomial logistic regression: the factors that had a significant impact on the likelihood of reporting exposure to different types of vibration

Likelihood ratio tests			
Model Factors	**Chi-square**	**df**	***P***
Gender	54.452	4	0.000
Age	47.620	16	0.000
Income	18.383	8	0.019
Workplace size	35.845	12	0.000
Education	30.419	12	0.002
Occupation	381.420	24	0.000
Industry	94.587	16	0.000
Minimal model	**1418.552**	**92**	**0.000**
Goodness of fit (Pearson)	**5732.594**	**5912**	**0.952**
Nagelkerke Pseudo R-square	**0.466**		

Table 15 The parameter estimates of the minimal multinomial logistic model exploring the likelihood of reporting different types of exposure to vibration

Type of exposure relative to not being exposed to vibration[a]						
	Parameter estimates					
Type of vibration control measures and model factors	**B**	**Std. Error**	**Wald**	**df**	***P***	**Odds ratio Exp(B)**
Hand-arm vibration						
Gender						
Male	1.006	0.206	23.757	1	0.000	2.734
Female	0[b]	.	.	0	.	.
Age						
15-24 years	1.182	0.303	15.184	1	0.000	3.262
25-34 years	0.980	0.225	19.006	1	0.000	2.663
35-44 years	0.546	0.197	7.642	1	0.006	1.726
45-54 years	0.588	0.193	9.296	1	0.002	1.801
55+ years	0[b]	.	.	0	.	.
Income						
Under $50 000	0.614	0.259	5.639	1	0.018	1.848
$50 000 to $99 999	0.638	0.244	6.809	1	0.009	1.892
$100 000+	0[b]	.	.	0	.	.
Education						
Year 12 not completed	-0.115	0.288	0.160	1	0.689	0.891
Year 12 completed	-0.111	0.310	0.128	1	0.721	0.895
Trade certificate/TAFE	0.295	0.233	1.604	1	0.205	1.343
Bachelor's degree or higher	0[b]	.	.	0	.	.
Workplace size						
Less than five	0.642	0.216	8.866	1	0.003	1.901
Five to 19	0.642	0.212	9.126	1	0.003	1.900
20 to 199	-0.014	0.202	0.005	1	0.946	0.986
200 or more	0[b]	.	.	0	.	.
Occupation						
Managers	2.462	0.622	15.650	1	0.000	11.726
Professionals	1.934	0.641	9.104	1	0.003	6.917
Technicians & trades workers	3.864	0.601	41.299	1	0.000	47.637
Community & personal services workers	1.639	0.732	5.017	1	0.025	5.151
Labourers	3.551	0.610	33.895	1	0.000	34.834
Machinery operators & drivers	2.290	0.642	12.714	1	0.000	9.874
Clerical & administrative workers and Sales workers	0[b]	.	.	0	.	.

Type of vibration control measures and model factors	B	Std. Error	Wald	df	*P*	Odds ratio Exp(B)
Industry						
Manufacturing	0.746	0.291	6.585	1	0.010	2.108
Transport & storage	0.714	0.340	4.410	1	0.036	2.042
Construction	0.800	0.301	7.068	1	0.008	2.226
Agriculture, forestry & fishing	0.654	0.341	3.670	1	0.055	1.923
Health & community services	0[(b)]	.	.	0	.	.
Intercept	-7.053	0.707	99.521	1	0.000	.
Whole body vibration						
Gender						
Male	0.921	0.181	25.841	1	0.000	2.511
Female	0[(b)]	.	.	0	.	.
Age						
15-24 years	0.675	0.368	3.358	1	0.067	1.964
25-34 years	0.482	0.229	4.423	1	0.035	1.619
35-44 years	0.205	0.193	1.124	1	0.289	1.227
45-54 years	0.379	0.180	4.440	1	0.035	1.461
55+ years	0[(b)]	.	.	0	.	.
Income						
Under $50 000	-0.117	0.249	0.221	1	0.638	0.890
$50 000 to $99 999	0.323	0.230	1.970	1	0.160	1.382
$100 000+	0[(b)]	.	.	0	.	.
Education						
Year 12 not completed	0.116	0.260	0.198	1	0.656	1.123
Year 12 completed	-0.451	0.308	2.140	1	0.144	0.637
Trade certificate/TAFE	0.321	0.222	2.085	1	0.149	1.378
Bachelor's degree or higher	0[(b)]	.	.	0	.	.
Workplace size						
Less than five	-0.136	0.229	0.352	1	0.553	0.873
Five to 19	0.054	0.219	0.061	1	0.806	1.055
20 to 199	0.213	0.190	1.256	1	0.262	1.238
200 or more	0[(b)]	.	.	0	.	.
Occupation						
Managers	0.602	0.291	4.270	1	0.039	1.825
Professionals	-0.335	0.348	0.928	1	0.335	0.715
Technicians & trades workers	0.138	0.298	0.215	1	0.643	1.149
Community & personal services workers	0.842	0.383	4.826	1	0.028	2.322
Labourers	1.194	0.291	16.847	1	0.000	3.300
Machinery operators & drivers	2.247	0.271	68.587	1	0.000	9.461
Clerical & administrative workers and Sales workers	0[(b)]	.	.	0	.	.
Industry						
Manufacturing	0.563	0.289	3.783	1	0.052	1.755
Transport & storage	1.060	0.300	12.486	1	0.000	2.886
Construction	0.528	0.307	2.963	1	0.085	1.696
Agriculture, forestry & fishing	2.033	0.309	43.359	1	0.000	7.637
Health & community services	0[(b)]	.	.	0	.	.
Intercept	-4.068	0.448	82.505	1	0.000	.
Both hand-arm and fullbody vibration						
Gender						
Male	1.276	0.311	16.863	1	0.000	3.581
Female	0[(b)]	.	.	0	.	.
Age						
15-24 years	1.597	0.361	19.562	1	0.000	4.940
25-34 years	0.925	0.285	10.553	1	0.001	2.523
35-44 years	0.127	0.267	0.227	1	0.634	1.136
45-54 years	0.206	0.256	0.648	1	0.421	1.229
55+ years	0[(b)]	.	.	0	.	.

Type of vibration control measures and model factors	B	Std. Error	Wald	df	*P*	Odds ratio Exp(B)
Income						
Under $50 000	0.303	0.341	0.789	1	0.374	1.354
$50 000 to $99 999	0.414	0.326	1.610	1	0.204	1.513
$100 000+	0[(b)]	.	.	0	.	.
Education						
Year 12 not completed	0.600	0.440	1.856	1	0.173	1.822
Year 12 completed	-0.276	0.519	0.283	1	0.595	0.759
Trade certificate/TAFE	0.872	0.395	4.868	1	0.027	2.392
Bachelor's degree or higher	0[(b)]	.	.	0	.	.
Workplace size						
Less than five	0.406	0.290	1.953	1	0.162	1.500
Five to 19	0.270	0.292	0.855	1	0.355	1.310
20 to 199	-0.239	0.281	0.725	1	0.395	0.787
200 or more	0[(b)]	.	.	0	.	.
Occupation						
Managers	1.161	0.583	3.968	1	0.046	3.194
Professionals	0.161	0.718	0.050	1	0.823	1.175
Technicians & trades workers	2.003	0.548	13.384	1	0.000	7.412
Community & personal services workers	1.305	0.846	2.377	1	0.123	3.688
Labourers	1.880	0.567	11.009	1	0.001	6.553
Machinery operators & drivers	1.885	0.578	10.642	1	0.001	6.587
Clerical & administrative workers and Sales workers	0[(b)]	.	.	0	.	.
Industry						
Manufacturing	1.443	0.577	6.267	1	0.012	4.235
Transport & storage	0.882	0.626	1.986	1	0.159	2.415
Construction	1.478	0.585	6.383	1	0.012	4.386
Agriculture, forestry & fishing	2.142	0.601	12.717	1	0.000	8.512
Health & community services	0[(b)]	.	.	0	.	.
Intercept	-7.160	0.866	68.307	1	0.000	.
Vibration type not determined						
Gender						
Male	-0.250	0.483	0.268	1	0.604	0.779
Female	0[(b)]	.	.	0	.	.
Age						
15-24 years	0.327	0.869	0.142	1	0.706	1.387
25-34 years	-0.109	0.726	0.022	1	0.881	0.897
35-44 years	0.306	0.544	0.316	1	0.574	1.358
45-54 years	0.339	0.519	0.426	1	0.514	1.403
55+ years	0[(b)]	.	.	0	.	.
Income						
Under $50 000	1.382	1.081	1.634	1	0.201	3.982
$50 000 to $99 999	1.051	1.063	0.977	1	0.323	2.860
$100 000+	0[(b)]	.	.	0	.	.
Education						
Year 12 not completed	-0.183	0.801	0.052	1	0.820	0.833
Year 12 completed	0.966	0.668	2.087	1	0.149	2.626
Trade certificate/TAFE	0.193	0.552	0.122	1	0.727	1.212
Bachelor's degree or higher	0[(b)]	.	.	0	.	.
Workplace size						
Less than five	0.388	0.656	0.350	1	0.554	1.474
Five to 19	0.126	0.661	0.036	1	0.849	1.134
20 to 199	0.704	0.537	1.715	1	0.190	2.022
200 or more	0[(b)]	.	.	0	.	.
Occupation						
Managers	0.066	0.816	0.007	1	0.935	1.069
Professionals	0.655	0.700	0.876	1	0.349	1.925

Type of vibration control measures and model factors	B	Std. Error	Wald	df	*P*	Odds ratio Exp(B)
Technicians & trades workers	1.000	0.672	2.213	1	0.137	2.718
Community & personal services workers	-0.565	0.916	0.381	1	0.537	0.568
Labourers	0.296	0.769	0.148	1	0.701	1.344
Machinery operators & drivers	-0.288	1.151	0.063	1	0.802	0.750
Clerical & administrative workers and Sales workers	0[(b)]	.	.	0	.	.
Industry						
Manufacturing	-0.038	0.620	0.004	1	0.951	0.963
Transport & storage	0.183	0.761	0.058	1	0.809	1.201
Construction	0.302	0.668	0.204	1	0.651	1.352
Agriculture, forestry & fishing	0.730	0.718	1.032	1	0.310	2.074
Health & community services	0[(b)]	.	.	0	.	.
Intercept	-6.296	1.367	21.198	1	0.000	.

a. The reference category is: Not exposed to vibration.
b. This parameter is set to zero because it is redundant.

What employment and exposure factors are important predictors of the provision of vibration control measures in the workplace?

Multinomial logistic regression for the provision of control measures

Table 16 The likelihood ratio tests of a multinomial logistic regression model: the factors that had a significant effect on the likelihood of the provision of vibration control measures

Likelihood ratio tests			
Model Factors	**Chi-square**	**df**	***P***
Industry	45.127	12	0.000
Occupation	29.842	18	0.039
Workplace size	39.527	9	0.000
Type of exposure	59.272	9	0.000
Minimal model	**257.783**	**48**	**0.000**
Goodness of fit (Pearson)	**761.478**	**699**	**0.050**
Nagelkerke Pseudo R-square	**0.219**		

Table 17 The parameter estimates of a multinomial logistic regression investigating the factors that affected the likelihood of providing vibration control measures

Vibration control measures relative to no control measures[a]						
	Parameter estimates					
Type of vibration control measures and model factors	**B**	**Std. Error**	**Wald**	**df**	***P***	**Odds ratio Exp(B)**
Vibration control measures other than PPE						
Occupation						
Managers	0.979	0.635	2.374	1	0.123	2.661
Professionals	-0.083	0.696	0.014	1	0.904	0.920
Technicians & trades workers	-0.104	0.574	0.033	1	0.856	0.901
Community & personal services workers	0.273	0.839	0.106	1	0.745	1.313
Labourers	-0.030	0.596	0.003	1	0.960	0.970
Machinery operators & drivers	0.189	0.528	0.128	1	0.721	1.208
Clerical & administrative workers and Sales workers	0[b]	.	.	0	.	.
Industry						
Manufacturing	0.479	0.634	0.571	1	0.450	1.615
Transport & storage	1.082	0.592	3.346	1	0.067	2.951
Construction	1.066	0.589	3.279	1	0.070	2.903
Agriculture, forestry & fishing	1.268	0.621	4.165	1	0.041	3.555
Health & community services	0[b]	.	.	0	.	.
Workplace size						
Less than five	-0.370	0.431	0.737	1	0.391	0.691
Five to 19	-0.517	0.431	1.443	1	0.230	0.596
20 to 199	-0.253	0.420	0.363	1	0.547	0.776
200 or more	0[b]	.	.	0	.	.
Type of exposure						
Vibration type not determined	-0.947	1.083	0.766	1	0.382	0.388
Whole body vibration	1.279	0.328	15.235	1	0.000	3.593
Both hand-arm & whole body vibration	1.295	0.391	10.962	1	0.001	3.650
Hand-arm vibration	0[b]	.	.	0	.	.
Intercept	-2.029	0.849	5.718	1	0.017	.
Vibration control measures and PPE						
Occupation						
Managers	1.739	0.535	10.569	1	0.001	5.694
Professionals	0.071	0.557	0.016	1	0.898	1.074
Technicians & trades workers	0.320	0.462	0.478	1	0.490	1.377
Community & personal services workers	0.597	0.688	0.755	1	0.385	1.817
Labourers	0.577	0.484	1.422	1	0.233	1.781
Machinery operators & drivers	0.719	0.457	2.477	1	0.116	2.052
Clerical & administrative workers and Sales workers	0[b]	.	.	0	.	.
Industry						
Manufacturing	1.826	0.438	17.413	1	0.000	6.208
Transport & storage	1.113	0.449	6.133	1	0.013	3.043
Construction	1.503	0.431	12.145	1	0.000	4.494
Agriculture, forestry & fishing	1.387	0.470	8.712	1	0.003	4.004
Health & community services	0[b]	.	.	0	.	.
Workplace size						
Less than five	-1.336	0.307	18.961	1	0.000	0.263
Five to 19	-1.286	0.304	17.936	1	0.000	0.277
20 to 199	-0.759	0.298	6.466	1	0.011	0.468
200 or more	0[b]	.	.	0	.	.

Type of vibration control measures and model factors	B	Std. Error	Wald	df	*P*	Odds ratio Exp(B)
Type of exposure						
Vibration type not determined	-0.212	0.475	0.200	1	0.655	0.809
Whole body vibration	0.330	0.231	2.051	1	0.152	1.391
Both hand-arm & whole body vibration	1.188	0.280	17.978	1	0.000	3.280
Hand-arm vibration	0[(b)]	.	.	0	.	.
Intercept	-0.466	0.639	0.530	1	0.466	.
PPE only						
Occupation						
Managers	2.095	0.771	7.388	1	0.007	8.126
Professionals	0.736	0.793	0.861	1	0.353	2.088
Technicians & trades workers	1.268	0.702	3.266	1	0.071	3.553
Community & personal services workers	1.598	0.887	3.244	1	0.072	4.941
Labourers	1.435	0.722	3.953	1	0.047	4.198
Machinery operators & drivers	1.258	0.713	3.113	1	0.078	3.520
Clerical & administrative workers and Sales workers	0[(b)]	.	.	0	.	.
Industry						
Manufacturing	1.333	0.477	7.817	1	0.005	3.793
Transport & storage	0.115	0.519	0.049	1	0.825	1.122
Construction	0.785	0.474	2.742	1	0.098	2.193
Agriculture, forestry & fishing	0.633	0.527	1.441	1	0.230	1.883
Health & community services	0[(b)]	.	.	0	.	.
Workplace size						
Less than five	-1.051	0.344	9.349	1	0.002	0.350
Five to 19	-0.989	0.340	8.460	1	0.004	0.372
20 to 199	-0.069	0.328	0.044	1	0.833	0.933
200 or more	0[(b)]	.	.	0	.	.
Type of exposure						
Vibration type not determined	-0.651	0.553	1.387	1	0.239	0.522
Whole body vibration	-0.468	0.265	3.113	1	0.078	0.626
Both hand-arm & whole body vibration	0.928	0.297	9.727	1	0.002	2.529
Hand-arm vibration	0[(b)]	.	.	0	.	.
Intercept	-1.291	0.851	2.301	1	0.129	.

a. The reference category is: No control measures.
b. This parameter is set to zero because it is redundant.

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