Vibration Toolkit: An Occupational Health Education Intervention for the Mining Industry

By

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Abstract

Background: Workers in the mining industry are exposed to whole-body vibration (WBV), hand-arm vibration (HAV), and foot-transmitted vibration (FTV). The purposes of the study were to: critically review occupational health and safety education intervention programs that have been conducted within rural and northern communities and industries; examine the vibration-focused education resources in northern Ontario; and develop, implement, and evaluate an occupational health education intervention program, the Vibration Toolkit.

Methods: The Content-Context-Process-Outcome framework was used to guide a mixed-methods study that included four phases. Phase 1 included a literature search of six electronic databases for peer-reviewed scientific journal articles focused on an occupational health education intervention or programs. Phase 2 consisted of an education review of the online education catalogues of Workplace Safety North, Workers' Health and Safety Centre, and Occupational Health Clinics for Ontario Workers. Phase 3 involved the development of an occupational health education intervention to address vibration exposure in the mining industry. Phase 4 was comprised of the implementation and evaluation of the effectiveness of the Vibration Toolkit on knowledge, attitudes, and behaviour beliefs related to vibration exposure with a local mining company.

Results: Phase 1 yielded six articles to provide recommendations for considerations for content development, context considerations related to the target population and industry, and approaches to improve process and outcomes of the intervention. In Phase 2, only one course and three resources documents were found to address vibration exposure (WBV=1, HAV=2, FTV=0). Phase 3 resulted in the creation of the Vibration Toolkit to provide education about all vibration types. Phase 4 implementation took place over a 5-month (February 2017 – June 2017) period at an underground mining operation in northern Ontario. Sixty-one participants attended all education sessions and completed the pre-intervention and post-intervention surveys. Statistically significant positive improvements were observed for behaviour belief scores between pre-intervention and post-intervention ($p<0.001$).

Conclusion: An identified gap was found to exist in education courses and materials focused on vibration exposure within the mining industry. The Vibration Toolkit was developed to fill the identified gap and resulted in significant improvements in behaviour beliefs related to vibration exposure.

Keywords:
Vibration, occupational health, education, intervention, mining, health and safety

Co-Authorship Statement

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Chapter 4: Evaluation of vibration-focused occupational health and safety education materials in mining

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Chapter 6: Evaluation of an occupational health intervention for underground mining-related vibration exposure

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Abbreviations, Definitions, and Terminology

1. Abbreviations

Abbreviation	Long Form
ACGIH	American Conference of Governmental Industrial Hygienists
CRE-MSD	Centre for Research Expertise for the Prevention of Musculoskeletal Disorders
CREOD	Centre for Research Expertise in Occupational Disease
DF	Dominant frequency
FTV	Foot-transmitted vibration
HAV	Hand-arm vibration
HAVS	Hand-arm vibration syndrome
HGCZ	Health guidance caution zone
HSSP	Health and Safety System Partner
IHSA	Infrastructure Health and Safety Association
ISO	International Organization for Standardization
IWH	Institute for Work & Health
LBP	Low-back pain
LHD	Load-haul-dump
MOL	Ontario Ministry of Labour
MSD	Musculoskeletal disorder
NIOSH	National Institute for Occupational Safety and Health
OCRC	Occupational Cancer Research Centre
OHCOW	Occupational Health Clinics for Ontario Workers
OHS	Occupational health and safety
OHSA	Occupational Health and Safety Act
PSHSA	Public Services Health and Safety Association
WBV	Whole-body vibration
WHMIS	Workplace Hazardous Materials Information System
WHSC	Workers Health and Safety Centre
WSIB	Workplace Safety and Insurance Board
WSN	Workplace Safety North
WSPS	Workplace Safety and Prevention Services

2. Terminology and Definitions

Attitude: Attitude is defined as positive or negative feelings towards performing certain behaviours and will be assessed with a sum score of 16 questions (Tiemessen et al., 2007; Glanz et al., 2008).

Behaviour Beliefs: Behaviour beliefs are an "individual's beliefs about outcomes or attributes of performing the behaviour" (p.71) (Glanz et al., 2008) and will be assessed with 11 questions (Tiemessen et al., 2007).

ISO 2631-1: The International Standard used to describe the effects of whole body vibration exposure on human health.

ISO 5349-1: The International Standard used to describe the measurement of hand-arm vibration exposure.

FTV: FTV has not been clearly defined within the literature; however, in this study, FTV refers to vibration that is transmitted to the body through the feet.

HAV: HAV is defined as "the mechanical vibration that, when transmitted to the hand-arm system, entails risks to health and safety of workers, in particular vascular, bone or joint, neurological or muscular disorders" (p.L177/14)(Directive, 2002).

Knowledge: Knowledge is defined as factual and interpretive information leading to understanding or usefulness for taking informed action (Glanz et al., 2008).

Resonance Frequency: The frequency at which resonance occurs. At the resonance frequency of a system, maximal oscillation will occur.

Root-mean-square (r.m.s.): For a set of numbers, the square root of the average of their squared values.

Transmissibility: The unit-less ratio of the response amplitude of a system, in steady-state forced vibration, to the excitation amplitude. A value greater than one would indicate the vibration was amplified as it travelled from the input location to the "output" locations whereas a value less than one would indicate attenuation.

Vibration: An oscillatory motion about a fixed reference point.

WBV: WBV is "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" (p.L177/14)(Directive, 2002).

Chapter 1: Introduction

Fatality reduction has been the primary focus of most occupational health and safety programs within the mining industry. Although efforts to address risk factors associated with fatalities are critically important, there also remains a need to address risk factors associated with occupational injury and disease (McPhee, 2004). The expectation of over 6000 new workers joining the mining industry by 2021 to meet demand and labour shortages, further necessitates the focus of health and safety programs to shift to prevention (MOL, 2015). In the Ontario mining industry, hand-arm vibration syndrome (HAVS), noise-induced hearing loss, and exposures comprise the top three occupational diseases resulting in approved Workplace Safety and Insurance Board (WSIB) claims for healthcare, being off work, loss of wages, or permanent disability (WSN, 2016). Furthermore, preventing vibration-induced injury amongst miners can be a challenge since workers can be exposed to whole-body vibration (WBV), hand-arm vibration (HAV), and foot transmitted vibration (FTV). Moreover, current literature suggests a link between occupational vibration exposure and harmful health effects, and Eger and colleagues (2006) confirmed that miners in northern Ontario are exposed to WBV above recommended guidelines (Bovenzi, 2005; Thompson et al., 2010; Thompson et al., 2011).

Occupational health research is often underdeveloped and intervention programs to prevent and reduce health concerns related to occupational vibration exposure are lacking (Hulshof et al., 2006). Few preventative intervention programs have been developed to decrease vibration exposure, which will contribute to an overall reduction in negative health effects (Tiemessen, 2008). Moreover, educational and training opportunities related to vibration exposure including hazard identification, symptom detection and exposure reduction, are lacking. However, training, in general within the field of occupational health and safety, has demonstrated positive results in increasing knowledge (Cohen and Colligan, 1998). Furthermore, the 2015 *Mining Health, Safety and Prevention Review* commissioned by the Chief Prevention Officer in Ontario, Canada, identified six key health and safety issues in underground mining including, health and safety hazards, training, skills and labour supply issues (MOL, 2015). Therefore, education of hazards and health effects associated with vibration-induced injury, and control strategies to mitigate risks in underground mining, are needed.

1. Research Objectives and Dissertation Outline

The primary objectives of this dissertation are to:

1) critically review occupational health and safety education intervention programs that have been conducted within rural and northern communities and industries;
2) examine the training resources in northern Ontario, in relation to occupational vibration hazards, health risks, and controls;
3) develop an occupational health education intervention program, the Vibration Toolkit, customized for the mining industry in northern Ontario; and
4) evaluate the effectiveness of an occupational health education intervention program, the Vibration Toolkit, on knowledge, attitude, and behaviour beliefs about occupational vibration hazards, health risks and control strategies within the mining industry in northern Ontario.

Four manuscripts comprise the body of the dissertation. The overall relationship of the papers within the dissertation is illustrated in Figure 1. Relevant literature was reviewed in Chapter 2 to highlight gaps in occupational health and safety training programs in general and training programs on vibration hazards in particular. In the first manuscript (Chapter 3), research objective one was addressed through an examination of occupational health education interventions that have been implemented within rural and northern workplace environments. Elements of the interventions were analyzed to recommend factors for ensuring future success in the prevention of injury and illness for workers in rural and northern work environments. Manuscript 2 (Chapter 4) included a review and evaluation of existing mining occupational health and safety (OHS) training programs and resources in northern Ontario for issues related to occupational vibration hazards, health risks, and controls. The manuscript provided the understanding of what is currently being offered as health and safety education to address the issue of vibration exposure within mining. The third manuscript (Chapter 5), presented a protocol for the development and design of an occupational health education intervention, the Vibration Toolkit. The design of the Vibration Toolkit was informed by the findings from manuscript 1 and it addressed a gap in existing resources that were reported in manuscript 2. The final manuscript (Chapter 6) reports outcomes from an evaluation of the Vibration Toolkit that was developed in manuscript 3. A one-group pre/post-test design was utilized to evaluate changes in workers' knowledge, attitudes and behaviour beliefs related to occupational exposure to vibration, post implementation of the Vibration Toolkit. Finally, key scientific contributions and future research, policy, and practice recommendations, arising from the manuscripts, are discussed in Chapter 7.

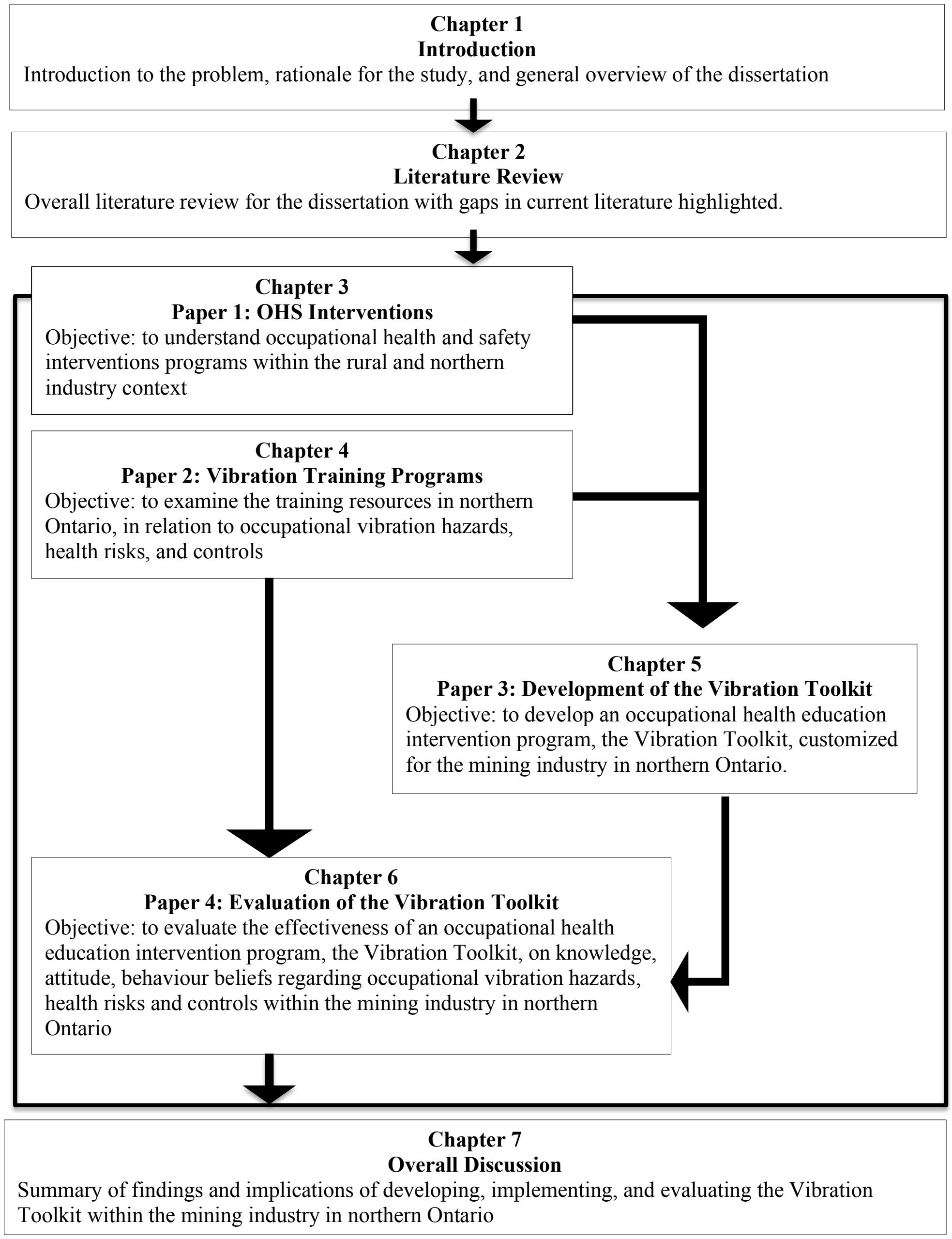

Figure 1: Overview of dissertation

2. Theory and Framework

A theoretical basis for the research project provides a conceptual base for improving existing methods and intervention programs, which will enhance interpretation and generalizability (Goldenhar and Schulte, 1994). The dissertation studies were guided by Robson and colleagues, (2012) conceptual model of workplace training interventions and informed by the principles of adult learning (NIOSH, 2002; Robson et al., 2012a). The model developed by Robson and colleagues (2012a) provided the overall justification for the project as it suggests workplace training will immediately influence knowledge, attitudes, and behaviour intentions (Robson et al., 2012a; Robson et al., 2012b). According to the model, outcomes will influence worker behaviour, and in the long term, should lead to a decrease in workplace injury and illness rates (Robson et al., 2012a; Robson et al., 2012b).

The development process of the intervention and understanding of previous interventions conducted in rural and northern Ontario workplaces, were discussed utilizing the Content-Context-Process-Outcome framework proposed by Karanika-Murray and Biron (2015). The framework provides four elements; content, context, process, and outcomes, to analyze and evaluate intervention research (Karanika-Murray and Biron, 2015). Principles of adult learning were used to inform the development of the occupational health content within the intervention. Teaching strategies were based on the assumptions that adults are: autonomous and self-directed, bring life experiences and knowledge to life learning experiences, goal oriented, relevancy oriented, practical, and need to be shown respect (Knowles, 1970; Knowles, 1973; NIOSH, 2002; Russell, 2006; Galbraith and Fouch, 2007).

3. Rationale for Northern Ontario

Rural and remote locations are common destinations for mining developments in northern Ontario (Donoghue, 2004). The boundaries defined by the Local Health Integration Network identify two northern Ontario regions (North East and North West) (LHIN, 2014; LHIN, 2014). There are 43 operating mines in Ontario that produce a number of precious minerals and resources, 34 of which are located in northern Ontario (OPA, 2015). The mining industry in Canada employs over 300,000 workers, of which 6000 are located within the Sudbury Basin (OMA, 2009; Haldane, 2013). In addition, the recruitment of over 6000 new workers by 2021 is anticipated in order to meet demand and labour shortages within the industry (MOL, 2015). The potential lack of emergency medical care, access to hospitals, and the distance from major medical centres argue for additional emphasis to be placed on prevention programs in occupational health and safety in rural, northern, and remote areas (Donoghue, 2004; Loue and Quill, 2010). The assurance of a safe and healthy work environment is needed to ensure a long-term, sustainable, productive and healthy workforce in northern Ontario.

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Chapter 2: Review of Literature

This chapter provides an overview of occupational vibration exposure within the mining context, the national and international regulations for addressing vibration exposure within the workplace, investigates the current level of knowledge, attitudes, and behaviour beliefs about vibration exposure within the mining industry, and summarizes previously published occupational health education interventions for workplace vibration.

1. Occupational Vibration Exposure

The mining industry has high productivity demands and has experienced a shift from heavy physical labour to the increased operation of mechanized equipment (McPhee, 2004). Consequently, understanding and documenting the characteristics of the differing exposures to vibration is important to determine the associated health effects (Griffin, 1990; Mansfield, 2005; Cardinale and Rittweger, 2006). The health effects can be characterized based on the region of the body in contact with the vibrating surface (Griffin, 1990). Many occupations expose workers to one type of vibration. However, miners can be exposed to whole-body, hand-arm, and foot-transmitted vibration while performing their job duties and operating various types of equipment (Eger et al., 2014).

1.1 WBV

WBV exposure in mining typically occurs when a miner is operating mobile equipment from a seated position (Bovenzi, 2005). Early estimates suggested that 4 to 7% of the workforce in North America and Europe are exposed to potentially hazardous levels of WBV in their workplace (Bovenzi, 1996). Eger and colleagues (2006) compiled WBV exposures collected in northern Ontario mines to assess health risk to miners, and found operators of surface haulage trucks, underground load-haul-dump trucks, bulldozers, and graders were commonly exposed to harmful levels of vibration (Eger et al., 2006; Eger et al., 2014).

The main health concern related to WBV exposure is an increased risk for disorders of the lumbar spine (Bovenzi, 1996; Bovenzi and Hulshof, 1999; Lings and Leboeuf-Yde, 2000; Bovenzi, 2005). Based on the literature associating occupational WBV exposure and low back pain, it is suggested that there is moderate to strong epidemiological evidence to support the association (Bovenzi and Hulshof, 1999; Tiemessen, 2008). Increased levels of adverse health effects and injuries for workers exposed to WBV are congruent with literature aligning the resonant frequency of the spinal column (i.e., 1 to10 hertz) with that produced by many types of equipment and vehicles in mining (Kitazaki and Griffin, 1998; Eger et al., 2006; Tiemessen, 2008).

1.2 HAV

HAV exposure occurs most commonly within the mining industry as a result of workers operating jackleg drills, long-hole drills, stopers, impact wrenches and other hand tools (Hill et al., 2001; Donoghue, 2004). Vibration is transmitted from the drill and into the hand-arm system of the worker while performing typical work tasks. Hand-arm vibration syndrome (HAVS) is a recognized occupational disease, which disturbs circulation in the fingers, impairs sensory perception from damage to the skin mechanoreceptors and nerve fibres, and can also involve loss of manipulative dexterity (Bernard et al., 1998; Hagberg, 2002; Bovenzi, 2005; Heaver et al., 2011; Youakim, 2014; Nilsson et al., 2017). The detrimental effects of the disease cannot be understated as activities of daily living and a worker's vocational potential can be significantly hindered (Youakim, 2014). The Stockholm Workshop scale is used to assess the vascular and neurological disturbances occurring from HAVS (Gemne et al., 1987). An assessment of HAVS at a northern Ontario mine was conducted by Hill and colleagues (2001), which concluded that 50% (81 of 162) of workers receiving a medical examination were diagnosed with HAVS. Still, there continues to be a dearth of research regarding the prevalence and recognition of HAVS across all industrial sectors in Canada (Thompson et al., 2011). In addition, the cold Canadian climate also has the potential to increase the risk of developing HAVS for workers exposed to HAV while working in a cold environment (Burström et al., 2010).

1.3 FTV

FTV occurs when a worker is standing on a vibrating surface while working and vibration travels into the body through the feet. Workers in mining are typically exposed to FTV while operating locomotives, jumbo drills, bolters, or drilling off raise platforms (Leduc et al., 2011; Eger et al., 2014). There are currently no epidemiological studies that differentiate between WBV and FTV, to provide an estimate of the number of workers exposed to FTV (Eger et al., 2014). FTV-documented exposures are rare in the literature, but changes in mining technology are resulting in more types of equipment that require workers to stand during operation, which exposes them to FTV. Further, complicating measurement and documentation of FTV is the lack of an agreed upon standard for measurement and assessment (Eger et al., 2014). Current evidence suggests that drilling from a raise platform exposes workers' feet to vibration levels above the ISO 2631-1 health guidance caution zone for WBV; therefore, suggesting health risks are likely (Leduc et al., 2011; Eger et al., 2014). Hedlund (1989) identified that six of 27 miners displayed a lack of blood flow in their feet after standing on platforms with attached drills. Furthermore, rock drill operators from Korea have experienced vibration-induced white toes (Choy et al., 2008). In the Canadian context, Thompson and colleagues (2010) documented the first medical case study of a miner diagnosed with vibration white foot. The miner reported 18 years of general vibration exposure and four years of FTV exposure from operating a bolter (Thompson et al., 2010). Further research is required to characterize, control, and increase awareness of FTV exposure as an occupational hazard within mining (Leduc et al., 2011; Eger et al., 2014). Additional case studies, related to FTV, need to be published to provide further evidence for increased vibration assessment for standing workers and determination of prevention and control strategies (Verma et al., 2002).

Finally, research is required to better understand the health effects associated with cumulative exposures to WBV, HAV, and FTV, which are common amongst underground miners. Furthermore, programs are needed to improve workers' knowledge of health risk and control strategies associated with exposure to vibration, and research evaluating the benefits of these programs is required. Moreover, the progressive nature of the injuries related to vibration exposure necessitates worker education and prevention measures.

2. Standards and Legislation

The field of occupational health has been suggested to be external to the scope of mainstream health care, and despite the medical science foundation, is influenced by the societal members through legislation and regulatory action (Verma et al., 2002; Verbeek et al., 2004). International vibration policies and standards for measurement exist including ISO 5349-1 (ISO, 2001), ISO 2631-1 (ISO, 1997), and ACGIH (2007). The ACGIH (2007) provides threshold limit values for recommended maximum permissible WBV and HAV exposure limits. ISO standards provide a protocol for measurement and assessment for WBV (ISO 2631-1) and HAV (ISO 5349-1) exposure. FTV is grouped within WBV (ISO 2631-1) and does not currently have a specific outlined measurement or reporting protocol (ISO, 1997). Within ISO 2631-1, the health guidance caution zone (HGCZ) is used to determine the level of risk associated with exposure to WBV, where "caution for health risk interpretation" is recommended for vibration exposures within the HGCZ, and "health risks are likely" for exposures documented above the HGCZ (ISO, 1997).

In 2005, legislation, European Directive on Vibration, was implemented in the European member states to protect workers from the risks of occupational vibration exposure (Directive, 2002). Obligations for employers included: determination and assessment of risks, the adoption of measures to avoid or reduce exposure, provision of worker information and training, and health surveillance (Tiemessen, 2008). Injuries and illnesses attributed to WBV exposure in the workplace are recognized as a compensable occupational disease in Germany, Belgium, the Netherlands, Italy and France (Johanning, 2015).

Despite HAVS being a recognized occupational disease, not all compensation boards within Canada classify it as a diagnosis requiring statistical records (Thompson et al., 2011). Between 2003-2005, there were 457 compensated HAVS claims within Canada (Thompson et al., 2011). However, based on the number of proposed cases from other industrialized countries, the number of cases in Canada is estimated to be between 72,000 and 144,000 (Thompson et al., 2011). British Columbia has implemented legislation for WBV and HAV exposure (WorksafeBC, 2005). The legislation provides exposure limits, evaluation protocol, an exposure control plan, and information about adverse effects, labeling, and exposure to cold (WorksafeBC, 2005). Despite the legislation, it has been noted that workers postpone making claims regarding HAVS (Youakim, 2012). From the onset of symptoms, loggers waited an average of six years and mechanics waited three years before making a claim (Youakim, 2012). New Brunswick implemented a HAV policy that provides exposure standards (91-1035, 1991). However, Ontario has not adopted any of the previously mentioned policies or regulations. In Ontario, prevention of injuries and disabilities related to occupational vibration exposure fall under the General Duty Clause, 25.(2)(h), within the Occupational Health and Safety Act, which states "take every precaution reasonable in the circumstances for the protection of a worker" (OHSA, 1990). As a result of the lack of legislation in Ontario, injuries or disabilities related to occupational vibration exposure are not adequately monitored or reported within workplaces or in a central system (Vojtecky, 1998; Johanning, 2015). An inadequate understanding of the prevalence and awareness of health effects related to occupational vibration exposure further impacts workers as companies are often guided by injury and illness statistics to design and implement their respective health and safety programs (Thompson, 2007). Therefore, both the legislative landscape within Canada and precaution at the workplace level are important in addressing and preventing injury and illness related to occupational vibration exposure (Verma et al., 2002).

3. Vibration Management

A vibration mitigation and management system must first begin with identification of the problem through vibration measurement (Griffin, 1990). A vibration assessment indicates the potential for health risk and the need for control strategies (Griffin, 1990). In line with the hierarchy of controls, the most effective but typically most difficult strategy, is the elimination of the hazard (NIOSH, 2018). Implementing engineering solutions to reduce the overall vibration exposure at the source or at the worker is the most effective strategy if vibration exposure cannot be avoided (Griffin, 1990; Mansfield, 2005). For example, previous research in underground mining has shown engineering solutions, such as drilling from a dampened platform, were successful in decreasing overall vibration exposure (Leduc et al., 2011). The reduction of the exposure duration or magnitude through administrative controls is the next step (Mansfield, 2005). Previous research has demonstrated workplace policies implemented related to road maintenance, tool maintenance, reduced driving speed limit, and seat selection can be successful at reducing vibration exposure (Tiemessen et al., 2007; Eger et al., 2011; Ji et al., 2016). Personal protective equipment (ie. anti-vibration gloves) to protect the worker is typically the last method to mitigate exposure to vibration as the effectiveness is limited (NIOSH, 2018).

Engineering modification and redesign are the more effective solutions for decreasing vibration exposure; however, concerns related to applicability, cost, and maintenance may present barriers for implementation (McPhee et al., 2009). Knowledge is also needed, in conjunction with other control strategies, to reduce vibration exposure (VIN, 2001). In addition, regardless of potential impact, most control strategies and interventions will not be implemented within organizations without evidence supporting the effectiveness of the control strategy or program (Zwerling et al., 1997; Hulshof et al., 1999).

4. Lack of Knowledge

Past research has revealed that occupational safety and health professionals from the USA self-reported to have little or no knowledge of WBV exposure hazards, health effects, and control strategies (Paschold and Sergeev, 2009). More specifically, 50 participants working within the industrial classification of mining scored below the mean scores for all categories when all of the other occupational classifications (agriculture, construction, manufacturing, wholesale and retail trade, transportation (warehousing and utilities), services (professional, education, government), healthcare and social assistance, national security (armed forces)) were combined (Paschold and Sergeev, 2009). The alarmingly low level of self-reported knowledge, documented in the USA health and safety professionals, provides further evidence for the need for the proposed research to be conducted in Canada (Paschold and Sergeev, 2009). Lack of knowledge regarding vibration exposure and potential health risk will inhibit a worker's ability to anticipate, recognize, evaluate, and control vibration hazards (Paschold and Sergeev, 2009). Therefore, enhanced training and education regarding occupational vibration exposure is warranted in order to ensure worker safety and protection (Paschold and Sergeev, 2009).

To date, research has yet to evaluate the level of knowledge, of different types of vibration exposure and health risk, held by workers within the mining industry in Canada. Additionally, there remains a need to develop standardized measures of occupational health and safety knowledge (Burke et al., 2006). The current study will address this gap in the literature by measuring level of knowledge, as opposed to perceived knowledge, which was measured in the study of occupational safety and health professionals (Paschold and Sergeev, 2009). Moreover, an improvement in supervisors' knowledge of occupational vibration may help in the development of company health policy, work scheduling, purchasing of equipment, and removal of other workplace barriers (Tiemessen, 2007). Furthermore, improving workers' knowledge of workplace risk factors is critical for prevention of vibration-induced injury. Awareness of the types of occupational vibration exposure may also improve a worker's ability to seek appropriate health care and treatment, if needed, as a result of identifying the potential occupational origin of their condition (Curti et al., 2015). Increasing a worker's knowledge may also facilitate discussions with their physician as it relates to the origin of medical concerns and may indirectly influence the reporting of occupational diseases (Curti et al., 2015). Elsewhere, it has been suggested that health care professionals may not be aware of the impact of occupational vibration on health as a result of the technical complexity, and at times, the perceived potential of non-specific adverse health outcomes or difficulty in diagnosing work-related disease (Vojtecky, 1998; Jetzer, 2011; Johanning, 2015).

5. Occupational Health Interventions

Occupational health and safety educational interventions are intended to influence workers' knowledge, attitudes or behaviours regarding hazardous workplace exposures and associated occupational diseases (Goldenhar and Schulte, 1994). With respect to occupational health related to vibration exposure in the workplace, past research has focused on the technical aspects of vibration in order to reduce a worker's exposure (Tiemessen, 2009). Appropriate information and knowledge, in addition to technical measures, are important aspects of a prevention program for reducing vibration exposure (See Figure 1, Appendix E) (VIN, 2001). Education regarding risk factors for vibration exposure, and early health effects, needs to be incorporated into workplace health and safety training (Robson et al., 2012a). Furthermore, control strategies to reduce vibration exposure should be discussed, as knowledge alone does not always lead to effective prevention (Hulshof et al., 2006; Tiemessen, 2009; Johanning, 2015). Current control strategies in the workplace that may be modifiable through training include: limiting travel speeds and travel distances, maintaining travel surfaces and equipment, implementing correct seat adjustment procedures, utilizing task variation, and adopting the use of personal protective equipment (Hill et al., 2001; Donoghue, 2004; McPhee, 2004; Tiemessen, 2008).

Evidence of occupational health programs focused on the prevention and reduction of vibration exposure is lacking (Hulshof et al., 2006; Tiemessen et al., 2007; Tiemessen, 2009). An educational program, information leaflet and instructional sessions containing information on hazards, prevention strategies and legislation, was developed for forklift drivers, managers, occupational physicians and occupational hygienists (Hulshof et al., 2006). Although, the knowledge scores were not significantly different following the intervention program, all groups showed slight increases in their respective mean scores (Hulshof et al., 2006). Hulshof and colleagues (2006) noted a lack of focus on the health education component and insufficient intensity of the program as limitations of their study.

Tiemessen and colleagues (2007) also developed an intervention program to reduce WBV exposure (Tiemessen, 2009). Drivers were provided with an information brochure, which outlined legislation regarding WBV, determinants of exposure, and solutions to reduce exposure, with the goal of improving their knowledge (Tiemessen et al., 2007; Tiemessen, 2009). The pre-test scores for vibration knowledge for the workers were 72% and 71% (correct answers) for the intervention and care-as-usual groups, respectively (Tiemessen, 2009). No significant differences in knowledge were found when comparing pre- and post-test scores for both workers and the employers; however, there were relevant reported reductions in measured vibration exposure (Tiemessen, 2009). Further reductions in measured vibration exposure were also indicated for workers who were compliant with the study requirements, suggesting potential for positive results in future studies (Tiemessen, 2009).

The impact of a HAV education intervention, a double-sided, laminated information document, for construction workers while receiving an assessment for HAVS at an occupational health clinic, has been evaluated (Thompson et al., 2012; Leduc et al., 2016). Following the education session at the clinic, there was a statistically significant increase in the use of anti-vibration gloves at their respective worksites (4.1% at baseline and 53.2% at follow-up, $p<0.05$). Changes which occurred in the workplace as a result of sharing the information included: purchase of lower vibration tools (20.4%), process changes (16.0%), decreased exposure time (16.3%), and additional HAVS training opportunities offered by the employer (14.6%) (Thompson et al., 2012). Topics advised to be addressed during proposed worker educational sessions on HAVS included: the importance of utilizing anti-vibration equipment, ways to prevent HAVS, how to prevent further deterioration, and other health behaviours, medical conditions, and hobbies that may further impact HAVS (Hill et al., 2001). Therefore, vibration-targeted educational interventions may be beneficial for increased awareness within the workplace for the prevention of HAVS through symptom identification and reduction of vibration exposure.

The scientific contributions from the previously published manuscripts are critical for the prevention of injury and illness related to workplace vibration exposure for the whole body and hand arm system. However, none of the manuscripts considered the mining work environment or workers with exposure to whole-body, hand-arm, and foot-transmitted vibration. Therefore, the current dissertation focused on the development of an educational intervention for workers in the mining industry, who have exposure to WBV, HAV, and FTV

6. Dissertation Objectives

This dissertation will seek to provide a synthesis of occupational health education interventions that have been completed within rural and northern industries to inform the development of an intervention for mining. Additionally, an overview of the training opportunities and resources available for the mining industry in northern Ontario specific to addressing vibration hazards, health effects, and control strategies, will be presented. The results will highlight the types of exposure and the associated content currently being taught, and remaining gaps will be used to further inform the intervention development. An evaluation of the developed intervention program, the Vibration Toolkit, will be assessed for the ability to improve knowledge, attitudes, and behaviour beliefs related to vibration exposure in mining. The findings from the intervention will align with the current requests for recommendations to enhance worker and supervisor occupational health and safety training within the mining industry (MOL, 2015). The health and safety of workers in northern Ontario is greatly influenced by the standards set within the mining industry. The need for solutions to reduce or eliminate occupational vibration hazards is imminent and convincing with the support of documentation, suggesting miners may be experiencing potentially harmful exposures and health effects (Eger et al., 2014). Improving the health amongst this population is critical for the health of northern Ontario residents.

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Chapter 3: Critical Review of the Application of Occupational Health Education Interventions to Rural and Northern Industries and Communities

Abstract

Background: Challenges exist for researchers when conducting occupational health education interventions within the field. Additional challenges and considerations occur as a result of the uniqueness and nature of conducting research within rural and northern occupational settings.
Purpose: The purpose of the paper is to provide a critical review of the literature on occupational health education interventions that have been conducted within rural and northern workplaces.
Methods: Six electronic databases were searched: Academic Search Ultimate, CINAHL, CINAHL Complete, ERIC, MEDLINE, MEDLINE Complete, in June 2018. Peer-reviewed scientific journal articles that were written in English and focused on an occupational health education intervention or program were included.
Results: The Content-Context-Process-Outcome framework was used to analyze six scientific journal articles focused on occupational health education interventions. Recommendations for future intervention research include considerations for content development, context considerations related to the target population and industry, and approaches to improve process and outcomes of the intervention.
Conclusions: The careful consideration of areas for modification when partnering with individuals and workplaces in rural and northern industries and communities will assist with future prevention efforts targeted at occupational health exposures and injuries.

1. Introduction

The occupation types, hazards, and exposures experienced by workers in rural and northern communities influence the rural and urban differential seen in health status (Smith et al., 2008). Injuries and illnesses associated with occupational exposures have the ability to impact the health of the workers and overall communities. The subsequent burden on the livelihood of the individual, community, and company requires action to decrease and prevent injuries and illnesses, through education and training programs for workers. Difficulties continue to arise with respect to occupational health as a result of challenges in diagnosing work-relatedness and underreporting of illness and injury

(Vojtecky, 1998). However, the breadth of research and depth of knowledge in occupational health is increasing in regards to the health effects of work and working conditions; consequently, companies are prompted to action in terms of prevention and policy (Levenstein, 1996; Verbeek et al., 2004).

Workplace interventions are key contributors in the prevention of occupational injuries and illnesses through the translation of theory into practice; however, additional research in this field is still needed (Karanika-Murray and Biron, 2015). Due to the economic constraints in which workplaces operate, there is a need for occupational health services and programs from both within and beyond the company (Hulshof et al., 1999). However, interventions will not be implemented within organizations without evidence supporting the effectiveness of the program (Zwerling et al., 1997; Hulshof et al., 1999). Moreover, there is often a long latency period for an individual in the development of symptoms after initial exposure and a longer period of time before the workplace implements control strategies, and even longer for regulation across sectors (Verma et al., 2002). Therefore, solutions through occupational health interventions are important to protect the immediate and long-term health of workers, and evermore critical when discussing deteriorating damage with continued exposure.

Occupational health has been defined by the World Health Organization (WHO) and the International Labour Office (ILO) as “the promotion and maintenance of the highest degree of physical, mental, and social well-being of workers in all occupations by preventing departures from health, controlling risks and the adaptation of work to people and people to their jobs” (ILO, 1998). Within the broader context of prevention-focused interventions, occupational health education intervention research can be defined as, the study of planned and applied educational activities within the workplace designed to produce designated outcomes related to improving occupational health-specific competencies and the overall health of the workers (Goldenhar and Schulte, 1994; Robson et al., 2012a). Frequently, through the use of education sessions, training, and communication, occupational health education interventions are designed to influence the attitudes, knowledge, beliefs and behaviours, of participants, in relation to hazardous exposure and recognition. Furthermore, topics may range to include: the use of personal protective equipment, safe work practices, risk factors and symptoms of occupational disease (Goldenhar and Schulte, 1994; Robson et al., 2012a; Lunt, 2013). Therefore, occupational health and safety professionals and decision makers within companies need valid results regarding strategies to reduce occupational hazards (Schulte et al., 1996).

The common assumption that both occupational health and safety are managed through the same programs is inaccurate (Lunt, 2013). Occupational health hazards, both physical and psychological, have long latency periods between the onset of exposure and symptoms. The long latency period and often multifactorial etiology present a challenge for measurement when conducting research (Zwerling et al., 1997). In order to see changes in outcomes related to injuries or illnesses, with long latency periods, the intervention may need to span years (Zwerling et al., 1997). Additionally, repeated and prolonged exposure to hazards may eventually lead to the onset of symptoms or health effects. However, safety hazards are typically tangible and result in immediate consequences or injury (Lunt, 2013). Therefore, greater attention is needed to educate workers and direct their attention to the long term harm of occupational hazards that can lead to illness and disease (Lunt, 2013).

1.1 Northern and Rural Communities and Industry

Understanding the application of the terms northern and rural is important to establish. Regions considered to be northern may differ from province to province within Canada and within other countries internationally. However, the local context of this paper defines northern Ontario as the geographical boundaries of the two northern regions, north west and north east, outlined by the Local Health Integration Network (LHIN, 2014; LHIN, 2014). With respect to rurality, a broad definition of rural was utilized to encompass all communities that have a population less than 30 000 and are more than 30 minutes away in travel time from an urban centre with more than 30 000 people (Care, 2010).

Several industries that are prevalent within northern and rural Canada have impacted worker health, including agriculture, fisheries, forestry and mining, due to higher exposures to chemical, biological, physical and mechanical hazards associated with the jobs (Health, 2002; Strasser, 2003; Donoghue, 2004; Smith et al., 2008). Due to the unique factors found within workplaces in rural and northern communities, there is a need for published literature on occupational health and safety practices and solutions for employees within the varying industry sectors. Furthermore, there is a limited understanding of occupational illness and disease risks for rural and northern workers, with the exception of evidence provided from agriculture (Loue and Quill, 2010).
The challenges of conducting intervention research are compounded when applied in occupational settings. Frameworks designed to inform intervention development, and design parameters for evaluation within occupational health, are lacking (Karanika-Murray and Biron, 2015). Prescriptive guidelines for conducting research within

occupational health and safety are also limited and underdeveloped (Goldenhar and Schulte, 1994). However, the potential benefits to a worker's lifelong wellbeing and health should not be understated. The goal of educating workers and changing behaviour and attitudes to adopt safe working practices is an important endeavor to avoid debilitating and permanent occupational illness and disease. Researchers must learn from both successes and failures of published intervention studies, and they must continue to implement, and evaluate, workplace health and safety intervention studies. Moreover, results stemming from occupational health education interventions have not been synthesized for application in rural and northern industry and communities. Occupational settings are complex and suggested attention to the process and details of the intervention, in addition to the outcomes, is needed for expanding the field (Goldenhar and Schulte, 1994).

1.2 Critical Review Framework

A critical review approach can be used to provide an analysis of the literature beyond description in order to provide conceptual development and innovation (Grant and Booth, 2009). A focused evaluation on quality assessment based solely on the outcomes of the study narrows the overall understanding and limits the field from progressing forward (Goldenhar and Schulte, 1994). Undertaking a critical review places the importance on the conceptual contribution of each research study rather than focusing on an inclusion criteria based on a formal assessment of quality (Grant and Booth, 2009). Furthermore, the end result of a critical review is intended to become a starting point for future research and evaluation and it is not intended to be the endpoint (Grant and Booth, 2009). Therefore, valuable lessons can be learned from considering the potential components of an intervention that lead to success, and lessons can also be learned from interventions that did not lead to measured improvements (Karanika-Murray and Biron, 2015). Upon completion of an occupational health education intervention, research often evaluates its efficacy and effectiveness without regard for the conditions that facilitated the success or failure (Karanika-Murray and Biron, 2015). The implementation of an intervention, 'the how and why it worked', in addition to the evaluation, 'did it work', is a critical reflection needed for researchers and practitioners to consider (Nielsen et al., 2010; Karanika-Murray and Biron, 2015). Specific to rural and northern industries and communities, a reflection can ensure both existing and future programs have the ability to provide meaningful results. Individual workplace environments, locations and cultures are unique; however, overall design principles pertaining to occupational health interventions carry the potential to provide workplaces and researchers with an awareness of areas within a program where attention is needed to ensure appropriate fit.

1.3 Purpose

The purpose of the paper is to provide a critical review of occupational health education interventions that have been conducted within northern and rural workplaces. The Content-Context-Process-Outcome framework will be used to conduct the analysis, in order to identify recommendations for future interventions within northern or rural industries or communities (Karanika-Murray and Biron, 2015).

2. Methods

2.1 Search Protocol

Six electronic databases were searched: Academic Search Ultimate, CINAHL, CINAHL Complete, ERIC, MEDLINE, MEDLINE Complete, in June 2018. The inclusion criteria for the articles were: a) written in English, and b) article published in a peer-reviewed scientific journal. Following the purpose of the study on occupational health education interventions conducted in rural and northern industry, the exclusion criteria were: a) did not include an occupational health education component; b) was not addressing an occupational health hazard or exposure, and; c) was not conducted in a rural or northern community or industry. The keywords included: “Occupation* health”, “work* health”, coupled with intervention, program, or education. The keywords were searched with the following restrictions: “Limits: journal articles, Language: English, Field: Title and Field: Abstract”. Subsequently, the contextual filter of searching rural OR northern was applied. Furthermore, the bibliography of ‘the systematic review of occupational health and safety training’ conducted by Robson and colleagues (2012a) was searched for the studies completed in rural and/or northern setting and the reference lists of selected articles were also searched. Figure 2 displays an overview of the search protocol that was used to condense the yielded search results into the articles selected for analysis.

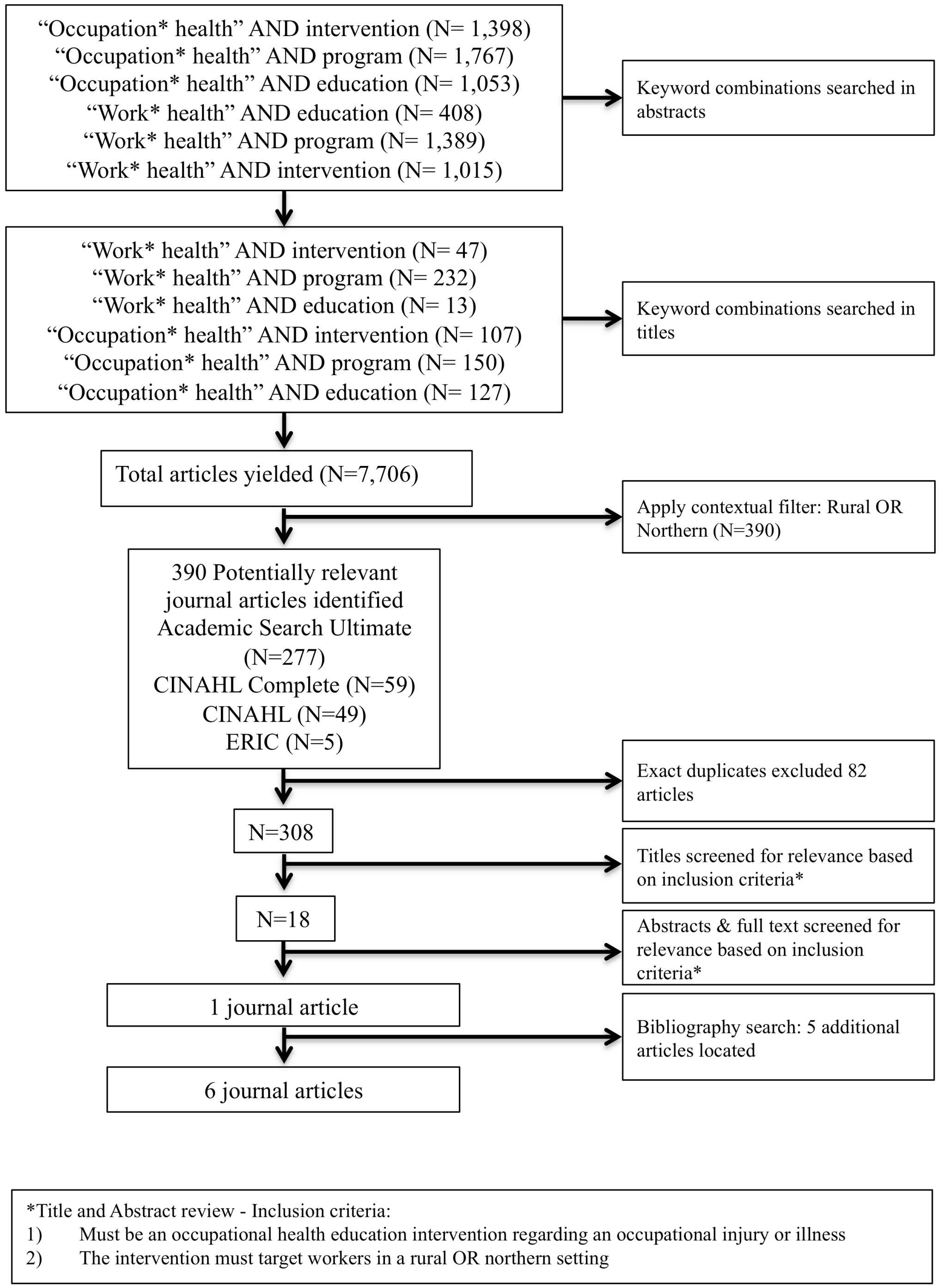

Figure 2: Literature Search Protocol

2.2 Content-Context-Process-Outcome Framework

Occupational health education interventions conducted in rural and northern settings will be discussed by analyzing the appropriate elements of the Content-Context-Process-Outcome framework that may have lead to the success or failure of the intervention (Karanika-Murray and Biron, 2015). The Content-Context-Process-Outcome framework proposed by Karanika-Murray and Biron (2015) was used to deconstruct the elements of an intervention into the four suggested pillars: content, context, process, and outcomes, to provide a basis for analysis and interpretation of previous research.

2.2.1 Content

Content refers to the activities that make up the intervention, in this case, the occupational health education component (Karanika-Murray and Biron, 2015). The design of program curriculum implemented is an important component to evaluate and is often overlooked. Gaining an understanding of the teaching materials and methods in relation to the selected participants provides further insight into the strengths or weaknesses of the intervention. Furthermore, content that is developed and delivered should be examined from the varying perspectives that comprise the population.

2.2.2 Context

The second element for consideration is context, defined as the aspects of the environment and constraints that may facilitate or constrain the outcome variables (Karanika-Murray and Biron, 2015). There are two types of context that warrant consideration: omnibus and discrete. Omnibus context refers to the broader context in which the intervention is implemented; whereas, discrete context, is related to factors which occur during the intervention (Karanika-Murray and Biron, 2015). Interventions that consider the broader context in which they take place have an increased likelihood of success and sustainability (Karanika-Murray and Biron, 2015).

2.2.3 Process

The third element in the framework to consider is process. Karanika-Murray and Biron (2015) define process as “how the intervention was delivered, perceived, and experienced by the participants and stakeholders” (p. 3). Process evaluation is often termed formative evaluation, as it describes the factors which influence, positively or negatively, how the intervention was implemented with the overall goal of improvement (Hersey et al., 1996). Process variables documented that are essential for consideration are: recruitment strategies, dose delivered and received, participant attitudes regarding quality of the intervention, and reach (Karanika-Murray and Biron, 2015). The process of the intervention needs to be documented and reported in order to further occupational health and safety intervention research.

2.2.4 Outcomes

The final element of intervention evaluation is the outcome, or the desired effect of the intervention effort (Karanika-Murray and Biron, 2015). Outcome evaluation, often termed summative evaluation, is concerned with understanding the effects demonstrated by the study. It is important to ensure the measurement is appropriate to measure the objectives of the study (Shannon et al., 1999).

Table 1: Summary details of the intervention studies evaluated in this paper

Authors / Publication year	**Parkinson et al., 1989**	**Gjerde et al., 1991**	**Lusk et al., 1999**	**Rasmussen et al., 2003**	**Rye et al., 2014**	**Sendall et al., 2016**
Workplace	14 coke oven facilities in the USA and Canada	102 Swine confinement workers (education group) 107 workers (control group)	652 regional Construction workers 185 national plumber/ pipefitter trainers	201 farms, (99 intervention group, 102 control group)	14 workplaces (agricultural, building and construction, public sectors) 150 workers pre-test 50 workers post-test	14 workplaces (agricultural, building and construction, public sectors) 2 specific workplace case studies presented
Rural or Northern Setting	USA and Canada	Eastern Iowa	Midwest USA	Ringkoebing, Denmark	Rural and regional Queensland, Australia	Rural and regional Queensland, Australia
Objectives of Occupational Health Education	Improve knowledge of the Coke Oven Standard and cancer hazards and designated behaviour changes to reduce emissions	Improve knowledge, attitudes, behaviours related to respiratory disease	Theory-based intervention to increase use of hearing protection	Improve safety behaviour among farm workers on work accidents and injuries	Evaluate outdoor workers' sun-related attitudes, beliefs, and behaviours	Qualitative data on workers' behaviours, attitudes and beliefs on sun exposure and protection at work
Theory	Followed criteria set by American Public Health Association	Health Belief Model	- Health Promotion Model - Guided mastery experience - Social modeling of positive attitudes and perceptions - Active participation in health	- Behavioural change - Participatory action research	Participatory action research	Participatory action research
Intervention Description	4 modules (2-hours) at 6-month intervals over 2-year period	6 educational home study modules and reference material	- 20-minute video - Pamphlet - Written handouts - 15-minute guided practice session on hearing protection	- Farm safety check (½ day) - 1-day safety course (occupational health physicians/psychologists) - Video and written course	Outdoor worker sun protection project: - Policy - Structural and environmental - PPE - Education - Role modeling - Skin examinations	Outdoor worker sun protection project: - Toolbox talks - Verbal reminders - Informal discussions - Staff meeting, - Monthly staff memo

				content for participants unable to attend		- Messages on pay slip - Brochures - Posters - Weekly emails - Added information to induction sessions
Content	- Module 1: History - Module 2: Types of cancer and effective medical surveillance - Module 3: Personal workplace practices/engineering controls - Module 4: Current status of control program at each plant	- Group meeting including: a meal, social time, a demonstration of equipment, and a problem-solving discussion	- Video: discussion between worker and occupational health nurse -Hands on practice with various types of HPD (hearing protection devices)	5 elements to safety course: 1. Risk factors 2. Focus group discussions 3. Direct confrontation 4. PPE 5. Group discussion	Education: - Sun safety awareness and protection - Correct use of PPE	Education: - Sun safety and protection - Skin cancer - Skin examinations - UVR index - Language barrier for written resources
Context	Two pilot programs performed to inform current program with 8 years of collaboration between the union and university	- Majority of workers were male, high school educated, married, and had 15 years experience - High knowledge on some questions and favorable attitudes	Younger workers wore their hearing protection less often and lower intentions for the future	- Farms are typically family unit with 1 or few labourers - Varying types of farms included	Tailored sun protection action plan for each workplace	- Workplace 1: small family-owned agricultural business - Workplace 2: large public sector organization
Process	- 7 pairs of matched plants (geographic location, work force size, ethnic composition) to compare experimental to control - In-depth publicity campaign, flyers on plant bulletin boards, mailing to workers'	- Mailed a series of 6 modules and periodic newsletters over year 1. - Received metal sign of project logo to identify farm.	2 trainers (4 in total) directed each session Solomon four-group design	- Part of a longitudinal 4-year randomized trial - Participated in farm safety check then attended 1-day course 1-4 weeks afterwards (5-6 farms per session)	- Weekly contact - 3 workplace site visits - Project website	Workplace champions at each worksite to implement and execute the tailored strategies at each workplace

	homes. Refreshments served at the sessions and small gifts were given to participants					
Outcome	- Significant improvements in the knowledge and behaviours of the participants in the intervention group. - Workers who attended more than one session had improvement	1 year follow-up; Statistically significant improvements for knowledge, attitudes, and behaviour for the intervention group	10-12 Months follow up; significant increase in use of HPD and no effect on intention to use HPD in the future	Reduction in injury rates and significant improvements in safety behaviour	18-month intervention; increased workers' sun protective attitudes, beliefs, and behaviours	Successful implementation of multiple sun safety intervention strategies at each workplace

3. Results

Six articles with a focus on occupational health education interventions conducted in rural and/or northern locations were selected to be included within the analysis and were evaluated according to the Content-Context-Process-Outcome framework to provide recommendations on creating successful interventions (Karanika-Murray and Biron, 2015). The general description and information related to the Content-Context-Process-Outcome framework from each article were compiled in Table 1.

3.1 Content

The first element within the framework for consideration is content (Karanika-Murray and Biron, 2015). The content of the intervention needs to be tailored specifically to meet the needs of the individuals within the population (Lusk, 1999). In the study by Lusk et al. (1999), the importance was highlighted in viewing educational material from an age perspective, as younger workers wore their hearing protection less and had lower intentions of using hearing protection in the future. An understanding of the stages of change has also been suggested as a potential modification for future studies to have greater success (Lusk et al., 1999; Nielsen et al., 2010).

The first language spoken and written by the members of the workplace is also an important consideration for content development. In a 2016 study by Sendall and colleagues on the effectiveness of a sun safety intervention, written resource materials developed in English were deemed to have a limited effectiveness because the majority of workers participating in the education intervention had a first language other than

English. In addition, low levels of worker literacy were noted to have potentially impeded participation within the study (Sendall et al., 2016).

Collaboration between stakeholders is also important in content development. In the study by Parkinson et al. (1989), the success of the intervention program was linked to the collaborative approach of the union, workplace, and university that was adopted to develop program content, presentations, questionnaires, and interviews. In addition, the education intervention followed the American Public Health Association guidelines in the design of the content. Lastly, input was welcomed from an advisory committee comprised of representatives from the members and staff of the United Steel Workers of America, union representatives, and faculty (Parkinson et al., 1989). Similarly, swine confinement workers participating in an occupational health education intervention were invited to provide feedback and an evaluation of the educational materials and their group meeting session (Gjerde et al., 1991). Similar observations were noted within the Outdoor Worker Sun Safety Protection Project, as the authors commented, those within the workplace are situated to know what will work within their respective work environment and structure (Sendall et al., 2016).

Providing a detailed description and inclusion of an intervention's content in published literature or reports assists in future research to modify, apply, or replicate the content. For example, an occupational health education intervention was designed to improve knowledge, attitudes, and safety behaviours of swine confinement workers in southeastern and northeastern Iowa (Gjerde et al., 1991). Although the educational content was not the focus of the paper, the author cited the paper by Ferguson and colleagues (1989) in which the educational content components of the intervention were described. A detailed description of the included material and topics covered was provided, to help readers understand the content of the intervention. In addition, an appendix was provided with an example of one of the occupational health education handouts, in order to assist future research.

Understanding the existing workplace structures and organization of work has also been noted to influence the design and delivery of the occupational health content. Parkinson and colleagues (1989) implemented a collaborative health education intervention program throughout 14 coke oven facilities in the United States of America (USA) and Canada. The intervention comprised four two-hour modules delivered at the workplace, outside of work hours, over a two-year period (Parkinson et al., 1989). The explanation for conducting the intervention program outside of regular work hours was not fully provided; however, the collaborative team approach, multiple pilot projects, and adaptable program would suggest this would have been deemed the most appropriate time frame (Parkinson et al., 1989).

3.2 Context

Understanding the context of the overall industry, organization, and worksite-specific details is an important component for consideration in the design of an occupational health intervention. Elements related to the context of rural and northern communities and industries necessitate consideration. As highlighted by Lusk and colleagues (1999), construction sites differ in numerous ways which may impact workers' hearing protection (multiple job sites per day, varying amounts of noise); however, the authors did not provide sufficient details for other researchers to understand differences in the context of the different worksites in the study.

Success has been documented and attributed to the ability to further understand and consider context in the design of the intervention. Intervention context is important to discuss as intervention research has been criticized in the past for only including large workplaces with comprehensive occupational health and safety programming and overall better safety records (Levenstein, 1996). However, Sendall et al. (2016) reported smaller workplaces (less than 30 employees) were able to successfully implement more components of an intervention compared to the larger workplaces (more than 100 employees) included within the study. The reasons cited for success were more face-to-face contact, less paperwork, and faster progression for decision making, and action (Sendall et al., 2016).

3.3 Process

Failing to understand the overall contextual intricacies of a specific industry has the potential to impact the overall success of the intervention. For example, in the 2003 study by Rasmussen and colleagues, the failure of an intervention to reduce workplace injuries within agriculture was linked to a non-optimal process in which the intervention should have been implemented. Further, the intervention for the control and experimental group were not conducted within the same farming seasons and the overall poor time frame chosen negatively influenced the desired outcomes (Rasmussen et al., 2003).

Details related to the process of conducting the intervention are often missing from published literature. However, Lusk and colleagues (1999) provided process details and a discussion of inter-trainer reliability (two trainers participating in each session and rotated as acting leader and debriefing field notes after each session) to improve process evaluation (Lusk et al., 1999).

3.4 Outcome

Barriers of incorporating assessment measurements following an intervention implementation period often lead to outcome measurements of self-reported behaviour and not objective assessment measurements (Lusk, 1999; Ewigman, 1990). Furthermore, outcome measures are often taken immediately following the intervention period; however, intermediate outcomes of knowledge, attitudes, and behaviour are only meaningful if associated with long-term declines in illness or injury rates (Zwerling et al., 1997). A longer follow-up time period can also lead to challenges. For example, the six-month follow-up period in the agriculture study conducted by Rasmussen et al. (2003), occurred during two different seasons which could also influence injury outcomes.

4. Discussion

The purpose of the current paper was to provide a critical review of occupational health education interventions that have been conducted within northern and rural workplaces. Through the analysis of the literature utilizing the Content-Context-Process-Outcome framework, recommendations for future research applicable to being utilized within northern or rural industries or communities were outlined (Karanika-Murray and Biron, 2015).

4.1 Content Considerations

Interventions in rural and northern settings should consider language, literacy levels, and cultural backgrounds of a diverse workforce, to aid workers' understanding of risk communication materials (Gong et al., 2009; Rye et al., 2014). Indigenous and francophone peoples comprise a large proportion of the population in rural and northern communities which highlights the need for tailored content materials (LHIN, 2014; LHIN, 2014). Intervention studies should also consider evaluation approaches beyond the traditional written questionnaire, such as picture-based methods which are able to compensate for linguistic and literacy limitations (Gong et al., 2009). Future interventions with a diverse workforce could also consider unconventional qualitative methods, such as associative imagery and thought bubbles, and developing education content and resources for multilingual and low literacy levels (Gong et al., 2009; Rye et al., 2014).

4.2 Context Considerations

Intervention research has been criticized for engaging primarily with large workplaces with experienced occupational health and safety departments, developed resources and safety records at the exclusion of smaller workplaces, and workplaces located in rural and northern areas (Levenstein, 1996). To be successful, unique elements of rural and remote worksites need to be considered when conducting intervention research in rural and northern regions. Furthermore, researchers also need to understand the potential challenges faced by rural and remote worksites that may undermine the benefits of a solution or intervention (Lipsey, 1996).

Understanding the industry context within rural and northern communities helps to inform researchers when planning and conducting an intervention with a workplace partner. Within a rural context, the agriculture industry has had some success with implementing occupational health interventions which have resulted in reduced injury and illness rates among farmers (Goldenhar et al., 1996). To be successful, interventions for the agriculture industry have had to consider the impact of rural isolation on the overall health of farmers (Hope et al., 1999). The seasonal work of farmers also has to be taken into consideration and has been compared to challenges that are often faced by shift-workers, as both farmers and shift-workers have to contend with long and often irregular work-hours (Loue and Quill, 2010). Furthermore, many workers in remote areas, including farmers and fly-in fly-out miners, also have challenges with the overlap of residence and home, varying work activities, and changing characteristics of the work site (Loue and Quill, 2010). Therefore, conducting an intervention in a geographic location that experiences seasonal fluctuations can have a negative influence on desired outcomes (Lipsey, 1996). Northern Ontario experiences four distinct seasons, and as a result, seasonal variations need to be considered when determining the timeframe for an intervention.

Mining is another work environment that plays an integral role in the work and health of individuals in northern and rural regions. Mining has seen the inclusion of occupational health and safety initiatives broaden, with a greater emphasis on prevention (McPhee, 2004). The conditions of a mining work site are dynamic, and evolve daily, and workers in all sectors need to ensure they are aware of potential hazards. The increase in mechanization across all industry sectors has also led to an increase in workplace accidents and exposures (Donoghue, 2004). Likewise, the impact of innovation and mechanization has led to injuries and illnesses, a challenge which has been cited as the hardest to resolve (Pratt, 1990). The majority of mines in northern and rural Canada operate 24 hours a day, 7 days a week and require their employees to work 10 and 12 hour shifts on rotating shiftwork schedules (Donoghue, 2004). All of these factors need to be considered when designing an intervention for the mining industry.

4.3 Process Considerations

Successful interventions are also built on strong collaborations and partnerships formed between the researchers and the workplace. Parkinson and colleagues (1989) attributed intervention success to collaborative efforts of the union, workplace and university to achieve credibility, relevance and sponsorship from the workplace. They also showed a lack of support of managers can negatively influence the attitudes of workers (Parkinson et al., 1989). Furthermore, intervention success can be attributed to the unique collaborative efforts between the union, workplace, and university in developing the program content and presentations, questionnaires and interviews, and hiring and training of project support personal (Parkinson et al., 1989). A collaborative partnership is required to work effectively and efficiently for the success of the overall project, and the amount of time, effort, and resources, both monetary and in-kind, cannot be underestimated. The partnership was also able to facilitate access to facilities across the USA and Canada, which helped the research team overcome the challenge of gaining access to a rural study population.

Support from administrators is also important to ensure intervention success and researchers need to acknowledge that a lack of support demonstrated by senior managers can influence worker attitudes (LaMontagne and Needleman, 1996; Nielsen et al., 2010). Rye et al. (2014) also highlighted the importance of management in supporting and enabling the delivery of the intervention within the workplace.

Researchers should also develop and nourish partnerships with those who will apply their research results within a workplace or industry (Frank and Cullen, 2006). The vast geography of northern Canada can also hinder researchers' ability to travel to numerous worksites quickly, which creates additional logistic difficulties (Rasmussen et al., 2003). Therefore, adequate travel funds and a dedicated team are needed to conduct research across multiple sites over large distances. Moreover, the adoption of an active multi-disciplinary team is an essential component to designing, implementing, and evaluating an occupational health educational intervention for northern and rural workplaces (Rosenstock, 1996; Frank and Cullen, 2006). Workers' perspectives should also be consulted when considering context. For example, workers should be involved in the design of the research process and asked to provide feedback on program materials to ensure knowledge is translated into action within their workplace in a meaningful way (Boden, 1996; Frank and Cullen, 2006).

4.4 Outcome Considerations

Prevention interventions should remain focused on ensuring the results of the study are generalizable to other populations (Skov and Kristensen, 1996). Outcomes in the form of statistical significance are often not equal and proportionate to the practical influence within the workplace, and as a result, practical impact to the health of the workers should also be used to discuss the meaningfulness of the outcomes (Lipsey, 1996). Researchers must measure and monitor the implementation of intervention programs by quantifying key activities, as often as possible (Lipsey, 1996; Griffiths, 1999). Moreover, interpretation of results can be difficult without knowing how, where, when, and with whom the intervention was conducted (Griffiths, 1999). Further hindered by a lack of understanding related to process variables, is the ability to transfer research evidence into practice and policy (Nielsen et al., 2010).

Although researchers agree that a theoretical basis for interpreting intervention outcomes is important, there remains a lack of use of a theoretical basis during the development phase (Hersey et al., 1996; Shannon et al., 1999). A sound theoretical basis for design, implementation and evaluation of intervention research cannot be understated. In order to provide interpretable and generalizable results, theory must be utilized throughout, as challenges can arise when attempting to explain how or why an intervention has succeeded or failed without a theoretical basis (Goldenhar and Schulte, 1994) (Goldenhar and Schulte, 1996). Therefore, appraisals of success and failure should reflect on the theory of the intervention, the content producing the outcomes, the implementation of the intervention, and the process and context, leading to the given results (Karanika-Murray and Biron, 2015).

Expanding the use of qualitative methods has also been suggested to lead to meaningful results and understanding (Needleman and Needleman, 1996). LaMontagne and Needleman (1996) went on to suggest qualitative exploration should be adopted to understand the context of the workplace prior to launching a larger scale quantitative intervention. Quantitative methods, which have dominated occupational health research, have been critiqued as not capturing the meaning behind the interventions (Griffiths, 1999; Mergler, 1999). However, qualitative approaches have been suggested to help understand an individual's behaviour as well as overall system influences (Needleman and Needleman, 1996). Similarly, qualitative approaches have the ability to be flexible and adapt, which is often a positive attribute when working with organizations, to lead to successful collaborations and outcomes (Needleman and Needleman, 1996).

4.5 Limitations

Identifying published scientific literature pertaining to occupational health education interventions that have been completed within a rural and northern context is a challenging endeavor (Verbeek et al., 2005). Although occupational health education interventions have widespread use across industries and countries, valuable contextual information regarding the location of the work setting and implementation of the intervention is often missing (Karanika-Murray and Biron, 2015). Therefore, there may be additional occupational health education interventions published within the English literature, which were conducted in a rural or northern setting, but were not found through the search strategy employed in this study. Despite the desire for more information, health-related data or results must be utilized and handled with the utmost of sensitivity and confidentiality in order to ensure it is not used for identifying or discriminatory purposes against participating workers (ILO, 1998). In addition, a publication bias towards intervention research that has been deemed successful also leads to the potential inability of gaining an understanding from failed intervention research (Nytrø et al., 2000). As a result, this study did not include a formal quality assessment of the included intervention papers, but rather the components of the interventions were analyzed.

4.6 Future Research

The application of the Content-Context-Process-Outcome framework assisted with the synthesis of literature to provide an analysis of previously completed occupational health education interventions conducted in rural and northern industries and communities (Karanika-Murray and Biron, 2015). The recommendations suggested in the current study provide a starting point for the design of future intervention studies. Furthermore, the Content-Context-Process-Outcome framework should be used to design, implement and then evaluate future interventions for rural, northern, and remote worksites (Karanika-Murray and Biron, 2015).

5. Conclusions

Occupational injuries and illnesses, resulting from exposures while working in rural and northern industries, could impact the health of the workers and the broader community in which they reside. Challenges related to conducting occupational health interventions in rural and remote locations, include shift work, episodic and seasonal employment, and changing or unpredictable work conditions (Ringen and Stafford, 1996). The importance of intervention research in rural and northern industries cannot be understated. Karanika-Murray and Biron (2015) stated: “interventions are the crux of translating theory into practice for improving working lives and organizational and individual health” (p.276). Therefore, research on the development, implementation, and evaluation of occupational health education interventions is essential for the health of individuals and workplaces in rural and northern locations. Implementing context appropriate programs, utilizing qualitative approaches to a greater extent, bringing together a collaborative multidisciplinary team, ensuring stakeholder engagement, and applying theory in the development and interpretation of interventions, will lead to successful outcomes to ensure rural and northern workers and communities thrive.

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Chapter 4 - Evaluation of Vibration-Focused Occupational Health and Safety Education Materials in Mining

Abstract

Background: Increased operation of mechanized equipment in mining has led to workers being exposed to high levels of hand-arm, foot, and whole-body vibration. Worker health is at risk as a result of their vibration exposure. Knowledge and awareness of occupational vibration exposure and opportunities for training and education are noted to be lacking. Occupational health and safety (OHS) training is an important component of OHS programs and is needed to educate workers on how to best recognize and control for hazards, establish safe work practices, ensure proper usage of personal protective equipment and implement appropriate emergency procedures and preventative actions.
Objectives: To document and evaluate vibration-focused OHS training opportunities conducted by health and safety organizations that provide service to the mining industry in Ontario.
Methods: The online training catalogues of Ontario's OHS system partners, that deliver training to the mining industry, were searched for courses containing vibration-related content. A data extraction and critical appraisal tool was utilized to systematically extract the provided course names, course outlines, and descriptions of training, in order to identify relevant training objectives related to vibration.
Results: Opportunities for vibration-focused education and training are lacking. Only one course focused solely on whole-body and hand-arm vibration. Vibration content was only listed explicitly in the description of one additional course. No courses or descriptions provided information on foot-transmitted vibration.
Conclusions: Training specific to identify vibration as a hazard and potential risk factor for injury or illness is lacking. The results highlight the need to develop a vibration-focused OHS education program for workers in the mining industry

1. Introduction

Increased operation of mechanized equipment and high production demands have resulted in increased exposure to occupational vibration (McPhee, 2004; Leduc et al., 2011; Eger et al., 2013; Eger et al., 2014). Vibration exposure is characterized by the location of the body that is in contact with the vibrating tool or equipment, it is classified as hand-arm vibration (HAV) if the primary route of exposure is through the hands, foot-transmitted vibration (FTV) if the primary route of exposure is through the feet, and whole-body vibration (WBV) if exposure is through the back, buttocks and feet (Griffin, 1990).

The main health concern for workers exposed to WBV is an increased risk for disorders of the lumbar spine (Bovenzi, 1996; Bovenzi and Hulshof, 1999; Lings and Leboeuf-Yde, 2000; Bovenzi, 2005). More specifically, specialized equipment used in mining typically expose workers to vibration with a dominant exposure frequency between 1 to10 Hz, the known resonance frequency for the spinal column (Kitazaki and Griffin, 1998; Eger et al., 2006; Tiemessen, 2008). The human body harmlessly attenuates most vibration; however, frequencies between 1 to 20 Hz cause the pelvis and spine to resonate and are associated with increased injury risk (Thalheimer, 1996; Kitazaki and Griffin, 1998).

Exposure to HAV and FTV can also lead to irreversible damage to worker's hands and feet (Hill et al., 2001; Thompson et al., 2010). Hand-arm vibration syndrome (HAVS), can develop from prolonged exposure to HAV, resulting in circulation and sensory impairment in the fingers, leading to tingling, numbness, and a loss of manipulative dexterity (Bernard et al., 1998; Hagberg, 2002; Bovenzi, 2005; Heaver et al., 2011; Youakim, 2014). Similarly, prolonged FTV can lead to vibration-induced white feet, resulting in vascular impairment, tingling, and numbness within the toes (Thompson et al., 2010; Eger et al., 2014).

1.1 Vibration Education Programs

Education regarding risk factors for WBV, HAV, and FTV exposure and associated health effects needs to be incorporated into workplace health and safety training (Robson et al., 2012a). Workers require education to understand the symptoms and changes in health that may result from vibration exposure. Furthermore, despite the potential for progressive and irreversible damage in the hands, workers often postpone filing a compensation claim for HAVS (Youakim, 2012). According to Youakim (2012), from the onset of symptoms, loggers delayed filing a claim for HAVS an average of six years and mechanics waited three years. Therefore, awareness is needed to inform workers of HAVS symptoms and additional information needs to be provided to assist workers to advocate on their own behalf when seeking medical care (Curti et al., 2015). Increasing one's understanding of occupational sources of vibration exposure may also assist during patient and physician interactions and indirectly influence the reporting and diagnosis of occupational diseases (Curti et al., 2015).

To date, the level of worker and supervisor knowledge, in the mining industry in Canada, about different types of vibration exposure and impact on health risk is not known. A previous study examined perceived knowledge levels of occupational health and safety professionals in the USA and found they self-reported little or no knowledge of WBV hazards, health effects, and control strategies (Paschold and Sergeev, 2009). More alarming, the mean scores for all categories of knowledge were lowest for the 50 participants working within the industrial classification of mining (Paschold and Sergeev, 2009). An overall lack of knowledge about vibration exposure and potential health risk is a concern, since lack of knowledge will inhibit a worker's ability to anticipate, recognize, evaluate, and control vibration hazards (Paschold and Sergeev, 2009).

Improvements in knowledge related to vibration have been documented through educational components of preventative occupational health and safety interventions.

Information leaflets and instructional sessions focused on WBV were developed for forklift drivers, managers, occupational physicians and occupational hygienists, resulting in slight increases in their respective mean knowledge scores (Hulshof et al., 2006). An information brochure developed by Tiemessen and colleagues (Tiemessen, 2007; Tiemessen, 2009), as part of an intervention program to reduce WBV, did not lead to significant differences in knowledge scores, but resulted in reported relevant reductions in measured vibration exposure (Tiemessen, 2009). Furthermore, a double-sided laminated information document, for construction workers, who received an assessment for HAVS at an occupational health clinic, was distributed to improve their awareness of HAVS (Thompson et al., 2012; Leduc et al., 2016). After receiving the information, several improvements were noted at the worksites including: increased anti-vibration glove use, the purchasing of lower vibration tools, process changes, decreased exposure time, and additional HAVS training opportunities (Thompson et al., 2012).

Despite the positive results of occupational health education interventions targeted at WBV and HAV exposures, there has yet to be a published evaluation of an education intervention program that includes information on WBV, HAV and FTV exposure as experienced within the mining industry. Furthermore, it is not known whether the Ontario Health and Safety System Partners are currently offering vibration-focused training materials to the mining industry in order to provide necessary education to prevent injuries and illnesses related to the varying types of vibration exposure.

1.2 Benefits of Evaluating OHS Education Programs

Evaluating and documenting resources for occupational health concerns is important to ensure training practices are addressing and educating workers on appropriate hazards within their workplace. For example, Zack and colleagues (2018) recently characterized gaps in skin-specific training for workers with possible contact dermatitis. Their review concluded that at least half of workers characterized as at-risk for contact dermatitis were not receiving the appropriate training (Zack et al., 2018). In a study by Leduc (2016), construction workers exposed to vibration reported receiving general occupational health and safety training (90% OHSA, 96% WHMIS, 85% general health and safety), yet, only 5% had received training discussing HAVS. Likewise, only 8% of surveyed construction workers reported to have received training on the use of anti-vibration gloves, in comparison to 49% reporting to have received training on protective gloves in general. As such, identifying gaps in training content related to vibration hazards, health effects, and control strategies is an important step in leading to the creation of education programs focused on prevention for WBV, FTV, and HAV exposures in mining.

1.3 Objectives

The objectives of the current study are to: 1) document the training courses and education, focused on occupational vibration exposure, being conducted by Ontario Health and Safety System partners servicing the mining industry within northern Ontario, and; 2) describe the resources and content being utilized which discusses vibration exposure, controls strategies, and the impact on health.

2.0 Methods

2.1 Ontario Health and Safety System Partners and Sample Selection

There are a number of Health and Safety System Partners (HSSP) operating in Ontario (Table 6, Appendix 2); however, only the HSSPs that consistently provide core services to the mining industry were selected to be included in the study. As a result, the Occupational Health Clinics for Ontario Workers (OHCOW), the Workers' Health and Safety Centre (WHSC) and Workplace Safety North (WSN) were selected.

2.2 Analysis Tool and Search Strategy

A data extraction and critical appraisal survey, adapted from Egan and colleagues (2003), was utilized to systematically extract vibration training information, from the on-line training catalogues of the selected HSSPs. The training catalogues, from WSN, WHSC, and OHCOW, that are available on-line from their respective websites, were accessed by a member of the research team between August-October, 2016. Course names, course outlines, and descriptions of training were screened to identify relevant training objectives related to vibration. Example information extracted included: the types of vibration exposure discussed in the training, health effects and symptoms outlined, duration and location of the course, and the teaching methodologies utilized (Appendix 3). Course content materials were appraised, utilizing the survey, for the components of the training course and content related to vibration.

2.3 Data Analysis

Statistical software, IBM SPSS Statistics for Macintosh, Version 23.0 (IBM Corp., Armonk, NY), was used to provide a descriptive summary including frequencies of the number of courses with vibration content and the various types of vibration exposures (WBV, HAV, FTV). Contextual information was presented, if provided, to further understand the setting in which vibration education was discussed and delivered to the workers.

3.0 Results

Findings from the analysis of vibration training materials delivered by the selected Ontario HSSPs that serve the mining industry are summarized in Table 2.

3.1 Workplace Safety North

The search of the WSN training catalogue, that was published on-line, yielded 121 courses offered (89 English, 32 French), with 35 courses (28 English, 7 French) targeted for the mining industry. Within the 35 potential courses for the mining industry, there were five courses highlighted that could include vibration content (Table 2). Although, none of the five course outlines or descriptions included the word “vibration”, the nature of the course suggested the trainer could potentially reference vibration when delivering the material.

3.2 Workers Health and Safety Centre

The search of the WHSC training catalogue, published and accessed on-line, yielded 150 courses offered (127 English, 23 French) with 15 targeted specifically for the mining industry. From these 15 courses, three were identified with potential vibration content (Table 2). The WHSC was the only agency to have a course with “vibration” in the title: Vibration Hazard Module. Moreover, the Vibration Hazard Module course description contained references to both whole-body and hand-arm vibration content. Furthermore, the course titled, “Ergonomics: recognizing injuries, risk factors and design principles” also had a direct reference to vibration in the course description, but it did not specify which type of vibration exposure would be presented or discussed.

3.3 Occupational Health Clinics for Ontario Workers (OHCOW)

A search of OHCOW’s training catalogue, published on-line, identified 17 fact sheets (15 English, 2 French), 27 general handouts and brochures (23 English, 4 French), nine technical information sheets (English) and two reports on musculoskeletal disorders (English). From the 55 identified education materials, three were found to have vibration (HAV and WBV) content (Table 2).

Table 2: Summary of vibration educational materials delivered by Ontario Health and Safety System Partners that serve the mining industry

Health and Safety System Partner	Course Identified	Reference to Vibration	Delivery Method	Duration of Course
Workplace Safety North	Musculoskeletal Disorder Prevention Workshop	Vibration content not specifically listed but nature of the course suggests potential for vibration content	Course: In person	1 day
Workplace Safety North	Supervisor Common Core: Occupational Health and Industrial Health Hygiene	Vibration content not specifically listed but nature of the course suggests potential for vibration content	Course: In person	1 day
Workplace Safety North	Joint Health and Safety Committee Certification Training- Part 1	Vibration content not specifically listed but nature of the course suggests potential for vibration content	Course: In person	3 days
Workplace Safety North	Joint Health and Safety Committee Training – Mining, Mining Job/Task Analysis	Vibration content not specifically listed but nature of the course suggests potential for vibration content	Course: In person	3 days
Workplace Safety North	Musculoskeletal Disorder Awareness	Vibration content not specifically listed but nature of the course suggests potential for vibration content	Course: Online	20 minutes
Workplace Health and Safety Centre	Vibration Hazard Module	WBV, HAV	Course: In person	3 Hours
Workplace Health and Safety Centre	Ergonomics: Recognizing Injuries, Risk Factors and Design Principles	Indicates vibration content but does not specify type	Course: In person	6 Hours
Workplace Health and Safety Centre	Hand tools	Vibration content not specifically listed but the nature of the course suggests potential for vibration content	Course: English French	3 Hours
Occupational Health Clinics for Ontario Workers	Carpal Tunnel Syndrome	HAV	Online PDF	13 pages
Occupational Health Clinics for Ontario Workers	HAVS: hand-arm vibration syndrome	HAV listed	Online PDF	6 pages
Occupational Health Clinics for Ontario Workers	Ergonomics and Driving	WBV listed	Online PDF	4 pages

4.0 Discussion

The primary objective of the current study was to document training courses and education materials, focused on occupational vibration exposure, being conducted by Ontario HSSPs servicing the mining industry within northern Ontario.

Overall, OHS educational opportunities in northern Ontario focused on vibration as a workplace hazard and potential risk factor for injury or illness, are lacking (Table 2). Out of 50 courses offered by the three agencies that serve the mining industry, only one course in the search, the Vibration Hazards Module offered by WHSC, was found to have a detailed description and primary focus of vibration education (Table 2). Furthermore, only seven courses were identified to potentially include vibration in the delivered content. Fifty-five educational resources offered by OHCOW yielded three documents discussing both HAV and WBV exposures within the workplace. These findings are alarming as workers in mining continue to be exposed to potentially harmful levels of WBV, HAV, and FTV (Hill et al., 2001; Eger et al., 2006; Leduc et al., 2011; Eger et al., 2013; Eger et al., 2014).

The second objective of this study was to describe course content, if specific reference to vibration exposure, health risk or controls strategies was present. One course and one document that specifically mentioned WBV, and one course and two documents that specifically mentioned HAV were identified. No course or documents made any reference to FTV exposure or associated health risk. There is a need for additional training opportunities as miners are regularly exposed to WBV, HAV, and FTV. More specifically to FTV, the literature suggests workers who are standing and drilling off raise platforms, bolting, or operating a jumbo drill are exposed to FTV levels associated with the development of vibration-induced white feet (Leduc et al., 2011; Eger et al., 2014). Therefore, a lack of awareness and education regarding the risks associated with FTV exposure may lead to a continuation of workers experiencing impairment in their toes (Thompson et al., 2010; Eger et al., 2014).

Training opportunities that specifically address hazard identification of vibration sources within the workplace, potential control strategies, and potential symptoms and implications for health, are all necessary components to be included within health and safety programs. Gaining knowledge of an occupational risk factor alone, does not always lead to effective prevention strategies (Hulshof et al., 2006; Tiemessen, 2009; Johanning, 2015). Therefore, in addition to providing awareness and recognition of vibration hazards, it is important to include a discussion of control strategies to reduce vibration exposure. Current control strategies in the workplace that may be modifiable through training include: limiting travel speeds and travel distances, travel surface maintenance, request for equipment maintenance, correct seat adjustment procedures, task variation, work organization and practices, decreased grip force when grasping tools, body posture, and use of personal protective equipment (Hill et al., 2001; Donoghue, 2004; McPhee, 2004; Tiemessen, 2008). More specifically to HAVS, topics that have been advised to be covered within a session are: the importance of utilizing anti-vibration equipment, prevention of HAVS, prevention of further deterioration, and other health behaviours, medical conditions, and hobbies that may further impact HAVS (Hill et al., 2001). Additionally, an improvement in knowledge across all types of vibration exposures may also improve a worker's ability to seek appropriate health care and discuss treatment and care options with a health care provider (Curti et al, 2015).

4.1 Limitations

Only materials that were available from the on-line catalogues of the selected HSSPs were examined for this study. Future research should attempt to obtain a copy of all associated course materials including full presentations, leader's guides, and participant materials. As a result of not having complete training manuals, videos, presentations, or handouts, it is not fully known if vibration was discussed as part of the formal curriculum or mentioned by the trainer. Furthermore, OHCOW also provides educational and occupational health services by request, which would not be accounted for within the search. Moreover, this review did not consider education provided internally within mining companies. Workers in the minerals industry may be able to receive training on vibration exposure through on-site education from their respective occupational health and safety department, which was not considered in this paper. Training materials provided by private consulting companies, who serve northern Ontario clients, were also not included within the search. However, despite these limitations, the search results indicate the HSSPs in Ontario servicing the mining industry, do not appear to be providing the necessary and required education related to vibration exposure to inform and protect workers.

4.2 Future Research

Future studies should evaluate both the written course material and the content of materials delivered via presentations and videos. An analysis of training programs offered to other resource-based industries that operate in northern Ontario should also be examined, as workers in forestry, pulp and paper, steel manufacturing, and construction can also be exposed to occupational vibration associated with injury.

5. Conclusions

Our findings highlight the gap that exists in occupational health and safety training focused on vibration exposure for workers in the mining industry. Furthermore, training programs are required for WBV, HAV, and FTV. Finally, vibration-focused education interventions, for the mining industry, are needed to increase awareness, about hazards, health risks, and control strategies, in order to prevent vibration-induced injuries.

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Chapter 5 – Vibration Toolkit: Protocol for Designing an Occupational Health Education intervention Focused on Vibration Exposure in Mining

Abstract

Background: Workers in the mining industry are typically exposed to three types of vibration exposure while performing their job tasks: whole-body vibration (WBV), hand-arm vibration (HAV), and foot-transmitted vibration (FTV). Despite the potential for increased health risks to exposed workers, currently there is a lack of education and training resources to address the health and safety issues related to vibration exposure within the mining industry.
Purpose: The purpose of this study is to provide a protocol for the development of an occupational health educational intervention, tailored for the mining industry, to reduce whole-body, hand-arm, and foot-transmitted vibration exposure.
Methods/Design: An empirically-based and theoretically-informed vibration education intervention, the 'Vibration Toolkit', was developed for an underground mining setting. The intervention was designed to provide education on hazard identification, health effects, and control strategies for WBV, HAV, and FTV exposure. The resulting Vibration Toolkit contained: educational sessions, posters, stickers, hazard identification cards, a device to measure WBV exposure, anti-vibration gloves, and insole samples.
Discussion: The development process, which utilized the framework proposed by Karanika-Murray and Biron (2015) and included principles from adult education theory, informed the creation of the Vibration Toolkit for miners in northern Ontario.

1.0 Introduction

1.1 Vibration in Mining

Workers operating equipment in the mining industry are often exposed to whole-body vibration (WBV), hand-arm vibration (HAV), and foot-transmitted vibration (FTV) (Eger et al., 2013). Underground miners are typically exposed to WBV when operating specialized underground mobile equipment from a seated position (Bovenzi, 2005). Estimates suggest that 4% to 7% of the workforce in North America and Europe are exposed to potentially hazardous levels of WBV in their workplace (Bovenzi, 1996). Although exposure levels in mining have not been specifically reported, Eger and colleagues (2006) compiled WBV exposures collected in northern Ontario mines and found that many of the commonly used mobile equipment, including: surface haulage trucks, underground load-haul-dump trucks, bulldozers, and graders, exposed workers to potentially harmful levels (Eger et al., 2006; Eger et al., 2014). As a result of high exposures and resonant frequencies between 1 to 10 Hz, miners are at an increased risk for disorders of the lumbar spine (Bovenzi, 1996; Bovenzi and Hulshof, 1999; Lings and Leboeuf-Yde, 2000; Bovenzi, 2005) (Kitazaki and Griffin, 1998; Eger et al., 2006; Tiemessen, 2008).

Workers in the mining industry also need to be aware of their potential for HAV exposure while handling and holding specialized tools used during the mining process (Hill et al., 2001; Donoghue, 2004). Prolonged exposure to vibration from hand tools may result in hand arm vibration syndrome (HAVS), which can lead to impairment of vascular, neurological, and musculoskeletal structures in the fingers and hands (Bernard et al., 1998; Hagberg, 2002; Bovenzi, 2005; Heaver et al., 2011; Youakim, 2014). Furthermore, normal functioning, including activities of daily living, and in turn, vocational potential, may decline as a result of the occupational disease (Youakim, 2014).

FTV exposure is a concern for workers standing on mining equipment such as locomotives, jumbo drills, bolters, or raise platforms (Leduc et al., 2011; Eger et al., 2014). Thompson and colleagues (2010) documented the first published medical case study, in the English language, to highlight the changes that can occur in the feet as a result of prolonged FTV exposure. The progressive nature of the changes occurring in the feet warrants immediate preventative action.

1.2 Interventions to Mitigate Health Risks

In order to mitigate risk factors associated with exposure to vibration in an underground mine, the hierarchy of controls should be followed. Previous research has shown engineering solutions, such as drilling from a dampened platform, is successful in reducing vibration exposure (Leduc et al., 2011). Research has also shown operational strategies related to road maintenance, tool maintenance, reduced driving speeds, vehicle loading conditions and seat selection have also been successful at decreasing vibration exposure (Tiemessen et al., 2007; Eger et al., 2011; Ji et al., 2016). Although not all solutions and control strategies are within a workers' immediate control, some have been shown to be modifiable through training such as, limiting travel speeds and travel distances, maintaining travel surfaces, request for equipment maintenance, correct seat adjustment procedures, task variation, work organization and practices, and use of personal protective equipment (Hill et al., 2001; Donoghue, 2004; McPhee, 2004; Tiemessen, 2008; Eger et al., 2011). Furthermore, knowledge of vibration as a hazard does not guarantee action with respect to the implementation of effective measures to prevent injury and illness. Feasible, concrete and measurable control strategies and solutions should be discussed within education and training opportunities (Hulshof et al., 2006; Tiemessen, 2009; Johanning, 2015). Moreover, OHS programming is critical in influencing workers' knowledge, attitudes, and/or behaviour beliefs regarding hazardous workplace exposures, occupational injuries and diseases, and the potential to decrease injury risk through the adoption of control strategies (Goldenhar and Schulte, 1994)

Despite the potential benefits of training programs, education and training opportunities related to occupational vibration exposure, including hazard identification, symptom detection and exposure reduction, are lacking across industries (Hulshof et al., 2006; Tiemessen et al., 2007; Tiemessen, 2007; Tiemessen, 2009). There are few published examples of evidence for existing occupational health programs focused on the prevention and reduction of vibration exposure (Hulshof et al., 2006; Tiemessen et al., 2007; Tiemessen, 2009; Thompson et al., 2012). Hulshof and colleagues (2006) created an intervention program targeted at WBV exposure for forklift drivers, managers, occupational physicians and occupational hygienists. The intervention consisted of an educational program, information brochure and instructional sessions that highlighted the hazards, prevention strategies and legislation (Hulshof et al., 2006). All groups displayed slight increases in their mean knowledge score after the intervention (Hulshof et al., 2006).

Tiemessen and colleagues (2007) also developed an intervention program designed to improve knowledge and reduce WBV exposure (Tiemessen, 2009). An information brochure was provided to the workers with the objective of improving their knowledge by outlining legislation regarding WBV, determinants of exposure, and control strategies to decrease overall exposure (Tiemessen et al., 2007; Tiemessen, 2009). There were no significant differences found in knowledge when comparing pre- and post-test scores, although the measured vibration exposure levels were reported to have been reduced (Tiemessen, 2009).

An occupational health education program, about the impact of HAV exposure at work and the prevention of HAVS, was developed for construction workers (Thompson et al., 2012). A double-sided, laminated information document was created and distributed to construction workers who received an assessment for HAVS at an occupational health clinic (Thompson et al., 2012). Following the educational session at the clinic, there was a statistically significant increase in the use of anti-vibration gloves at their respective worksites (i.e., 4.1% baseline and 53.2% follow-up, $p<0.05$). Changes which occurred in the workplace as a result of sharing the information included: purchase of lower vibration tools (20.4%), process changes (16.0%), decreased exposure time to HAV (16.3%), and additional HAVS training opportunities offered by the employer (14.6%) (Thompson et al., 2012). Therefore, early evidence of a focused HAV educational intervention showed promise in increasing the awareness within the workplace for the prevention of HAVS (Thompson et al., 2012; Leduc et al., 2016).

A limitation of previous intervention programs was a singular focus on only WBV or HAV (Tiemessen, 2007; Tiemessen, 2009; Thompson et al., 2012). Moreover, there has yet to be published literature of an occupational health educational intervention targeted at FTV exposure, or all three types of exposure combined, despite the need within the mining industry. Additionally, the previous intervention programs were not developed for industries that operate in a rural or remote location, yet previous research suggests interventions will fail if the unique elements (specific equipment, population characteristics) of rural and northern industries are not considered (Leduc, Chapter 3).

1.3 Vibration Training Programs for Mining

The benefits of OHS training programs that address the three types of vibration exposure as a hazard for workers in the mining industry are unknown. To the author's knowledge, there are currently no published studies that have examined the benefits of vibration educational programs in mining. Moreover, existing training programs that address vibration as a hazard in the mining industry are limited (Leduc, Chapter 4). In 2016, Leduc and colleagues reviewed training programs to reduce vibration hazards offered by Ontario health and safety system organizations that primarily serve the mining industry. Only one training course, out of a possible 50, was found to directly address vibration as a workplace hazard in mining (Leduc, Chapter 4). The authors concluded that there is insufficient evidence of training opportunities currently being offered, which educate workers in the mining industry about how to minimize occupational vibration exposure.

The need for vibration hazard awareness training programs for the mining industry is especially important since many underground miners are exposed to WBV, HAV and FTV, and health implications of combined exposure is not well known. Moreover, there are limited or no treatment options available for the resulting impact on health from WBV, HAV, and FTV exposure (Thompson et al., 2010; Eger et al., 2014; Shen and House, 2017).

1.4 Study Objective

The objective of this paper is to provide a protocol for the development of an occupational health education intervention, tailored for the mining industry, to reduce whole-body, hand-arm, and foot-transmitted vibration exposure. The education intervention is designed to improve knowledge, attitudes, and behavioural beliefs about the three types of vibration exposure.

2.0 Methods

2.1 Theoretical Framework

The Content-Context-Process-Outcome framework by Karanika-Murray and Biron (2015) was used to inform the creation of a vibration intervention program designed for the mining industry. This framework was used to ensure the developed program was relevant and responsive to the needs of rural and northern industries, specifically mining. The framework also provided the structure for the development and description of the various elements of the intervention program.

2.2 Intervention Framework

The development of the Vibration Toolkit was based on the previous design and protocol for a WBV intervention program for forklift drivers developed by Tiemessen and colleagues (Tiemessen, 2007). The development of the Vibration Toolkit attempted to also have the main emphasis on providing education to improve awareness and modify behaviour of the workers, rather than to solely rely on technical aspects of vibration exposure (Tiemessen, 2007). Behavioural interventions are used within OHS research and workplaces to influence workers' knowledge, attitudes, beliefs, or behaviours to a potentially hazardous exposure, occupational-related disease, or health and safety procedure (Goldenhar and Schulte, 1994). Aspects of skills and behaviour in relation to WBV exposure have been associated with a reduction in exposure and are lower in cost and are easier to implement than technical solutions (Tiemessen et al., 2007; Tiemessen, 2007). Similarly, the theoretical underpinning of the interventions developed by Tiemessen and colleagues, suggests that an intention or belief that predicts behaviour and changes in attitude toward vibration exposure may result in changes in behaviour and lead to the adoption of control strategies known to reduce overall vibration exposure (Tiemessen, 2007). The intervention program in this study was also developed with the goal of creating a partnership between employees and the employers in addressing issues of vibration exposure within the workplace (Tiemessen, 2007). Prevention measures were implemented using interactive presentations and health surveillance (Tiemessen, 2007).

3.0 Outcomes

The Vibration Toolkit was developed to provide occupational health education about exposure to WBV, HAV, and FTV in the mining industry. The Content-Context-Process-Outcome framework was employed in the development, design and delivery of the program, to ensure components were relevant and meaningful to the workers at an underground mine site operating in northern Ontario (Karanika-Murray and Biron, 2015). The components of the Vibration Toolkit are outlined and described in Table 3.

Table 3: Description of the Vibration Toolkit components and strategic considerations

Component	Vibration Toolkit				
	Safety Meeting	Hazard Identification Safety Check Card	Posters, Fact Cards, Stickers	iPod and iOS Application (WBV)	Personal Protective Equipment Samples
Description	3 sessions were developed to address vibration in mining: • WBV • HAV • FTV	5 question cards, to assess vibration hazards in the workplace were developed for: • WBV • HAV • FTV	9 posters were created to highlight 3 key messages from each of the 3 safety meeting sessions (WBV, HAV, FTV). Fact card with definitions for WBV, HAV, FTV were developed A sticker was developed for WBV	An inexpensive WBV measurement device was offered as part of the toolkit	Sample anti-vibration gloves were offered to workers after the HAV safety meeting Sample Anti-fatigue insoles were offered to workers after the FTV safety meeting
Strategic Considerations	Educate workers	Engage workers to discuss vibration in their workplace with their supervisor	Reinforce key messages from safety meetings and act as a reminder	Evaluate vibration levels and test control strategy effectiveness	Educate workers about the proper wear and fit of anti-vibration gloves and anti-fatigue insoles

3.1 Content

The content of the Vibration Toolkit was targeted at WBV, HAV, and FTV exposure within an underground mining work environment. It was designed based on principles of adult learning (e.g., autonomous and self-directed, bring life experiences and knowledge to life learning experiences, goal oriented, relevancy oriented, practical, and need to be shown respect) with the aim to improve workers' knowledge, attitudes, and behaviour beliefs regarding vibration exposure in the workplace (Knowles, 1970; Starfield, 2001; NIOSH, 2002).

3.1.1 Whole-Body Vibration Exposure

The WBV educational component was developed to provide an awareness of WBV exposure and to identify mobile equipment within the underground and surface mining environments that would expose workers to WBV. The development of the WBV components was based on previous whole body intervention programs (Hulshof et al., 2006; Tiemessen, 2007; Tiemessen, 2009). Moreover, educational materials were tailored to reflect the mining work environment and equipment commonly utilized underground (Eger et al., 2006; Leduc et al., 2011).

Potential health effects resulting from WBV exposure in mining were discussed in the intervention material with a predominant focus on the lower back (Bovenzi, 1996; Bovenzi and Hulshof, 1999; Tiemessen, 2008). Control strategies were also highlighted to provide guidance on reducing WBV exposure (Tiemessen et al., 2007; Eger et al., 2011). Attention was focused on factors within the worker's control to potentially modify and included: decreasing driving speeds, maintaining a neutral trunk and neck posture when seated, adjusting the seat to match worker mass and to avoid end stops, maintaining vehicles, and requesting road maintenance (Tiemessen, 2007; Eger et al., 2011). A worker's perceived control over the risk for a workplace hazard, has been suggested to be influential in the success of occupational health and safety training efforts (Holmes et al., 1999). Specifically, the aim of the WBV component of the intervention was to improve knowledge about factors that may be modifiable by the worker in order to provide a potential positive modification of behaviour, that could in turn, decrease a worker's overall vibration exposure (Tiemessen, 2007; Eger et al., 2011).

3.1.2 Hand-Arm Vibration Exposure

Material related to HAV exposure in mining was developed to educate workers about early health symptoms and to inform them about the potential for the progression of HAVS (Hill et al., 2001; Thompson et al., 2012). The content related to HAV exposure in mining followed previous recommendations including: purchasing anti-vibration equipment, decreasing exposure to HAV through job rotation, decreasing grip force when operating hand-held tools, maintaining hand-held tools, keeping hands warm and dry, seeking medical attention when symptoms of HAVS appear, and using anti-vibration gloves when warranted (Hill et al., 2001; (Thompson et al., 2012; Leduc et al., 2016). Other health behaviours, medical conditions, and hobbies that may further impact HAVS were also discussed (Hill et al., 2001). As there is no cure for HAVS, the central message conveyed to workers is the need for prevention and early detection of symptoms (Shen and House, 2017). The first aim of this component of the intervention was to improve worker's knowledge of HAVS symptoms in order to encourage them to seek medical advice, as soon as possible, if they started to experience signs of HAVS. The second aim was to improve worker's knowledge of control strategies, within their control, in order to reduce their overall exposure.

3.1.3 Foot-Transmitted Vibration Exposure

The topic of the final education component of the Vibration Toolkit was FTV exposure. Previous vibration interventions have not included FTV exposure as part of their education components. However, previous research within mining was used to provide the scientific evidence for the education component (Thompson et al., 2010; Leduc et al., 2011; Eger et al., 2014). Symptoms related to the development of vibration-induced white feet and potential measures to reduce exposure (ie., utilize a mat or stand on an isolated platform) were highlighted (Thompson et al., 2010; Leduc et al., 2011; Eger et al., 2014). The objective of the FTV intervention component was to provide awareness of the type of vibration exposure that workers may not realize they are experiencing, emphasize where workers can stand to reduce their exposure and to highlight the associated symptoms in order to improve the likelihood that medical attention will be sought, if needed.

3.2 Context

The Vibration Toolkit was designed for implementation in an underground mine site that operates in northern Ontario. Unique elements of an underground mine's work environment that could influence context were, a dynamic worksite, environmental conditions (dark, hot, humid), increased mechanization, shift scheduling, productivity demands, and the potential for exposure to WBV, HAV, and FTV (Ringen and Stafford, 1996; Donoghue, 2004; McPhee, 2004). Many of the job tasks have become increasingly mechanized, and as such, it is imperative to include an occupational health education intervention that targets specific equipment and tools used for each type of vibration exposure (McPhee, 2004). Many workers also change job tasks throughout their shift, which may result in a variety of different vibration exposures. Furthermore, an understanding of the production demands, and shift scheduling must be addressed when designing the intervention. Typically, workers in an underground mine will work 10 to12 hour shifts per day, with high productivity demands, and alternating day and night shift schedules (McPhee, 2004). Knowing how, and when, workers move, travel, and congregate throughout the mine site, also assists in appropriate placement of reinforcement posters and informing the ideal time and location for holding meetings where information can be shared. Typically, the workers congregate in a designated area at the start of their shift in order to receive their tasks, updates, and safety information. In addition, gaining an understanding of the demographic information and work history information of the workforce is also important for the development of the content material to be effectively tailored and delivered to the workers.

3.3 Process

3.3.1 Outline of the program

The intervention program addressed one vibration exposure topic per month over a three-month period. Each education session was created to last approximately 30 minutes to one-hour and occurred during a regularly scheduled on-site safety meeting. As part of the overall program, a customization form was developed for partnering organizations to further tailor the program to their site and industry-specific needs. Customization ensured materials were created and delivered in a manner that reflects the input and feedback from the workplace prior to commencing the program (Table 4). The physical components of the occupational health education intervention programming contents were contained within a hard, waterproof case that was able to withstand the elements found in surface and underground mining environments.

Table 4: Timeframe for delivery of the Vibration Toolkit occupational health education intervention

Pre-Intervention	Month 1	Month 2	Month 3	Post- Intervention
Customization	Topic: WBV	Topic: HAV	Topic: FTV	Feedback Outcome Measures (if evaluating)
	Presentation	Presentation	Presentation	
	Posters	Posters	Posters	
	Hazard Identification Safety Check Card	Hazard Identification Safety Check Card	Hazard Identification Safety Check Card	
	iOS application to measure WBV exposure	Anti-vibration gloves	Anti-fatigue insoles	

3.3.2 Vibration Education Session Presentation

The objective of the safety meeting presentation was to provide education and information with the objective of increasing knowledge (Tiemessen, 2007). Each monthly session was designed to highlight one of the vibration exposure types (whole-body, hand-arm, and foot-transmitted vibration). Each session was divided into the following sections: hazard identification, impact on health, and prevention and control strategies. With respect to control strategies, emphasis was placed on strategies within a workers' control. Furthermore, during each session, workers were encouraged to seek attention from a supervisor if they believed a concern existed within their specific work environment. Participating workers were also invited to ask questions or seek clarification.

3.3.3 Interactive Components

Highly engaging techniques have been shown to have a greater impact in increasing knowledge and skill acquisition (Kearsley, 1990; Burke et al., 2006; Robson et al., 2012a). High-engagement classified teaching techniques such as: behavioural modeling, simulation, and hands-on training, were incorporated into the training sessions. One example in the WBV session can be seen through the use of an iPod and iOS application for WBV measurement (Burke et al., 2006; HSE, 2014; Wolfgang et al., 2014). The free iOS application (WBV), operating on a fifth-generation iPod Touch (Apple Inc, Cupertino, CA, USA; 123x59x6mm, 88g), is able to provide an inexpensive measurement device to allow workers, to collect information about their WBV exposure levels (Burgess-Limerick and Westerfield, 2014; Wolfgang and Burgess-Limerick, 2014; Wolfgang and Burgess-Limerick, 2014; Wolfgang et al., 2014; Burgess-Limerick and Lynas, 2015). The Vibration Toolkit includes at least two iPods loaded with the application so that both workers and supervisors, exposed to WBV during their regular work assignments, can use the device to monitor their exposure to WBV. The Vibration Toolkit also contains a leader's guide and short workshop materials to show workers how to use the device to measure WBV and how to interpret the results to determine if they are at increased risk for vibration-induced injury. The workshop also reviewed how to use the device to evaluate benefits of potential control strategies.

Hazard identification safety check cards were also developed and designed for distribution at the vibration education session and by supervisors. The hazard identification safety check cards were created with the intention of being utilized when the worker arrives at their work location and before commencing work tasks. The worker completes the checklist to consider the potential for vibration exposure during their work tasks. The cards can be collected or discussed with the supervisor. They provide the opportunity for the worker to assess their vibration exposure and determine potential control strategies available before they begin work. The hazard identification safety check cards also provide an opportunity for workers to discuss, with their supervisor, issues or concerns that were identified within the worksite related to their vibration exposure.

Personal protective equipment was incorporated into the program as a way to highlight the associated symptoms and health effects that are associated with vibration exposure. Anti-fatigue insoles were selected for the FTV session and a sample of anti-vibration gloves were available during the HAV session. Workers were able to select an anti-fatigue insole from several styles to enable them to identify one that fit their work boot style and felt comfortable with their foot anatomy. Workers were reminded to monitor the condition of the insoles and replace when necessary. The added attention drawn to the worker's feet will also increase awareness of symptoms being experienced by the worker after they are exposed to FTV while working. Additional benefits of increased comfort while standing and working are also important for overall health and productivity.

Anti-vibration glove samples were provided during the HAV session. Varying sizes and types of certified anti-vibration gloves were provided to ensure a correct fit for each worker. Workers had the opportunity to try the anti-vibration gloves while working with vibrating tools to test the comfort, reduction of vibration, and durability of the gloves for their specific tasks.

3.3.4 Reinforcement Components

Knowledge gains are supported through receiving repeated exposure to new information (Tiemessen, 2007). Three key messages taken from each of the vibration educational sessions were highlighted during the month for each vibration exposure type. Accounting for the dynamic work environment of the mining industry and to ensure reinforcement throughout the intervention, posters were printed on laminated water-proof heavy paper in various sizes and displayed in areas where workers frequently congregate or on existing bulletin or notice boards. The posters reinforced knowledge, positive attitude to toward controls, and suggested the appropriate behaviour for the concepts pertaining to each type of vibration exposure discussed in the education sessions. The intervention was designed to have the posters changed monthly to align with the delivered education session.

3.4 Outcome

Suggested outcome measures may assess workers' knowledge, attitudes, and behavioural beliefs about occupational vibration hazards, health risks, and control strategies, both before and after, the intervention time period (Griffin and Bovenzi, 2007; Paschold and Sergeev, 2009; Tiemessen, 2009). Objective vibration exposure measurements could be conducted before and after the intervention time period to assess changes in overall exposure (Hulshof et al., 2006). A discomfort, health survey, or health surveillance can also be utilized to investigate changes related to comfort, pain, or injury, before and after the intervention time period.

4.0 Discussion

The Vibration Toolkit was designed to improve the knowledge, attitudes, and behaviour beliefs of workers, within the mining industry, in regard to occupational vibration exposure risks, health effects, and control strategies. The development protocol was designed to ensure the context of rural and northern industries, specifically mining, was at the forefront of all stages of the process (Leduc, Chapter 3). The toolkit was also designed to enable each kit to be further customized in order to meet the needs of individual worksites by building in time to consult with workers and trainers prior to program delivery.

Hulshof and colleagues (2006) noted limitations of their study, including inadequate focus on the health educational component and an insufficient program intensity. The design of the Vibration Toolkit addressed issues related to training session content. Furthermore, the evidence-based content, tailored to the mining industry about health concerns and control strategies, was developed based on previous literature and occupational health educational interventions targeting vibration exposure (Eger et al., 2006; Hulshof et al., 2006; Tiemessen et al., 2007; Tiemessen, 2007; Tiemessen, 2009; Thompson et al., 2010; Leduc et al., 2011; Eger et al., 2014; Leduc et al., 2016). Moreover, a concerted effort to incorporate principles of adult education and interactive components within the training sessions enhanced engagement of the workers (Burke et al., 2006).

Tiemessen and colleagues (2009) also reported greater reductions in measured vibration exposure for workers who were compliant with their study agreements (e.g., an agreement made with the occupational health physician regarding one or more measures to reduce vibration) (Tiemessen, 2009). The educational component of the Vibration Toolkit was recommended to occur during the daily crew meeting at the start of the shift to ensure maximum attendance. Furthermore, additional posters were placed in strategic visible locations to reinforce, with workers, the content of the education sessions.

At the present time, the Vibration Toolkit is only available in English. However, given the demographics of northern Ontario, future provision for the translation of materials into French should be considered (LHIN, 2014; LHIN, 2014). Customization to include equipment and vehicles used in surface mining operations would also be beneficial. The inclusion of health surveillance to provide a greater understanding of the health impacts of cumulative and documented vibration exposure has been included in past intervention studies, but it is not a part of the design of the current Vibration Toolkit (Tiemessen, 2007). Future partnerships with industry may seek to establish or build upon existing health surveillance practices within the company to focus on concerns related to vibration exposure. Furthermore, the use of the iPod and free iOS application for WBV measurement may provide the necessary data to document workers' WBV exposure. The iPod and iOS application can also be used to continually assess vibration exposure levels through the monitoring and evaluation of potential control strategies (Wolfgang and Burgess-Limerick, 2014; Wolfgang and Burgess-Limerick, 2014).

5.0 Conclusions

A Vibration Toolkit was developed to address health and safety issues for all three types of vibration exposure (Leduc, Chapter 4). The toolkit allowed for accommodation and modification to be made to ensure the training was relevant to the mining industry and tailored to the nuances of the daily operation at different mine sites (Leduc, Chapter 3). Future research should evaluate the efficacy of the Vibration Toolkit in positively impacting a worker's knowledge, attitudes and behaviours surrounding vibration exposure and the adoption of control strategies. In addition, further research should also consider adapting the Vibration Toolkit for other rural and northern industries where vibration exposure is also common, including forestry, pulp and paper, transportation, construction, and agriculture.

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Chapter 6 – Evaluation of an occupational health intervention for underground mining-related vibration exposure

Abstract

Introduction: Occupational health and safety (OHS) programs are critical in influencing workers' knowledge, attitudes and/or behaviours about hazardous workplace exposures that can contribute to occupational injuries and diseases. Furthermore, vibration education and management programs tailored to the underground mining industry are lacking. However, workers in the mining industry are often exposed to whole-body, hand-arm, and foot-transmitted vibration. The objective of this study was to implement and evaluate a comprehensive occupational health education intervention (Vibration Toolkit) to improve workers' knowledge, attitudes, and/or behaviour beliefs associated with underground mining-related vibration exposures.
Methods: The Vibration Toolkit was implemented over a period of five months in an underground mining operation in northern Ontario. A pre-test survey was completed one-month prior to the intervention and a post-test survey one-month after. The survey addressed work histories, and workers' knowledge, attitudes, and behavioural beliefs about underground mining-related vibration exposures.
Results: One hundred and forty-two workers took part in various aspects of the Vibration Toolkit intervention. Sixty-one participants attended all the education sessions and completed pre-intervention and post-intervention surveys. Data analyses were performed for the 61 matched pairs. Statistically significant improvements were observed for workers' behaviour beliefs, for pre-test ($M=4.46$, $SD=5.697$) versus post-test ($M=8.02$, $SD=6.417$), $t(60)=4.212$, $p<0.001$.
Conclusions: Understanding workers' knowledge, attitudes and behavioural beliefs about underground vibration exposure is important to assist with education, prevention, and control strategies in the mining industry.

1.0 Introduction

Occupational health and safety behavioural interventions are intended to influence workers' knowledge, attitudes and/or behaviours about hazardous workplace exposures and occupational diseases (Goldenhar and Schulte, 1994). Common practice includes the implementation of education, training, risk communication and/or behavioural modification methods (Goldenhar and Schulte, 1994). Previous research has focused on the technical aspects of vibration in order to reduce a worker's occupational exposure

(Tiemessen, 2009). In addition to technical approaches, appropriate information and knowledge are important aspects of a prevention program to reduce vibration exposure (See Figure 1, Appendix E) (VIN, 2001). Education about risk factors for vibration exposure and early health effects need to be incorporated into workplace health and safety training (Robson et al., 2012a). In addition, control strategies to reduce vibration exposure should be discussed with the workforce, because a worker possessing knowledge about an occupational risk factor alone does not always translate into implementation of effective prevention strategies (Hulshof et al., 2006; Tiemessen, 2009; Johanning, 2015). Control strategies, related to vibration exposure in the workplace that may be modifiable through training, include: limiting travel speeds and travel distances, maintaining travel surfaces, maintaining equipment, adjusting seats to avoid end stops, adopting neutral trunk and neck postures when driving, organizing work to include job rotation to decrease cumulative vibration exposure, and using personal protective equipment (Hill et al., 2001; Donoghue, 2004; McPhee, 2004; Tiemessen, 2008).

Evidence of occupational health programs focused on the prevention and reduction of vibration exposure is scarce (Hulshof et al., 2006; Tiemessen et al., 2007; Tiemessen, 2009). An educational program, information leaflet and instructional sessions containing information on hazards, prevention strategies and legislation, were developed for forklift drivers, managers, occupational physicians and occupational hygienists, within a plant environment (Hulshof et al., 2006). Although, the knowledge scores for participants were not significantly different following the intervention program, all groups showed slight increases in their respective mean scores (Hulshof et al., 2006). A lack of focus on the health education component and insufficient intensity of the program were cited as limitations of the study and should be addressed in future intervention studies (Hulshof et al., 2006).

Tiemessen and colleagues also developed an intervention program to reduce WBV exposure (Tiemessen, 2009). Drivers, operating equipment ranging from bulldozers to lawn mowing machines, were provided with an information brochure, outlining legislation regarding WBV, determinants of exposure, and solutions to reduce exposure, with the goal of improving their knowledge (Tiemessen et al., 2007; Tiemessen, 2009). No significant differences in knowledge were found when comparing pre- and post-test scores for both workers and employers; however, there were relevant reported reductions in measured vibration exposure (Tiemessen, 2009). Further reductions in vibration exposure were also indicated for workers who were compliant with the study requirements, suggesting potential for positive results in future studies (Tiemessen, 2009).

The impact of an educational intervention delivered to construction workers at an occupational health clinic has also been documented (Thompson et al., 2012; Leduc et al., 2016). Following the educational session at the clinic, there was a statistically significant increase in the use of anti-vibration gloves by workers (4.1% baseline and 53.2% follow-up, $p<0.05$)(Thompson et al., 2012). Construction worksites also implemented control strategies to reduce the overall exposure of workers through the purchase of lower vibration tools, process changes, decreased overall exposure time, and additional HAVS training opportunities offered by the employer (Thompson et al., 2012). Furthermore, topics advised to be included in proposed worker educational sessions about HAVS included: importance of utilizing anti-vibration equipment, prevention of HAVS, prevention of further deterioration, and the impact of other health behaviours, medical conditions, and hobbies (Hill et al., 2001). Therefore, vibration-targeted educational interventions may be valuable in increasing awareness within the workplace for the prevention of HAVS through symptom identification and reduction of vibration exposure.

To the author's knowledge, no research to date has developed or evaluated the benefits of an educational intervention aimed at mitigating underground vibration exposure. In 2006, Hulshof and colleagues evaluated a program for forklift operators, in 2009, Tiemessen and colleagues evaluated the effectiveness of a program for drivers operating a variety of equipment resulting in WBV exposure, and in 2012, Thompson and colleagues evaluated the benefits of an educational intervention in the construction industry. The previous studies only addressed a single type of vibration (either WBV or HAV), while none of the interventions included education about WBV, HAV and FTV. In 2018, Leduc and colleagues (Leduc, Chapter 5) developed an occupational health education intervention, the Vibration Toolkit, for the underground mining industry. The Vibration Toolkit addressed WBV, HAV, and FTV through a series of safety meetings, hazard identification safety check cards, posters, and samples of personal protective equipment (Leduc, Chapter 5). The purpose of the current study was to evaluate the effectiveness of that occupational health education intervention, the Vibration Toolkit which is aimed at improving knowledge, attitude, and behavioural beliefs of workers at a northern Ontario underground mine site.

2.0 Methods

2.1 Participants

An international mining company with underground mining operations in northern Ontario agreed to partner with the researchers in the implementation of the Vibration Toolkit. All workers attending the mine site's start of shift line-up meeting, to hear their shift assignments, updates, and safety announcements, were eligible to participate. The partnering mining company conducted operations utilizing a four-crew structure.

2.2 Intervention

An occupational health education program, the Vibration Toolkit, was customized, in consultation with the partnering mining company, and implemented within the existing organizational structures of the local mine site (Leduc, Chapter 5). Members of the research team met with the senior management team and the occupational health and safety department manager in the mine, to discuss the components of the Vibration Toolkit, in order to customize the intervention to integrate with existing health and safety programing (Leduc, Chapter 5). The areas of customization included: equipment used by workers, length of safety meeting presentation, content for each safety meeting, scheduling and mode of delivery of the safety meetings, size and number of posters, and the number of personal protective equipment samples (Leduc, Chapter 5).

The intervention was implemented over a three-month period of time (March to May). In order to keep the duration of the education session to less than 30 minutes, a singular type of vibration exposure was discussed at each session. WBV exposure was the focus of the intervention in the first month, followed by HAV in the second month, and lastly, FTV exposure during the third month. Including the evaluation components, the overall program occurred over a five-month period (February-June) as shown in Table 5.

2.3 Pre-test Protocol

The Laurentian University Research Ethics Board approved the research project. Members of the research team visited each of the four work crews at the start of their shifts, approximately one month prior to the commencement of the intervention program. A standardized recruitment script asked workers to participate in a written survey about their work vibration exposure. The importance of confidentiality, anonymity, and reassurance of job security, regardless of participation and outcome, was conveyed to workers both verbally, and in writing on the consent form, prior to survey administration. All workers were informed that they were still able to withdraw from the study at any time without repercussion from their employer or the research team. Each individual received a participant package including: a recruitment letter, informed consent form, and a sealed survey envelope. Consenting participants were instructed to complete the knowledge, attitudes, and behavioural beliefs survey prior to completing the health and work history survey. Although, the health and work history did not contain any specific answers to survey questions, questions related to the use of equipment and areas of discomfort may have indicated a connection regarding vibration exposure and health to the worker. Completion of baseline measures took approximately 15 minutes, which is consistent with previous workplace vibration-related surveys (Tiemessen, 2009).

Table 5: Overview of the vibration toolkit implementation schedule

Component of the Program		Timeline				
Topic	Content	Month 1 (Week 1-4)	Month 2 (Week 5-8)	Month 3 (Week 9-12)	Month 4 (Week 13-16)	Month 5 (Week 17-20)
Pre-Survey	• Questions on knowledge, attitudes, and behaviour beliefs • Questions on work history	4 site visits during Week 1: Crew 1 Crew 2 Crew 3 Crew 4				
WBV Education Intervention	• Safety meeting • Hazard identification safety cards • Stickers		4 site visits for 30 min session on Week 5: Crew 1 Crew 2 Crew 3 Crew 4			
	• Posters on control strategies		Week 6 Week 7 Week 8			
HAV Education Intervention	• Safety meeting • Hazard identification safety cards • AV glove samples			4 site visits for 30 min session on Week 9: Crew 1 Crew 2 Crew 3 Crew 4		
	• Posters on control strategies			Week 10 Week 11 Week 12		
FTV Education Intervention	• Safety meeting • Hazard identification safety cards • Insole samples				4 site visits for 30 min session on Week 13: Crew 1 Crew 2 Crew 3 Crew 4	
	• Posters on control strategies				Week 14 Week 15 Week 16	
Post-Survey	• Questions on knowledge, attitudes, and behaviour beliefs • Questions on work history					3 site visits on Week 20: Crew 1 Crew 2 Crew 3 Crew 4 (not present)

2.4 Post-test Protocol

The research team returned to the mine site at the start of work shift, approximately one month following the final intervention session. Participants were given the same participant package as the baseline collection and the research team followed the pre-test protocol.

2.5 Measures

The survey contained two sections: 1) the knowledge, attitudes, and behavioural beliefs of occupational vibration hazards, health risks, control strategies, and 2) work and vibration exposure history (Appendix 8). The first section of the survey (the knowledge, attitudes, and behavioural beliefs components) was modified from previously utilized surveys in occupational health and safety to assess WBV knowledge (Griffin and Bovenzi, 2007; Paschold and Sergeev, 2009; Tiemessen, 2009). The knowledge assessment included 21 true/false questions about whole body, hand-arm, and foot-transmitted vibration (the knowledge score was a sum of the 21 questions) (Paschold and Sergeev, 2009; Tiemessen, 2009). Example knowledge true/false questions included: regular maintenance of my tools and equipment is not important to the vibration level; the kind of vibration felt when drilling and driving is the same, and; keeping my feet dry and warm will help to prevent health effects in my feet. Attitude questions were assessed using the summed score from 16 questions (Tiemessen, 2009). Attitude was assessed on a 4-point scale with options ranging from -2 to +2 (Tiemessen, 2009). A positive score suggested a positive attitude; whereas, a negative score indicated a negative attitude (Tiemessen, 2009). Example attitude questions included: PPE is more annoying than helpful; my feet are often numb at the end of the day but it is part of the job, and; my co-workers and I sometimes talk about the vibration we feel at work. Tailored behaviour beliefs questions were determined based on the summed score from 11 questions (Tiemessen, 2009). Answering options for attitude and behaviour items were on a 4-point scale ranging from -2 to +2 (Tiemessen, 2009). A positive score suggested a positive attitude or behaviour aimed at decreasing vibration exposure, whereas, a negative score indicated a negative attitude or behaviour (Tiemessen, 2009). Examples of behaviour belief questions included: I wear anti-vibration gloves while working with tools or equipment that are vibrating; I make sure that my equipment and tools are in good working order, and; I think about how I drive to have a smoother ride.

The work history section solicited the participant's age, gender, and current job title. Self-reported current vibration exposure type and estimated daily and yearly vibration exposure, according to equipment type, throughout their work history, was included.

2.6 Data Analysis

Statistical software, IBM SPSS Statistics for Macintosh, Version 23.0 (IBM Corp., Armonk, NY), was used to compile and analyze all data. Frequencies, percentages, and cross tabulations were used to analyze participant demographic information. Assumptions of normality were assessed by Shapiro-Wilk's test. Parametric (paired samples t-test) and non-parametric (Wilcoxon signed rank test) analyses were used to determine differences in knowledge, attitude, and behaviour beliefs scores between pre-test and post-test for participants. A probability level (p) of less than 0.05 was used as the criterion of significance.

3.0 Results

A total of 142 workers participated in either the pre-intervention survey or the post-intervention survey. Of the 142 workers, 125 participants completed the pre-test survey and 77 completed the post-test survey, and 61 matched pairs completed both surveys. Only the matched pairs were included within the analysis to evaluate intervention effectiveness. For the 61 matched-pairs, the participants were predominately male 97% (n=59) and only 3% female (n=2). The mean age of the participants was 46.7 years (SD=10.21) with an average of 14.2 years (SD=11.56) of mining experience. Participants' self-reported vibration exposure is summarized in Table 6.

Table 6: Self-reported vibration exposure in current job

Vibration Type	Frequency (N)	Percent (%)
HAV Only	7	11.5
WBV Only	6	9.8
FTV Only	0	0
HAV and FTV	3	4.9
HAV and WBV	13	21.3
HAV and WBV and FTV	**23**	**37.7**
None	9	14.8
Total	61	100.0

The highest percentage of participants, 37.7% (n=23), reported exposure to WBV, HAV, and FTV in their current job. Self-reported equipment use in their current job was reported in 0-3 hour, 4-6 hour, and 7-12 hour increments (Table 7). For 0-3 hours during a shift, participants reported utilizing pneumatic tools (39.3%), jackleg (36.1%), LHD (36.1%), and a stoper (34.4%) most often. Furthermore, the same four types of equipment, pneumatic tools (18%), LHD (14.6%), jackleg (13.1%), and a stoper (11.5%), were the highest reported pieces of equipment for 4-6 hours during a shift in their current job. For 7-12 hours during a shift, operating an LHD (13.1%), other equipment (11.5%), and a forklift (6.6%) were the highest reported pieces of equipment.

Table 7: Self-reported equipment use in current job (hours)

Equipment	**0-3 Hours n (%)**	**4-6 Hours n (%)**	**7-12 Hours n (%)**	**Does Not Operate n (%)**
Jackleg	22 (36.1%)	8 (13.1%)	2 (3.3%)	29 (47.5%)
Stoper	21 (34.4%)	7 (11.5%)	2 (3.3%)	31 (50.8%)
Jumbo Drill	12 (19.7%)	4 (6.6%)	1 (1.6%)	44 (72.1%)
Bolter	2 (3.3%)	1 (1.6%)	1 (1.6%)	57 (93.4%)
Pneumatic Tools	**24 (39.3%)**	**11 (18.0%)**	0	26 (42.6%)
LHD/Scoop	22 (36.1%)	9 (14.8%)	**8 (13.1%)**	22 (36.1%)
Locomotive	2 (3.3%)	0	0	59 (96.7%)
Surface Haul Truck	5 (8.2%)	2 (3.3%)	2 (3.3%)	52 (85.2%)
Bulldozer	2 (3.3%)	0	0	59 (96.7%)
Grader	2 (3.3%)	1 (1.6%)	2 (3.3%)	56 (91.8%)
Loader	6 (9.8%)	1 (1.6%)	0	54 (88.5%)
Forklift	14 (23.0%)	6 (9.8%)	4 (6.6%)	37 (60.7%)
Pickup Truck	7 (11.5%)	5 (8.2%)	1 (1.6%)	48 (78.7%)
Other Equipment	6 (9.8%)	8 (13.1%)	7 (11.5%)	40 (65.6%)

The participants' history of equipment use was self-reported in Table 8. Participants self-reported the highest use of the following equipment: jackleg for 0-4 years (14.8%), LHD (18%) and forklift (18%) for 5-9 years, and pneumatic tools (36.1%) for 10 or more years of operation.

Table 8: Self-reported equipment work history (years)

Equipment	Past Years			Did Not Operate n (%)
	0-4 Years n (%)	5-9 Years n (%)	10+ Years n (%)	
Jackleg	**9 (14.8%)**	10 (16.4%)	18 (29.5%)	24 (39.3%)
Stoper	8 (13.1%)	10 (16.4%)	17 (27.9%)	26 (42.6%)
Jumbo Drill	5 (8.2%)	2 (3.3%)	5 (8.2%)	49 (80.3%)
Bolter	4 (6.6%)	3 (4.9%)	5 (8.2%)	49 (80.3%)
Pneumatic Tools	4 (6.6%)	7 (11.5%)	**22 (36.1%)**	28 (45.9%)
Scoop/LHD	3 (4.9%)	**11 (18.0%)**	19 (31.1%)	28 (45.9%)
Locomotive	7 (11.5%)	7 (11.5%)	2 (3.3%)	45 (73.8%)
Surface Haul Truck	3 (4.9%)	4 (6.6%)	4 (6.6%)	50 (82.0%)
Bulldozer	1 (1.6%)	2 (3.3%)	1 (1.6%)	57 (93.4%)
Grader	1 (1.6%)	3 (4.9%)	1 (1.6%)	56 (91.8%)
Loader	2 (3.3%)	8 (13.1%)	3 (4.9%)	48 (78.7%)
Forklift	7 (11.5%)	**11 (18.0%)**	8 (13.1%)	35 (57.4%)
Pickup Truck	5 (8.2%)	5 (8.2%)	6 (9.8%)	45 (73.8%)
Other Equipment	3 (4.9%)	6 (9.8%)	1 (1.6%)	51 (83.6%)

3.1 Intervention Evaluation

Differences in knowledge scores were not normally distributed, as assessed by Shapiro-Wilk's test (p=0.042). Sixty-one participants completed both pre-test and post-test knowledge surveys. One outlier was detected in the difference in knowledge scores that was more than 1.5 box-lengths from the edge of the box in a boxplot. Inspection of the value revealed to be extreme (decrease by 6 points); therefore, the associated participant was excluded from the knowledge survey analysis. Of the 60 participants included in the analysis, 30 participants improved their post-test knowledge score compared to their pre-test knowledge score, whereas 11 participants saw no improvement and 19 participants scored lower. A Wilcoxon signed-rank test determined there were no statistically significant median increase found when comparing pre-test knowledge scores (*Mdn*=16.0) to post-test knowledge scores (*Mdn*=17.0), z=1.425, p=.154.

A paired-samples t-test was used to determine whether there was a statistically significant mean change in attitudes between pre-test and post-test. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test (p=.183). No statistically significant change in scores was found between pre-test attitude scores (M=12.95, SD=7.767) and post-test attitude scores (M=13.72, SD=9.413), $t(59)$=0.689, p=0.494.

A paired-samples t-test was also used to determine whether there was a statistically significant mean change in behaviour beliefs between pre-test and post-test. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test (p=.707). A statistically significant increase was found between the pre-test behavioural beliefs (M=4.46, SD=5.697) and post-test behaviour beliefs (M=8.02, SD=6.417), $t(60)$=4.212, p<0.001.

4.0 Discussion

The objectives of the current study were to evaluate the effectiveness of the Vibration Toolkit, on improving knowledge, attitude, and/or behaviour beliefs of workers, at an underground mine site in northern Ontario.

4.1 Knowledge

The slight improvement, but not statistically significant change, in knowledge scores is congruent with findings from forklift drivers in a previous WBV education intervention program (Hulshof et al., 2006). A direct comparison in knowledge scores cannot be made with the study conducted by Hulshof et al. (2006) as a result of modifying the survey instrument to include HAV and FTV. However, the forklift drivers in the study conducted by Hulshof and colleagues (2006), and the participants in the current study displayed similar results on WBV knowledge questions. Hulshof et al. (2006)

characterized their pre-test scores of the forklift drivers (*M*=15.9, *SD*=2.8) as being relatively high and suggested their knowledge questions may have been too easy (Hulshof et al., 2006). Similarly, the high pre-test scores in the current study may also suggest that the questions were too easy, as the true/false format made the answers fairly obvious. A final consideration was that the group already had prior knowledge of vibration exposure in the workplace. Tiemessen and colleagues (2009) also did not find any statistically significant changes in the knowledge scores of the mobile equipment drivers. Small improvements in knowledge in the current study, with half of the participants increasing their post-test score, may still lead to a positive impact within the workplace, as knowledge is a precondition for performing the job in the safest possible way (Christian et al., 2009). Therefore, some workers gained a greater understanding of strategies and techniques to perform their job, in ways to reduce vibration exposure, and some became aware of signs and symptoms associated with potential health effects.

4.2 Attitude

The positive improvements, but not significant change in attitude scores, shown in the current study were not in-line with the positive improvements found for the forklift drivers (pre-test attitude *M*=13.5, *SD*=10.2; post-test attitude *M*=18.1, *SD*=10.7) measured by Hulshof et al. (2006). Other studies have reported a relatively stable score, but in a negative direction, in post-test attitudes of OHS professionals (change of -0.7) and various mobile equipment drivers (change of -1.5) following WBV intervention studies (Hulshof et al., 2006; Tiemessen, 2009). Despite a small improvement in the current study, a positive shift in attitude related to vibration exposure may still lead to changes in behaviour within the workplace with the ultimate goal of a reduction in vibration exposure and improved health outcomes (Tiemessen, 2007).

4.3 Behavioural Beliefs

A statistically significant change in scores, when comparing pre-test and post-test results, was observed for behavioural beliefs. No statistically significant changes in behavioural beliefs have been reported in WBV intervention studies previously (Hulshof et al., 2006); (Tiemessen, 2009). The content of the Vibration Toolkit in the current study specifically focused on discussing control strategies and providing education regarding the potential for a worker to modify their overall vibration exposure. A meaningful improvement in participants' beliefs about safe work practices may lead to reductions in their overall vibration exposure if put into practice. Although not all control strategies are within a workers' ability to influence, there are ways in which a worker can seek to reduce their exposure by driving slower, requesting maintenance of vehicles and roads, adjusting seats, decreasing grip and improving posture while using tools, standing on an isolated platform or mat, taking breaks, and using personal protective equipment (Hill et al., 2001; Donoghue, 2004; McPhee, 2004; Tiemessen et al., 2007; Tiemessen, 2008; McPhee et al., 2009; Eger et al., 2011; Leduc et al., 2011; Thompson et al., 2012; Eger et al., 2014; Leduc et al., 2016). In addition, other aspects of the hierarchy of control were discussed, to encourage an open discussion and dialogue between workers and managers to adequately address vibration concerns. Members of the management team and varying numbers of front-line supervisors were in attendance for the education sessions. Furthermore, creating an open dialogue is facilitated more easily if the supervisor and members of the management team are also in attendance and receiving the same education. Discussions related to control strategies and concerns, as identified potentially by the hazard identification safety check cards, are more likely to be applied when all levels of the organization are educated.

4.4 Intervention

The customization of the Vibration Toolkit to meet the partnering company's specifications led to successful program implementation. Members of the research team met with the mine management prior to the commencement of the intervention to discuss the best strategies to engage each of the four crews, the duration, mode, and content of the education presentations, and the size and number of the posters. The research team ensured that the Vibration Toolkit was customized to meet the requirements set out by the company in order to complement their existing workplace structures. For example, the size of the posters selected was based on their existing bulletin board size. In addition, the education session at the start of the shift, delivered by a research team member was less than 30 minutes at the request of the participating company. Ease of implementation, provision of materials, and cost effectiveness of the intervention are strengths of the project and may improve interest for involvement of other worksites in the future (Tiemessen et al., 2007). As a result, the current program was designed to fit within the company's existing structures in order to reduce burden on the workplace and workers. In addition, all materials and PPE samples were provided to the organization at no cost. Similarly, use of the Content-Context-Process-Outcome framework presented by Karanika-Murray and Biron (2015) to guide the development of the Vibration Toolkit and to ensure it was tailored to the workers, equipment, scheduling, productivity demands, and existing OHS structures of the mining industry, were influential in ensuring success (Leduc, Chapter 5).

Conducting field research is not without unexpected challenges that arise and also includes variable workplace factors beyond the control of the researchers (Verbeek et al., 2004). Following the completion of the education components of the intervention, but before the post-test survey, the participating company restructured the work crews. The four-crew structure that initially started the intervention was modified to a new three-crew structure on site; the fourth crew moved off site to another mine site location. The follow-up survey was sent to the other mine-site location to ensure that all workers who moved off site still had the opportunity to complete the post-survey; however, a member of the research team was not present to introduce the survey and ultimately, very few surveys from the fourth crew were completed and returned to the research team. Furthermore, care should be taken in the interpretation of findings, as a control group was not included within the study design. The partnering mine site indicated there was a large amount of cross over and sharing of information between individual crews. As such, contamination across work shifts was a concern, and a control group was not planned. Contamination among workers was also raised by Hulshof et al. (1999) as a concern which could interfere with the ability to conduct an experimental design (Hulshof et al., 1999). Additionally, the intervention included posters that were posted in high traffic areas which would have been visible to all crews. Despite this limitation, a within-subject study design has been shown to yield similar results in knowledge acquisition when compared with between-subject study designs within occupational health and safety training (Burke et al., 2006). Within-subject study designs are encouraged during the evaluation of occupational health and safety training (Burke et al., 2006).

Feasibility constraints limited the follow-up time frame in the study to one month. Previous studies with a longer follow-up time frame of seven months to a year are typically preferred (Hulshof et al., 2006; Tiemessen, 2009). Due to the short follow up time period, potential benefits, such as a decrease in worker vibration exposure, may not be observed at the organizational level. Moreover, several studies have suggested reduced injuries and improved productivity may not be observed until 10 or more years of surveillance following the intervention (Cohen and Colligan, 1998; Hulshof et al., 1999). Despite this limitation, there is merit in evaluating short term changes at the individual level related to factors that may be influenced by training, such as, knowledge, attitudes, and behaviour beliefs, which can indirectly influence health and impact the overall organization (Hulshof et al., 1999).

Issues also arose with the sizing of gloves and insoles. The research team estimated sizes based on the demographic information provided in the initial survey. However, exact matches in quantities required for each glove and insole size were not met. Future implementation of PPE should include time at the beginning of the intervention to size workers correctly and enable them to try on different samples to ensure fit and function. An indication of size and quantities would allow for more accurate ordering and distribution of the PPE products.

4.5 Future Directions

Positive improvements in knowledge, behaviour beliefs, and attitudes warrant continued and further implementation of the Vibration Toolkit within the mining industry. Implementation of the Vibration Toolkit across multiple mine sites or with several partnering companies would provide education and training to a larger number of workers in the future. Future studies should also strive to include a larger sample of supervisors or managers. Previous WBV education intervention studies have shown lower scores for both the plant managers (pre-test knowledge M=10.0, SD=0.7; post-test knowledge M=10.4, SD=10.4) and occupational health professionals (pre-test knowledge M=12.3, SD=3.2; post-test knowledge M=15.3, SD=2.2) in comparison to the forklift drivers (pre-test knowledge M=15.9, SD=2.8; post-test knowledge M=16.5, SD=2.3). In addition, past research examining the self-reported knowledge of OHS professionals in the United States, also revealed low knowledge scores related to WBV (Paschold and Sergeev, 2009). Therefore, it is beneficial to ensure that all those influencing decisions related to workplace vibration exposure are knowledgeable.

The Vibration Toolkit could also be further customized for surface mining, smelter, and open pit operations. The Vibration Toolkit could also be customized for workers in forestry, agriculture, transportation, and construction. Many of the listed industries have jobs and equipment that result in workers being exposure to WBV, HAV, and FTV. Therefore, education that includes a combination of the multiple types of vibration and customization for the targeted industry will be important to ensure all workers are educated appropriately.

5.0 Conclusions

Statistically significant changes in knowledge and attitude scores following the participation in the Vibration Toolkit intervention were not found; however, there were positive improvements in both scores. Statistically significant positive improvements in behaviour beliefs towards vibration exposure and adoption of control strategies within the underground mining work environment were found. This study provided evidence for further improvement and expansion of the Vibration Toolkit intervention in order to address concerns related to occupational vibration exposure.

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Chapter 7 – Discussion and Conclusion

1. Introduction

This dissertation was comprised of four manuscripts intended to contribute to occupational health education program and vibration intervention literature. This concluding chapter will summarize the significant findings from each of the papers in the context of the overall study. Study strengths and limitations will be discussed. Thereafter, future implications and recommendations for practitioners, policy makers, and researchers will be presented.

The primary research objectives of the dissertation were to:

1) critically review occupational health and safety interventions programs that have been conducted within rural and northern industries (Chapter 3);
2) examine the education resources in northern Ontario, in relation to occupational vibration hazards, health risks, and controls (Chapter 4);
3) develop an occupational health education intervention program, the Vibration Toolkit, customized for the mining industry in Northern Ontario (Chapter 5); and,
4) evaluate the effectiveness of an occupational health education intervention program, the Vibration Toolkit, on knowledge, attitude, and behaviour beliefs about occupational vibration hazards, health risks and controls within the mining industry in Northern Ontario (Chapter 6).

2. Discussion of Main Findings and Overall Project

2.1 Occupational Health Education Intervention Programs within Rural and Northern Industries and Communities

A critical review of occupational health education interventions that have been previously conducted in rural and northern industries and communities was conducted. The literature search yielded six articles to be included for review and further analysis. The Content-Context-Process-Outcome framework was utilized as a means to organize the interventions into components that could be discussed with respect to the success and failure of the overall intervention (Karanika-Murray and Biron, 2015). The framework has been previously utilized to examine organizational interventions; however, to the author's knowledge, it has not been applied to understand the application of interventions for rural and northern industries and communities (Karanika-Murray and Biron, 2015).

2.1.1 Content Considerations for Rural and Northern Application

When considering content, it was concluded that when developing occupational health education materials applicable to rural and northern workplaces, specific attention should be given to language and literacy levels of the workplace or community (Gong et al., 2009; Rye et al., 2014). Rural and northern Ontario is home to a large proportion of Indigenous and francophone populations and consideration for ensuring materials are translated to meet the needs of the workforce is important for future intervention research (LHIN, 2014; LHIN, 2014). However, systematic barriers have been noted to hinder recruitment of Indigenous peoples within the Canadian mining workforce (MIHR, 2015). Furthermore, the consideration of age of the workforce was noted in the findings (Lusk et al., 1999). The cyclic economic nature of the mining industry in Canada has been noted to limit the number of younger workers (up to age 24 years old) seeking and obtaining full-time, permanent jobs (MIHR, 2015). The Canadian mining industry has regularly shown their workforce to be older, on average, than the overall Canadian workforce (MIHR, 2015).

2.1.2 Context Considerations for Northern and Rural Application

Understanding the context of the workplace, industry and community is important when conducting occupational health research in rural and northern locations. Rural and northern workplaces may face additional challenges when planning and implementing occupational health education intervention research related to the constant changing characteristics of the worksite (Loue and Quill, 2010). A typical mining operation in rural and northern Ontario operates 24 hours a day, 7 days a week, with workers performing 10 and 12 hour shifts on a rotating shiftwork schedule (Donoghue, 2004). The economic cycles faced by resource-based industries, and the pressure of production, may influence access to the workplace. An understanding of the contextual factors specific to how work is carried out is needed to ensure that intervention delivery and evaluation are congruent with the workplace structure and systems.

2.1.3 Process Considerations for Northern and Rural Application

Process considerations for ensuring success of future intervention research within rural and northern settings include the establishment of strong collaborations and partnerships throughout all stages of the research project (Parkinson et al., 1989). The influence of the senior management team within the partnering organization was also found to be a contributor to the success of the implementation of the intervention (LaMontagne and Needleman, 1996; Nielsen et al., 2010; Rye et al., 2014). A large geographic area and longer travel time to reach a workplace, a common occurrence in northern and rural Ontario, have been noted by previous researchers to contribute additional complexity to travel and logistic planning (Rasmussen et al., 2003).

2.1.4 Outcome Considerations for Northern and Rural Application

Outcome considerations concluded that intervention research which is applicable to northern and rural workplaces should include the expanded use of qualitative methods to gain a greater depth of understanding (Needleman and Needleman, 1996). Qualitative methods have the ability to provide researchers with a greater understanding of the context within an organization (LaMontagne and Needleman, 1996). Furthermore, a theoretical basis for the intervention research also needs to be explicitly stated and measured accordingly (Goldenhar and Schulte, 1994; Hersey et al., 1996; Shannon et al., 1999).

2.2 Evaluation of Vibration-Focused Health and Safety Education Materials in Mining

An assessment of the vibration-focused health and safety education provided by Ontario's OHS system partners was conducted in Chapter 4. WSN, WHSC, and OHCOW, were selected to be included within the study, as their mandates seek to serve the mining sector in northern Ontario. It was concluded that there is a limited number of vibration-focused occupational health education courses and materials targeted at the mining industry to address WBV, HAV, and FTV exposure.

2.2.1 Lack of WBV Education

The findings of the review (Chapter 4) concluded there was a lack of education about WBV exposure in mining. The results of the scan for WBV content yielded one three-hour 'Vibration Hazard Module' hosted by WHSC, and one online information document titled 'Ergonomics and Driving' by OHCOW. WBV exposure in northern Ontario mining has been documented within the literature to include measurements from: surface haulage trucks, underground load-haul-dump trucks, bulldozers, and graders (Eger et al., 2006; Eger et al., 2014). Potentially harmful exposure levels were documented, and as a result, control strategies need to implemented (Eger et al., 2006; Eger et al., 2014).

2.2.2 Lack of HAV Education

The review also concluded that there was a lack of education addressing HAV exposure in mining (Chapter 4). Similar to WBV, the results yielded the same one three-hour 'Vibration Hazard Module', hosted by WHSC, and two online information documents titled 'carpal tunnel syndrome' and 'HAVS: Hand-Arm Vibration Syndrome'. Despite the identified lack of education, HAV exposure within the mining industry in northern Ontario has been documented for workers operating jackleg drills, long-hole drills, stopers, impact wrenches and other hand tools (Hill et al., 2001). Hill and colleagues (2001) concluded that 50% (81 of 162) of workers receiving a medical examination were diagnosed with HAVS; therefore, education efforts within the mining industry to improve prevention of HAVS are needed. Workers with moderate to severe HAVS were interviewed by Handford et al. (2017) and specified that they had learned about HAVS through co-workers by word of mouth after having the disease. A worker expressed difficulty accessing information on the internet about HAVS (Handford et al., 2017). In addition, none of the 11 workers indicated they wore anti-vibration gloves, citing issues related to the fit of the gloves, suitability for the work task, cost, and how and where to get gloves, as primary reasons (Handford et al., 2017). Similar findings of a lack of HAV education have also been shown in the construction industry in Ontario (Leduc et al., 2016). Leduc et al. (2016) reported that, of the 100 participating construction workers surveyed, HAVS training was only reported by 5 participants and anti-vibration glove training by 8 participants (Leduc et al., 2016). The need for improved education regarding HAVS is further highlighted by research suggesting that there is a delay between the onset of HAVS symptoms and when workers file a claim (Youakim, 2012). As an example, mechanics have been documented to wait an average of three years and loggers waited six years before filing a claim (Youakim, 2012).

2.2.3 Lack of FTV Education

FTV exposure was not found to be included within any of the courses or materials located in the search. Although the findings did not identify any education resources, the literature does document findings of FTV exposure within northern Ontario mines (Leduc et al., 2011; Eger et al., 2014). Workers operating locomotives, jumbo drills, bolters, or drilling off raise platforms are all exposed to FTV (Leduc et al., 2011; Eger et al., 2014). The first medical case study from a Canadian context was published by Thompson and colleagues (2010), which provided evidence of a miner diagnosed with vibration white foot following 18 years of general vibration exposure and four years of specific FTV exposure from operating a bolter. Therefore, education related to identifying FTV in the workplace, potential symptoms and health effects, and control strategies, needs to be a part of occupational health and safety education within the mining industry.

2.3 Development of the Vibration Toolkit

An occupational health education intervention, the Vibration Toolkit, was developed to fill the identified gap in education tailored to the mining industry to address WBV, HAV, and FTV (Chapter 5). Findings presented in Chapter 3, with respect to the overall recommendations for conducting intervention research in rural and northern settings and the inclusion of the Content-Context-Process-Outcome framework, were incorporated into the development of the Vibration Toolkit (Karanika-Murray and Biron, 2015). The overall program consisted of: safety meeting content on WBV, HAV, and FTV, hazard identification safety check cards, educational posters, and the provision of personal protective equipment samples.

2.3.1 Content Considerations for the Vibration Toolkit

The first recommendation was ensuring the occupational health education intervention considered context throughout the entire research project. An understanding of the broader mining sector assisted with ensuring the Vibration Toolkit would be applicable to underground workers. In addition, consultation with the company at an early stage of content development assisted with providing details of the specific jobs and equipment that would be highlighted within the education sessions. Issues related to shift scheduling and time were considered throughout all phases of the research. Unfortunately, the limited budget for the development of the education materials only provided the materials in English. However, it was noticed anecdotally within the sessions that many workers would have benefitted from completing surveys and hearing the education sessions in French. Research conducted within rural and northern Ontario should consider the potential for requiring information in languages that represent their population (Chapter 3).

2.3.2 Context Considerations for the Vibration Toolkit

Building collaborations and partnerships between researchers and industry partners is recommended as best practice for conducting occupational health education research in rural and northern locations (Chapter 3). The critical review provided multiple examples of the success that may occur as a result of a positive relationship between the researchers and the workplace. For the implementation of the Vibration Toolkit, the partnering organization assisted in facilitating all of the on-site visits for the researchers to present to the participating workers. The organization was able to provide a training room that allowed for all of the workers on the shift to congregate and be seated, with the opportunity to participate in the research project. Furthermore, the organization was able to provide 30-45 minutes at the start of the shift, resulting in the largest possible number of people able to participate.

2.3.3 Process Considerations for the Vibration Toolkit

Cohesive integration and collaboration amongst a multi-disciplinary team was also recommended in the development, implementation, and evaluation of an occupational health education intervention (Chapter 3). A multi-disciplinary team was formed for the dissertation with expertise in occupational health and safety issues, occupational vibration exposure, occupational medicine, education, and rural and northern health. Therefore, the varying areas of expertise ensured all stages of the overall research project and intervention were viewed from different perspectives.

2.3.4 Outcome Considerations for the Vibration Toolkit

Outcome considerations related to an expanded use of qualitative methods were implemented in a limited manner. Short answer written questions were added to the survey to provide a greater understanding regarding PPE and barriers perceived by workers that exist in decreasing or eliminating their vibration exposure while at work; however, qualitative results were not presented within the current dissertation. The demand for workers' time and productivity to continue the mining cycle is at the forefront of all activities and scheduling of a worker's shift plan. Therefore, additional written responses, focus groups, or interviews, were unable to be completed in conjunction with the survey due to time constraints.

Developing intervention research with a strong theoretical base has been suggested by previous researchers; a theme that recurred throughout the critical review (Goldenhar and Schulte, 1994). The dissertation utilized the conceptual model of workplace training interventions by Robson and colleagues (2012). The model suggests the education within the Vibration Toolkit will immediately influence workers knowledge, attitudes, and behaviour intentions (Robson et al., 2012a; Robson et al., 2012b). The Vibration Toolkit was able to follow such guidelines and utilize a survey previously used in a WBV intervention to measure knowledge, attitudes, and behaviour beliefs of the participating workers (Hulshof et al., 2006; Tiemessen, 2009). In the long term, potential influence from behaviour to affect workplace injuries and illnesses is possible; however, not within the scope of the dissertation (Robson et al., 2012a; Robson et al., 2012b). In addition, the Content-Context-Process-Outcome framework was utilized throughout the dissertation to guide the development, implementation, and evaluation of the Vibration Toolkit

(Karanika-Murray and Biron, 2015). The framework provided the structure to consider how the intervention would be imbedded within the partner organization and mining industry. The resulting Vibration Toolkit was tailored to the underground mining industry (Chapter 5) and is ready to be easily implemented within their existing OHS system structures.

2.4 Evaluation of an Occupational Health Intervention, the Vibration Toolkit, for Underground Mining-related Vibration Exposure

The evaluation of the Vibration Toolkit, implemented at an international mining company with local mine sites in northern Ontario, was reported in Chapter 6. The Vibration Toolkit was further customized to meet the needs and requirements of the partnering mining company and was implemented over a five-month period. The study confirmed that mining presents a unique work environment with respect to vibration exposure in that the largest group (37.7% of participants) self-reported to be exposed to WBV, HAV, and FTV, in their current job. The varying types of vibration exposure were also shown through the self-reporting of equipment use in the participants' current jobs. Pneumatic tools, jackleg, stoper, LHD, other equipment, and forklift were the most commonly reported pieces of equipment used throughout their shift. The conceptual model for workplace interventions suggests the potential for immediate outcomes expected following an intervention related to knowledge, attitudes, and behaviour beliefs (Robson et al., 2012a; Robson et al., 2012b). The positive improvements in behaviour beliefs may result in positive intermediate outcomes related to behaviour, hazard controls and decreased vibration exposure in the future (Robson et al., 2012a). Likewise, there is potential for long-term impact on injuries, illnesses, fatalities, and costs (Robson et al., 2012a; Robson et al., 2012b).

2.4.1 Knowledge

No statistically significant median increases were found when comparing pre-test knowledge scores and post-test knowledge scores. The results from the current study are in line with previous literature (Hulshof et al., 2006; Tiemessen, 2009). Furthermore, OHS professionals in the USA self-reported to have little or no knowledge about WBV exposure hazards, health effects, and control strategies (Paschold and Sergeev, 2009). Notwithstanding the lack of statistically significant improvements, within the current study, half of the participants (N=30) did demonstrate an improved knowledge score from pre-test to post-test (Chapter 6).

2.4.2 Attitudes

No statistically significant changes in pre-test attitude scores occurred when compared to post-test attitude scores. The findings are not aligned with previous WBV intervention studies (Hulshof et al., 2006; Tiemessen, 2009). Despite not finding a statistically significant change following the implementation of the Vibration Toolkit, a positive improvement in attitude about occupational vibration exposure may still lead to changes in behaviour within the workplace (Tiemessen, 2007).

2.4.3 Behaviour Beliefs

A statistically significant change in scores was found between the pre- and post-test behaviour belief scores (Chapter 6), a finding were not previously reported in the literature (Hulshof et al., 2006; Tiemessen, 2009). The content of the Vibration Toolkit focused on control strategies that a worker could modify to potentially decrease their overall vibration exposure. As a result, workers may have gained a belief that their behaviour and actions have the ability to influence their vibration exposure. The current study did not measure actual changes in behaviour. However, the potential for improvements in behaviour are highlighted by Thompson et al. (2012), who found a statistically significant increase in the number of people wearing anti-vibration gloves following receiving an education handout on HAVS. The current findings provide evidence to support further modification and evaluation of the Vibration Toolkit to improve prevention efforts related to vibration exposure in the mining sector and other relevant industries.

3.0 Study Limitations

The findings presented in this dissertation may be influenced by several limitations. The recommendations and considerations for future intervention research conducted in rural and northern locations were based on the critical review conducted in Chapter 3. However, identifying occupational health education interventions to be included within the critical review was a challenge. In order to maintain confidentiality and anonymity of a workplace partner, location identifiers are often not included within publications. The importance of maintaining confidentiality is further exacerbated in rural and northern settings where the population is often small. Therefore, additional occupational health education interventions may be published; however, they were not identified using the search parameters employed in the current study. Researchers can utilize the Content-Context-Process-Outcome framework, presented by Karanika-Murray and Biron (2015), to overcome the limitation by ensuring all elements of their intervention are applicable to their targeted workplace.

Furthermore, the gap highlighted in vibration-focused education materials within the mining sector was based on the exclusive search of only Ontario HSSPs (Chapter 4). Therefore, the lack of education materials and courses focused on vibration exposure may be limited to only the mining industry in northern Ontario.

The development, implementation, and evaluation of the Vibration Toolkit (Chapter 5 and 6) were also limited by both time and budgetary constraints. Gathering multiple crews together at the same time and location for the education sessions was not feasible; therefore, the research team had to travel to the mine site four times for every session to reach all workers. As a result, a greater proportion of time and budget had to be allocated for travel.

Field research conducted in partnership with organizations often leads to both expected and unexpected challenges. At the outset of the intervention, the partnering mine site had four work crews that were on a day and night shift rotation. After the final education session, the organization needed a crew to work at a different location, and as a result, rearranged the crews into three work crews at the current site, and a fourth crew at a different location off-site. The crew restructuring had a negative impact on post-survey collection (Chapter 6). As a result of the issue, fewer participants than hoped completed both surveys. Also, the company decided to not include WBV measurement as part of the Vibration Toolkit resulting from a lack of on-site personal to assist with the storage and distribution of the device for each crew. Therefore, objective measurements of WBV vibration exposure experienced by the participants at the mine site are not known.

Additionally, the total population sample from the organization in the current study included very few women (Chapter 6). This was expected, as the number of women working in underground mining continues to be limited (MIHR, 2015). Within the Canadian mining industry, women represent 17% of the workforce and only 4% of trades and production occupations (MIHR, 2015). Therefore, the findings may not be generalizable to women working in the mining industry more generally.

4. Recommendations

The following section will provide recommendations for the appropriate audiences who may have a role in future research, policy and practice. The culmination of the dissertation findings can be used to inform future decisions regarding the broad development and delivery of occupational health education programming.

4.1 Recommendations for Future Research

Future directions of the overall design, implementation, and evaluation of occupational health education interventions should consider utilizing the Content-Context-Process-Outcome framework proposed by Karanika-Murray and Biron (2015), to enhance suitability within industries. The framework provides structure for reflection in the design process, implementation strategy, and evaluation to ensure an intervention program has the desired impact for the target population (Karanika-Murray and Biron, 2015).

Future research related to the Vibration Toolkit should continue to build upon the small improvements for further customization of the content to a targeted context. Education materials in the Vibration Toolkit should be provided in French to improve access for francophone miners working in northern Ontario. Qualitative assessment methods should also be used to improve understanding of successes and barriers related to managing vibration in a workplace. Focus groups or interviews are recommended for potential consideration in order to provide a more thorough comprehension and understanding related to occupational vibration exposure. For example, Ayers and Forshaw (2010) used an interpretative phenomenological analysis to provide an understanding of how individuals cope with HAVS from the workers' perspective and in greater depth than a quantitative method selection. Handford et al. (2017) conducted interviews with 11 workers to show the impact of HAVS on an individual's quality of life and overall functioning. Therefore, future research should also consider the broader implications for an individual's life beyond classification of medical symptoms associated with the development of a vibration-induced injury.

Gaining an understanding from the perspective of not only the worker, but also management and OHS professionals, is important to advance the discussion of relevant solutions and barriers to vibration exposure management. The continued involvement of all parties within the organization and the broader industry in the development of future research, will continue to ensure meaningful results are obtained and delivered for maximum impact throughout northern Ontario. Further expansion of the Vibration Toolkit to include a larger sample of workers, additional mine sites and companies would provide the necessary evidence for larger-scale implementation of the program. A longer follow up timeframe or longitudinal research study design to assess levels of worker knowledge, attitudes, and behaviour beliefs, would also provide evidence for the merit of the program. However, the ability to reach the same sample of workers over an extended period of time is also a challenge to be considered in the selection of a research design. Vibration exposure data, for workers participating in the program, could also be assessed over a period of multiple years to determine if the program led to decreases in vibration exposure or injuries and illnesses. However, many workers operate equipment in production areas of the mine with changing workplace conditions and terrain on a daily basis. Therefore, the context of the measurements should be noted. Additionally, future research may also want to include detailed evaluation studies that compare preventative methods in order to conclude the most effective prevention strategies targeted at addressing vibration exposure (Verbeek et al., 2004).

4.2 Recommendations for Policy

The overall dissertation highlights the need for all types of occupational vibration exposure to be recognized in Canada through the application of international standards and policies. Currently, policies and standards exist for the measurement and control of both WBV (ISO, 1997; Directive, 2002) and HAV (ISO, 2001), but not specifically for FTV. Current international standards have FTV grouped within the standards for WBV (ISO, 1997). In order to ensure risk factors associated with the development of vibration-induced white foot are addressed, an international standard guiding measurement and assessment of FTV is needed.

Legislation in Europe resulted in obligations for employers to address concerns related to occupational vibration exposure, and included risk assessment, control measures, health surveillance, and worker information and training (Tiemessen, 2008). Currently in Ontario, regulation and guidelines do not exist for the monitoring and control of vibration; however, inspectors may reference the General Duty Clause within the Occupational Health and Safety Act, which states that every reasonable precaution must be taken to ensure the safety of workers (OHSA, 1990). Furthermore, compensation for vibration-induced injuries are not recognized by the WSIB in Ontario for all vibration exposure cases. Moreover, injuries and disabilities, directly related to occupational vibration exposure, are not being appropriately monitored or reported at both the workplace and provincial level.

4.3 Recommendations for Practice

OHS education and training focused on vibration exposure should be expanded within the mining industry. Findings show that OHS education and training positively impacts the overall work practices of workers (Robson et al., 2012a). Continued efforts from occupational health and safety professionals, ergonomists, and engineers should also be applied to address technical and design changes that have the potential to reduce vibration exposure.

Targeted education material for the entire workforce is another aspect that can ensure all members are included in receiving common communication surrounding an occupational hazard. A common understanding related to hazards in the worksite for all members of the workforce has been suggested to be necessary in order to evaluate risk and implement effective control strategies (Holmes et al., 1999). Specifically, the training of supervisors cannot be overlooked. Supervisors play a pivotal role in the reinforcement of occupational health and safety information and training within a workplace (Ringen and Stafford, 1996). Moreover, the problem solving abilities of managers have the potential to shape the working conditions of the organization. Furthermore, employees responsible for selecting and purchasing equipment for the workers also need to be aware of occupational vibration exposure and they should be required to consider vibration exposure emissions when making purchasing decisions.

The consideration between safety and production also influences a worker's vibration exposure. For example, workers in the mining sector that perform job tasks, which expose them to vibration, are also the workers who drive production by drilling and hauling. Workers who drive faster, and take fewer breaks may be compensated for higher productivity at the expense of their health. Continued motivation for production without the same value on safety related to vibration exposure needs to be addressed (Hansez and Chmiel, 2010).

A free iOS application for WBV measurement was intended to be an interactive learning component of the WBV session within the Vibration Toolkit. The use of the device to provide systematic measurements of WBV exposure throughout the mine would ensure recommendations for control strategies are targeted to the areas of highest risk and evaluated for effectiveness (Wolfgang and Burgess-Limerick, 2014). In the current study, the company did not have the capacity to include the application as part of the intervention. Logistical issues related to having a dedicated person onsite to manage the issuing, charging, storing, and collecting the devices on a daily basis prevented usage during the intervention. Personnel resources to manage the devices on site would need to be established with organizations in future interventions in order to deploy the application for WBV measurement.

The Vibration Toolkit, as a framework, has the potential to provide meaningful vibration-specific education for other sectors that also experience vibration exposure including: transportation, agriculture, forestry, and construction. Each sector presents unique equipment and operating conditions for their respective workers. Furthermore, the industries also have varying shift schedules and often multiple work sites; therefore, the vibration toolkit would need to be customized for each industry.

5. Overall Conclusion

This dissertation has advanced understanding of conducting occupational health education interventions within workplaces in northern and rural industries (Table 9). Attention was focused on the prevention of occupational vibration exposure within the mining industry through an occupational health education intervention, the Vibration Toolkit. The resulting knowledge provides the opportunity for ensuring future decisions for prevention efforts are evidence-based, when possible (Verbeek et al., 2004). Specifically, the mining industry plays an influential role in the provision of work and as a result, the health of northern Ontario residents. The findings of this dissertation highlighted the gap that exists in occupational health education focused on addressing vibration in the workplace. As a result, the Vibration Toolkit was developed to enhance vibration-focused education and prevention efforts. Evidence provided from the evaluation of the Vibration Toolkit demonstrated positive improvements and provided a justification for future research and expansion.

Table 9: Summary of key findings from each paper that contributes to the complete dissertation

Study Title	Chapter	Study Objectives	Key Findings
Critical review of the application of occupational health education interventions in rural and northern industries and communities	3	To critically review occupational health and safety interventions programs that have been conducted within rural and northern industries and communities	Occupational health education intervention research within rural and northern industries and communities should include considerations related to the content, context, process, and outcome.
Evaluation of vibration focused occupational health and safety training materials in mining	4	To examine the training resources in northern Ontario delivered by Ontario Health and Safety System Partners, in relation to occupational vibration hazards, health risks, and control	Limited number of courses that included vibration content were identified: ▪ One course focused on WBV ▪ One course focused on HAV ▪ No training resources available for addressing FTV ▪ Vibration listed in one additional course description Vibration-focused OHS training resources are needed.
The development of the Vibration Toolkit: A study protocol for designing an occupational health education intervention focused on vibration exposure in mining.	5	To develop an occupational health education intervention program, the Vibration Toolkit, customized for the mining industry in northern Ontario	▪ Vibration focused OHS education resource developed to include WBV, HAV, and FTV components tailored for the underground mining environment. ▪ The Vibration Toolkit was developed with the Content-Context-Process-Outcome framework
Evaluation of an occupational health intervention for underground mining-related vibration exposure	6	To evaluate the effectiveness of an occupational health education intervention program, the vibration toolkit, on knowledge, attitude, and behaviour beliefs regarding occupational vibration hazards, health risks and controls within the mining industry in northern Ontario.	▪ No statistically significant change was found between pre-test and post-test scores for knowledge and attitude ▪ A statistically significant change was found for behaviour belief scores between pre-test ($M=4.46$, $SD=5.697$) and post-test ($M=8.02$, $SD=6.417$), $t(60)=4.212$, $p<0.001$.

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Appendices

Appendix 1: Ethics Approval

APPROVAL FOR CONDUCTING RESEARCH INVOLVING HUMAN SUBJECTS
Research Ethics Board – Laurentian University

This letter confirms that the research project identified below has successfully passed the ethics review by the Laurentian University Research Ethics Board (REB). Your ethics approval date, other milestone dates, and any special conditions for your project are indicated below.

TYPE OF APPROVAL / New X / Modifications to project / Time extension	
Name of Principal Investigator and school/department	Mallorie Leduc, School of Rural & Northern Health supervisor, Tammy Eger, School of Human Kinetics
Title of Project	Occupational Vibration Exposure: An Occupational Health Education Intervention within Northern Ontario
REB file number	2016-04-10
Date of original approval of project	May 24, 2016
Date of approval of project modifications or extension *(if applicable)*	
Final/Interim report due on: *(You may request an extension)*	June 01, 2017
Conditions placed on project	

During the course of your research, no deviations from, or changes to, the protocol, recruitment or consent forms may be initiated without prior written approval from the REB. If you wish to modify your research project, please refer to the Research Ethics website to complete the appropriate REB form.

All projects must submit a report to REB at least once per year. If involvement with human participants continues for longer than one year (e.g. you have not completed the objectives of the study and have not yet terminated contact with the participants, except for feedback of final results to participants), you must request an extension using the appropriate LU REB form. In all cases, please ensure that your research complies with Tri-Council Policy Statement (TCPS). Also please quote your REB file number on all future correspondence with the REB office.

Congratulations and best wishes in conducting your research.

Rosanna Langer

Rosanna Langer, PHD, Chair, *Laurentian University Research Ethics Board*

Appendix 2: Ontario HSSPs, mandate, and study inclusion

Ontario Health and Safety System Partners	**Classification**	**Mandate/Core Services (Labour, 2014)**	**Inclusion**
Ontario Ministry of Labour (MOL)	Regulation	"To set, communicate and enforce occupational health and safety legislation It also develops, coordinates and implements strategies to prevent workplace injuries and illnesses and can set standards for health and safety training."	Excluded
Workplace Safety and Insurance Board (WSIB)	Compensation	"No-fault workers' compensation and promotes workplace health and safety."	Excluded
Occupational Health Clinics for Ontario Workers (OHCOW)	Occupational Health Services	"Provides comprehensive occupational health services – to workers concerned about work-related health conditions and to workers, unions and employers who need support to prevent these health conditions from developing."	Included
Workers' Health and Safety Centre (WHSC)	Education and Training	"Provides training for workers, their representatives and employers from every sector and region of the province."	Included
Institute of Work and Health (IWH)	Research	"aims to protect and improve the health of working people by providing useful, relevant research to workers, employers, occupational health and safety professionals, disability management professionals, clinicians, policy-makers and more."	Excluded
Centre for Research Expertise for the Prevention of Musculoskeletal Disorders (CRE-MSD)	Research	"Conducts research to improve the understanding and prevention of work-related musculoskeletal disorders (MSDs).	Excluded
Centre for Research Expertise in Occupational Disease (CRE-OD)	Research	"Focused on the prevention and earyl recognition of non-malignant occupational disease."	Excluded
The Occupational	Research	"Dedicated to studying workplace	Excluded

Cancer Research Centre (OCRC)		cancer."	
Infrastructure Health and Safety Association (IHSA)	Health and Safety Association	"Serves: construction, electrical and utilities, aggregates, natural gas, ready-mix concrete and transportation"	Excluded
Public Services Health and Safety Association (PSHSA)	Health and Safety Association	"Serves: hospitals, nursing and retirement homes, residential and community care, universities and colleges, school boards, libraries and museums, municipalities, provincial government and agencies, police, fire and paramedics and First Nations."	Excluded
Workplace Safety North (WSN)	Health and Safety Association	"Serves: forestry, mining, smelters, refineries, paper, printing and converting."	Included
Workplace Safety and Prevention Services (WSPS)	Health and Safety Association	"Serves: agriculture, manufacturing, and service sectors."	Excluded

Appendix 3: OHS education evaluation checklist

Data to be Extracted/Notes to reviewer	***Information on the Training Course and Content***
Title of Course	
Author/Company/Organization	
Year of Publication	
Contains vibration content? *If "NO" exclude.*	Yes/No
Setting of course and teaching location:	City/region: Classroom/online:
Target audience of the course	Workplace/Industry:
Duration of course *Single session? Within another course? Time allotted for training*	
Timing *Initial training course? Refresher course?*	
Objectives of course are clearly stated? *Include learning objectives related to vibration, if reported*	
Teaching methodology indicated? *e.g., presentation, video, handout, posters*	

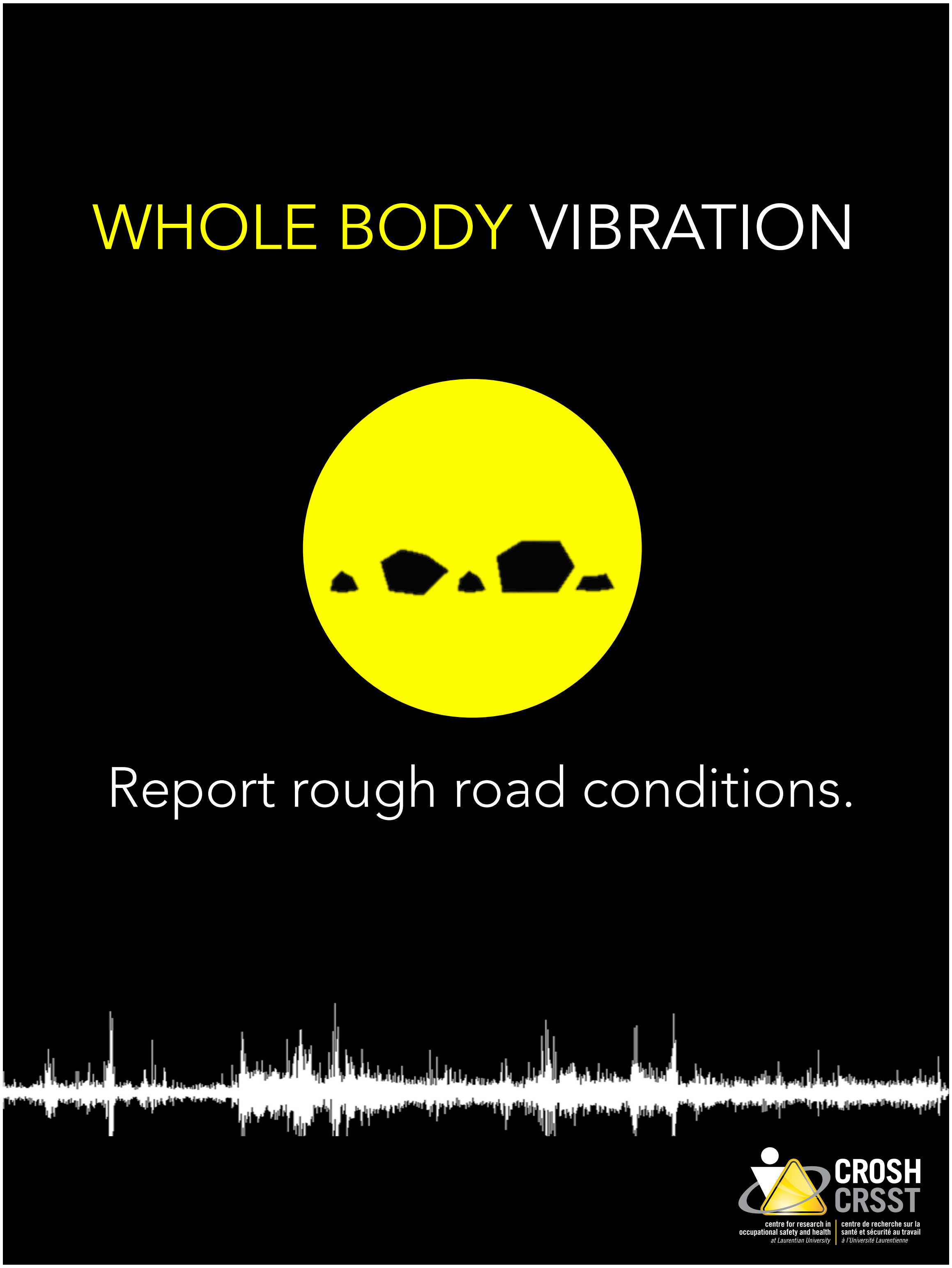
Whole-Body Vibration (WBV) Content	
Definition provided	
Outlines types of equipment that present a hazard? *e.g., locomotive, haul truck, load haul dump truck, scoop, grader, bull dozer, urban bus*	
Information on health effects? *Include information on types of injuries and symptoms*	
Measurement of WBV? *Discussion of methods*	
Control strategies *Discussion of ways to reduce vibration exposure*	
Prevention *Included? Key points listed*	
Discussion of standards/legislation, reporting, company policies?	

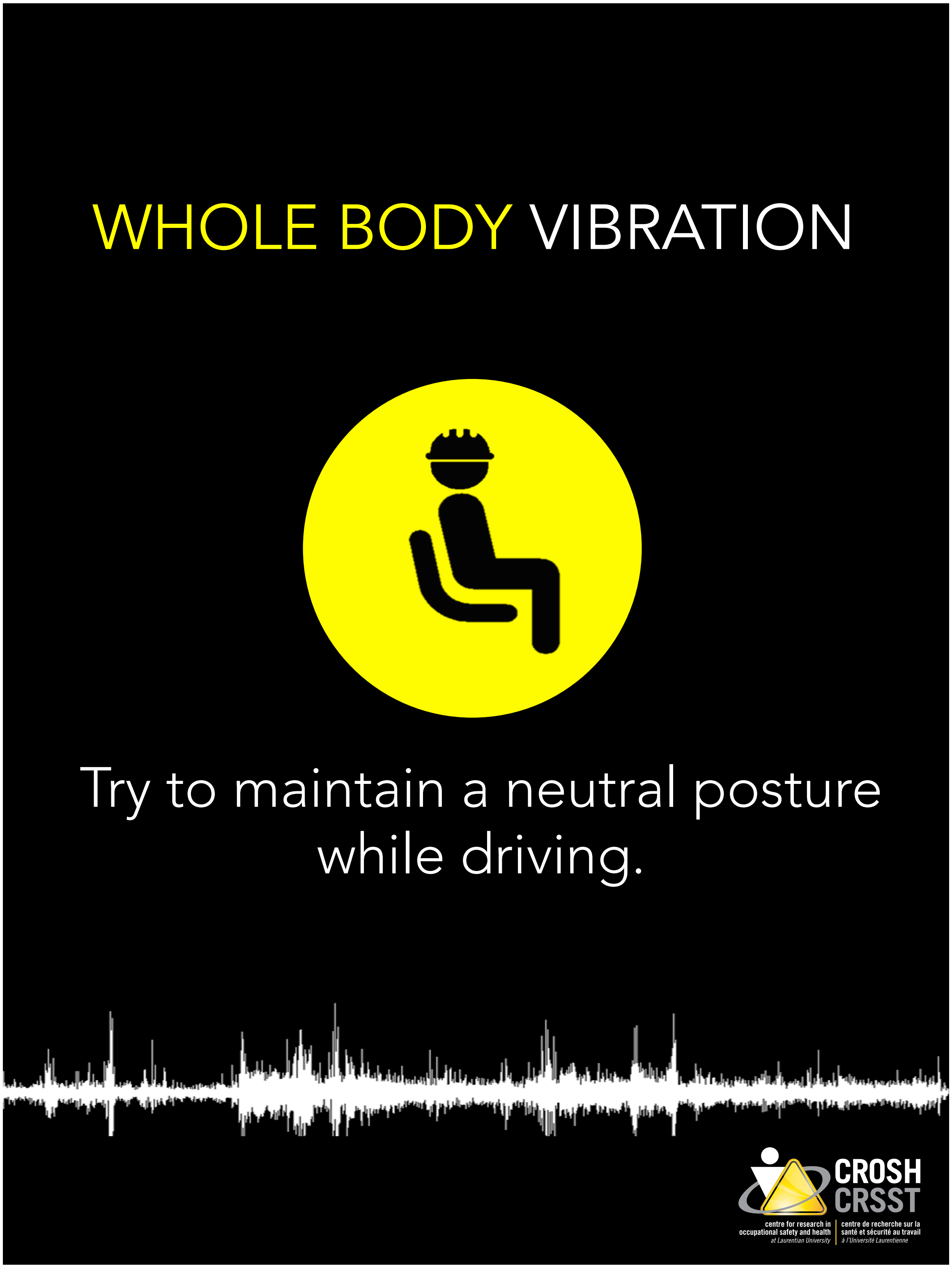
Hand-Arm Vibration (HAV) Content	
Definition provided	
Outlines types of equipment that present a hazard *e.g., jack leg, stoper, construction tools*	
Information on health effects *Include information on types of injuries and symptoms*	
Measurement of HAV *Discussion of methods*	
Control strategies *Include information on the strategies discussed*	
Prevention *Included? Key points listed*	
Discussion of standards/legislation, reporting, company policies?	

Foot-Transmitted Vibration (FTV) Content	
Definition provided	
Outlines types of equipment that present a hazard *e.g., raise platforms, jumbo drill, bolter, scissor lifts*	
Information on health effects *Include information on types of injuries and symptoms*	
Measurement of FTV *Discussion of methods*	
Control strategies *Include information on the strategies discussed*	
Prevention *Included? Key points listed*	
Discussion of standards/legislation, reporting, company policies?	

Summary/Additional Comments	
Overall impression/Additional Comments *Accurate? Updated/Outdated?*	

Appendix 4: Vibration Toolkit WBV posters


WHOLE BODY VIBRATION
Report rough road conditions.
CROSH
CRSST
centre for research in occupational safety and health at Laurentian University
centre de recherche sur la santé et sécurité au travail à l'Université Laurentienne


WHOLE BODY VIBRATION
Try to maintain a neutral posture while driving.
CROSH
CRSST
centre for research in occupational safety and health at Laurentian University
centre de recherche sur la santé et sécurité au travail à l'Université Laurentienne

Appendix 5: Vibration Toolkit HAV posters


HAND ARM VIBRATION
Anti-vibration gloves can help to lower the vibration that you feel.
CROSH
CRSST
centre for research in occupational safety and health at Laurentian University
centre de recherche sur la santé et sécurité au travail à l'Université Laurentienne

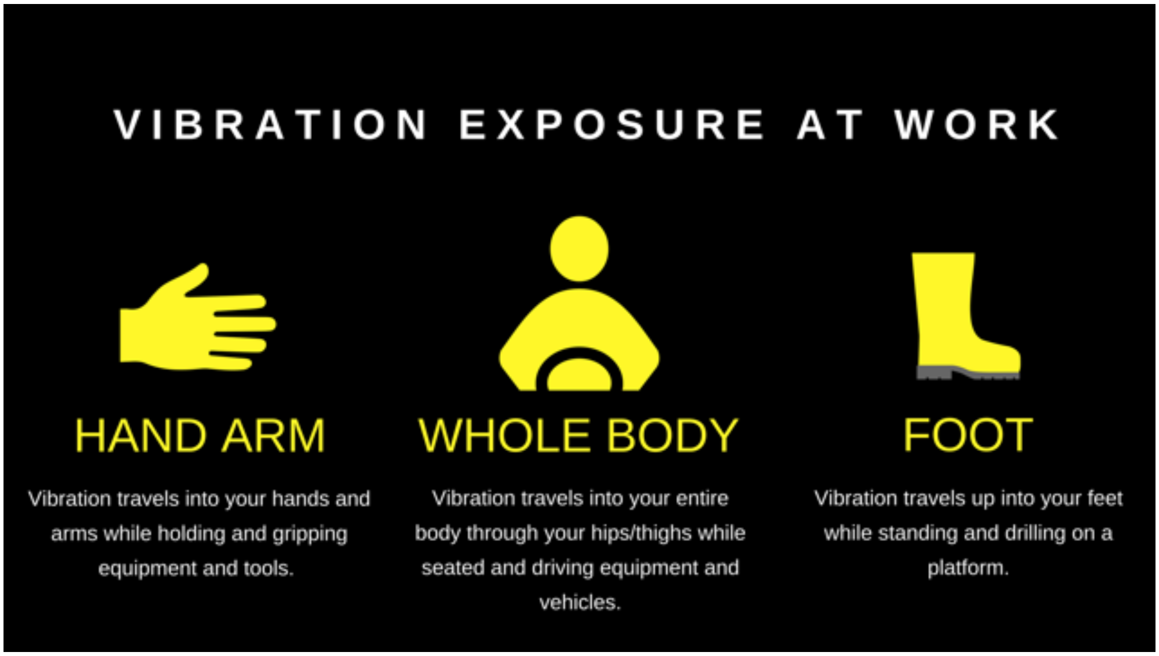

HAND ARM VIBRATION
Wear gloves to keep your hands warm and dry.
CROSH
CRSST
centre for research in occupational safety and health
at Laurentian University
centre de recherche sur la santé et sécurité au travail
à l'Université Laurentienne

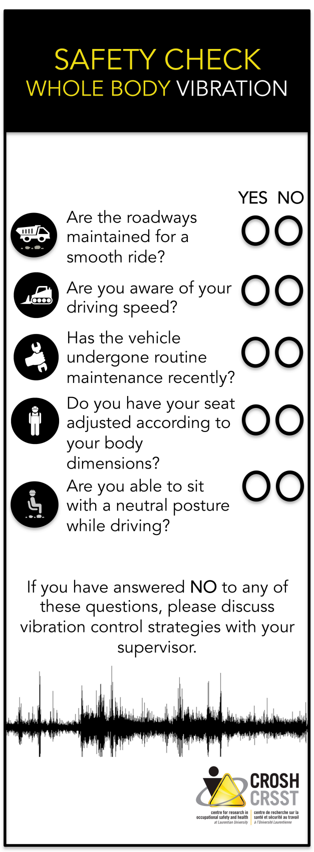
Appendix 6: Vibration Toolkit FTV posters

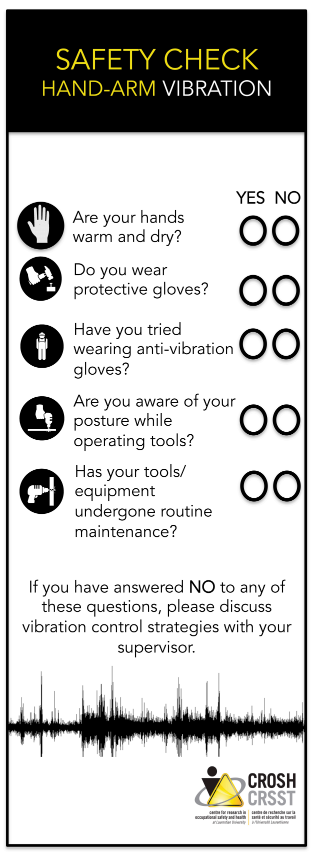

FOOT TRANSMITTED VIBRATION
Tingling and numbness felt in the toes and feet could be a sign of irreversible damage.
CROSH
CRSST
centre for research in occupational safety and health at Laurentian University
centre de recherche sur la santé et sécurité au travail à l'Université Laurentienne

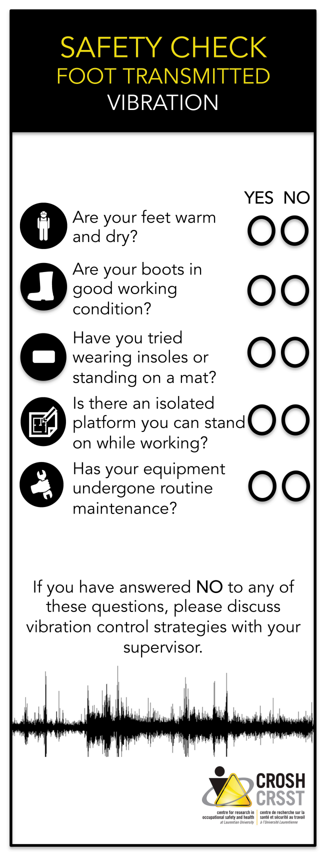

FOOT TRANSMITTED VIBRATION
Standing on a mat or isolated platform can help to lower vibration.
CROSH
CRSST
centre for research in occupational safety and health at Laurentian University
centre de recherche sur la santé et sécurité au travail à l'Université Laurentienne

Appendix 7: Vibration Toolkit Additional Components









DRIVING HEALTHY BACKS

APPLY CONTROL STRATEGIES
FOR VIBRATION REDUCTION

Appendix 8: Vibration Toolkit Survey

SECTION A: KNOWLEDGE, ATTITUDES, AND BEHAVIOURAL BELIEFS

Knowledge

The following questions are designed to see what you know about occupational vibration exposure. Please indicate whether you think something is true or false by circling TRUE or FALSE.

1. Exposure to hand-arm vibration has little health effect on my hands.	TRUE	FALSE
2. My back is able to absorb vibration while driving without any health problems.	TRUE	FALSE
3. Standing all day while drilling off a platform may cause health effects to my feet.	TRUE	FALSE
4. Driving slowly makes the vibration worse.	TRUE	FALSE
5. Regular maintenance of my tools and equipment is not important to the vibration level.	TRUE	FALSE
6. When drilling on a raise platform, I am only exposed to hand-arm vibration.	TRUE	FALSE
7. The conditions of the road or terrain impact how much vibration I am exposed to while driving.	TRUE	FALSE
8. If I feel tingling and numbness in my feet after being exposed to vibration, I should just rest and my feet will heal automatically.	TRUE	FALSE
9. Painful attacks of fingers turning white when exposed to cold or vibration is a symptom of hand-arm vibration syndrome.	TRUE	FALSE
10. In Ontario, there are regulations to limit vibration exposure levels.	TRUE	FALSE
11. The type and quality of tires on the vehicle have an influence on the vibration level.	TRUE	FALSE
12. When driving, the seat can make the vibration worse.	TRUE	FALSE
13. Keeping my hands cold and wet will help to prevent hand-arm vibration syndrome.	TRUE	FALSE
14. There are many effective treatments for hand-arm vibration syndrome and the symptoms can be cured.	TRUE	FALSE
15. My position while I am sitting or standing will impact how the vibration travels through my body.	TRUE	FALSE
16. Gripping the tools harder will reduce the vibration that travels into my hands.	TRUE	FALSE
17. Vibration exposure can be measured using an iPod or iPhone.	TRUE	FALSE
18. Standing on a mat will always reduce my vibration exposure.	TRUE	FALSE
19. Lower back pain is the number one complaint of workers operating/driving vehicles/mobile equipment.	TRUE	FALSE
20. The kind of vibration felt when drilling or driving is the same.	TRUE	FALSE

21. Keeping my feet dry and warm will help to prevent health effects in my feet.	TRUE	FALSE

Attitudes
The following questions are designed to see what you think about vibration and the impact that it has on your body and work. Please circle the number that goes along with the phrase that best describes what you think about each statement.

1 = Completely disagree
2 = Somewhat disagree
3 = Somewhat agree
4 = Completely agree
NA = Not applicable to my regular work tasks

1. I am knowledgeable about how vibration can impact my health.	**1**	**2**	**3**	**4**	**NA**
2. Personal Protective Equipment is more annoying than helpful.	**1**	**2**	**3**	**4**	**NA**
3. My feet are often numb at the end of the day but it is part of the job.	**1**	**2**	**3**	**4**	**NA**
4. Money and getting a pay cheque are more important than my health.	**1**	**2**	**3**	**4**	**NA**
5. Safety meetings are important and provide useful information.	**1**	**2**	**3**	**4**	**NA**
6. The bumps and rough roads/terrain do not cause me much harm.	**1**	**2**	**3**	**4**	**NA**
7. Driving fast is the only way I can drive to get my work completed.	**1**	**2**	**3**	**4**	**NA**
8. Maintenance of tools and equipment is an important part of lowering vibration exposure.	**1**	**2**	**3**	**4**	**NA**
9. Limiting the amount of vibration I experience each shift is something that I sometimes think about.	**1**	**2**	**3**	**4**	**NA**
10. I take breaks each shift no matter what.	**1**	**2**	**3**	**4**	**NA**
11. My co-workers and I sometimes talk about the vibration we feel at work.	**1**	**2**	**3**	**4**	**NA**
12. I try different ways to limit my vibration exposure.	**1**	**2**	**3**	**4**	**NA**
13. There are not many things within my control that I can change to reduce vibration.	**1**	**2**	**3**	**4**	**NA**
14. When I have a choice, I choose tools or equipment based on their vibration levels.	**1**	**2**	**3**	**4**	**NA**
15. I believe that vibration is near the top of hazards that needs to be addressed by health and safety professionals in Northern Ontario industries.	**1**	**2**	**3**	**4**	**NA**
16. Anti-vibration gloves are useful in reducing my vibration exposure.	**1**	**2**	**3**	**4**	**NA**

Behaviour Beliefs

The following questions are asking you about the way you work. You can choose from the following answers and circle the answer that best describes how often you do each statement.

1 = Never
2 = Sometimes
3 = Frequently
4 = Always
NA = Not applicable to my regular work tasks

1. I wear anti-vibration gloves while working with tools or equipment that are vibrating.	1	2	3	4	NA
2. I am comfortable telling someone when the driving conditions are rough.	1	2	3	4	NA
3. I am able to take regular breaks.	1	2	3	4	NA
4. I ask to use equipment and tools that have the lowest vibration levels possible.	1	2	3	4	NA
5. If my equipment has an isolated platform, I try to stand on it while doing my work tasks.	1	2	3	4	NA
6. I adjust my seat if the seat has adjustable features.	1	2	3	4	NA
7. If I am standing for a long time on a vibrating platform or equipment, I stand on a mat.	1	2	3	4	NA
8. I am able to switch my work tasks between doing tasks that expose me to vibration and tasks that do not.	1	2	3	4	NA
9. I make sure that my equipment and tools are in good working order.	1	2	3	4	NA
10. I think about how I drive to have a smoother ride.	1	2	3	4	NA
11. I wear insoles in my boots while performing jobs where I am standing on a raise platform or equipment that is vibrating.	1	2	3	4	NA

<u>SECTION B: WORK AND HEALTH HISTORY</u>
Job and Equipment Operating History

1. What is your current job title?
____

2. How long have you been performing your current job (months or years)?__________________________

3. What types of vehicles/equipment do you operate as part of your **CURRENT** job?

Please select the equipment you operate **CURRENTLY**:	My Estimated **HOURS** per day of exposure:		
☐ Jackleg	0-3 Hours ☐	4-6 Hours ☐	7-12 Hours ☐
☐ Stoper	0-3 Hours ☐	4-6 Hours ☐	7-12 Hours ☐
☐ Jumbo Drill	0-3 Hours ☐	4-6 Hours ☐	7-12 Hours ☐
☐ Bolter	0-3 Hours ☐	4-6 Hours ☐	7-12 Hours ☐
☐ Hand Held Pneumatic Tools	0-3 Hours ☐	4-6 Hours ☐	7-12 Hours ☐
☐ Scooptram/ Underground Load Haul Dump (LHD) Vehicle	0-3 Hours ☐	4-6 Hours ☐	7-12 Hours ☐
☐ Locomotive	0-3 Hours ☐	4-6 Hours ☐	7-12 Hours ☐
☐ Surface Haul Truck	0-3 Hours ☐	4-6 Hours ☐	7-12 Hours ☐
☐ Bulldozer	0-3 Hours ☐	4-6 Hours ☐	7-12 Hours ☐
☐ Grader	0-3 Hours ☐	4-6 Hours ☐	7-12 Hours ☐
☐ Loader	0-3 Hours ☐	4-6 Hours ☐	7-12 Hours ☐
☐ Fork-lift	0-3 Hours ☐	4-6 Hours ☐	7-12 Hours ☐
☐ Pick-up Truck	0-3 Hours ☐	4-6 Hours ☐	7-12 Hours ☐
☐ Other (please list):	0-3 Hours ☐	4-6 Hours ☐	7-12 Hours ☐

4. In your CURRENT job, are you exposed to vibration (check all that apply):

☐ Through your hands while holding/gripping a vibrating tool/equipment

☐ Through your feet when standing on a surface that vibrates (ex. Drilling with a jackleg on a metal platform)

☐ Through your back/buttocks/thighs when seated and operating equipment (ex. Driving an LHD)

5. Have you operated any of the following vehicles/equipment as part of **PREVIOUS** job positions?

6. In your PREVIOUS job, were you exposed to vibration (check all that apply):

Types of Equipment I have operated in a **PREVIOUS** job:	Estimated number of **YEARS** of exposure:	Estimated number of **HOURS** per day of exposure?
☐ Jackleg	0-4 ☐ 5-9 ☐ 10+ ☐	0-3 ☐ 4-6 ☐ 7-12 ☐
☐ Stoper	0-4 ☐ 5-9 ☐ 10+ ☐	0-3 ☐ 4-6 ☐ 7-12 ☐
☐ Jumbo Drill	0-4 ☐ 5-9 ☐ 10+ ☐	0-3 ☐ 4-6 ☐ 7-12 ☐
☐ Bolter	0-4 ☐ 5-9 ☐ 10+ ☐	0-3 ☐ 4-6 ☐ 7-12 ☐
☐ Hand Held Pneumatic Tools	0-4 ☐ 5-9 ☐ 10+ ☐	0-3 ☐ 4-6 ☐ 7-12 ☐
☐ Scooptram/ Underground Load Haul Dump (LHD) Vehicle	0-4 ☐ 5-9 ☐ 10+ ☐	0-3 ☐ 4-6 ☐ 7-12 ☐
☐ Locomotive	0-4 ☐ 5-9 ☐ 10+ ☐	0-3 ☐ 4-6 ☐ 7-12 ☐
☐ Surface Haul Truck	0-4 ☐ 5-9 ☐ 10+ ☐	0-3 ☐ 4-6 ☐ 7-12 ☐
☐ Bulldozer	0-4 ☐ 5-9 ☐ 10+ ☐	0-3 ☐ 4-6 ☐ 7-12 ☐
☐ Grader	0-4 ☐ 5-9 ☐ 10+ ☐	0-3 ☐ 4-6 ☐ 7-12 ☐
☐ Loader	0-4 ☐ 5-9 ☐ 10+ ☐	0-3 ☐ 4-6 ☐ 7-12 ☐
☐ Fork-lift	0-4 ☐ 5-9 ☐ 10+ ☐	0-3 ☐ 4-6 ☐ 7-12 ☐
☐ Pick-up Truck	0-4 ☐ 5-9 ☐ 10+ ☐	0-3 ☐ 4-6 ☐ 7-12 ☐
☐ Other (please list):	0-4 ☐ 5-9 ☐ 10+ ☐	0-3 ☐ 4-6 ☐ 7-12 ☐

☐ Through your hands while holding/gripping a vibrating tool/equipment

☐ Through your feet when standing on a surface that vibrates (ex. Drilling with a jackleg on a metal platform)

☐ Through your back/buttocks/thighs when seated and operating equipment (ex. Driving an LHD)

7. What is your current age? ____

8. What is your estimated current weight? (lbs)__________________________

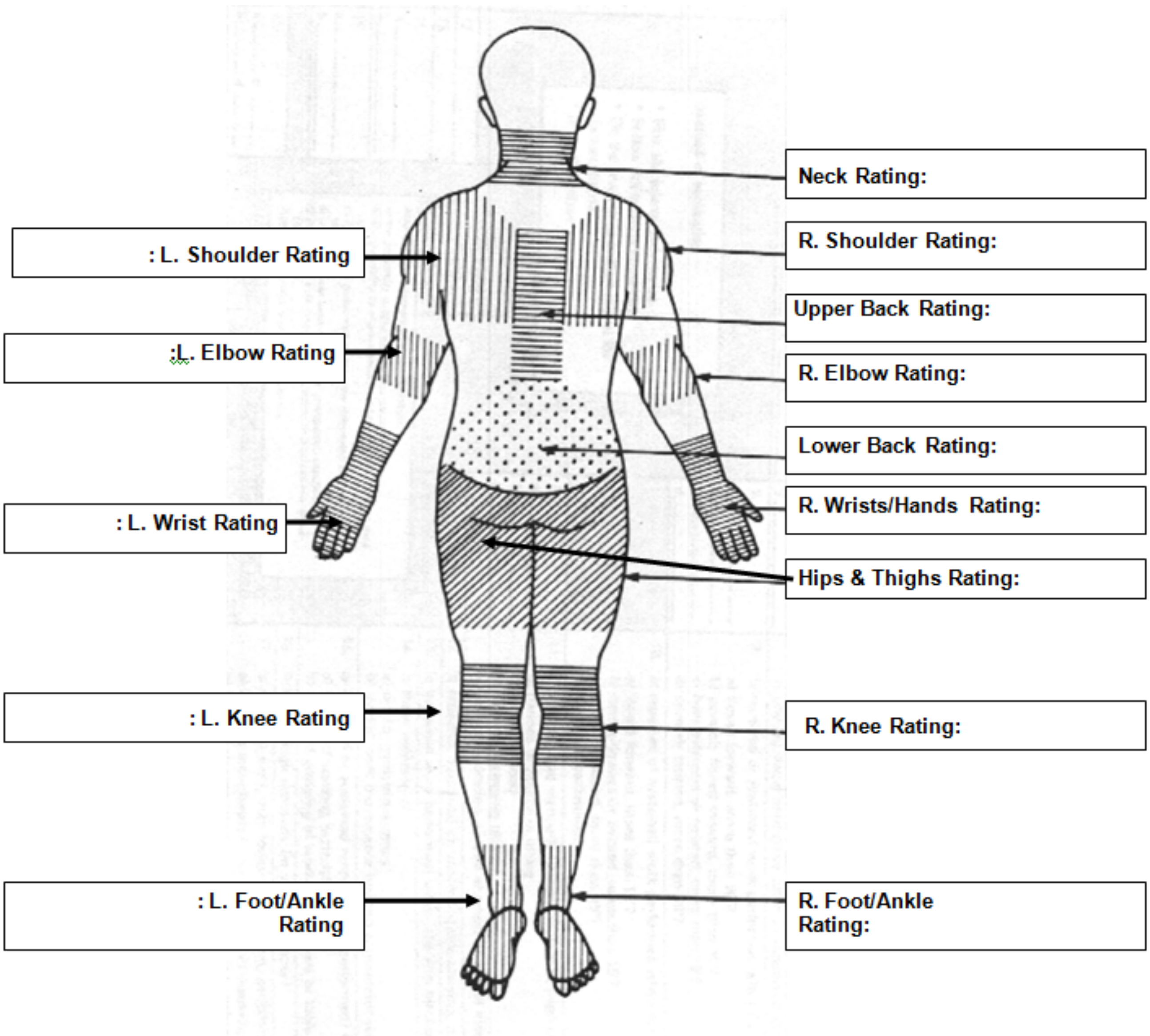
9. What is your estimated current height? (feet/inches)___________________

10. Gender: ______________________

Musculoskeletal Discomfort
The body has been divided into fourteen different regions (right). For each body region please indicate if you have had any trouble (**ache, pain, numbness or discomfort**) in the region in the **last 6 months**. If you have had trouble in the area in the last 6 months rate the severity of the trouble, at the worst episode that you felt.

Rating Score

1 = mild ache, pain, numbness or discomfort
2 = moderate ache, pain, numbness or discomfort
3 = severe ache, pain, numbness or discomfort
4 = very, very severe ache, pain, numbness or discomfort



Thank you for participating!

Appendix 9: Photos from on site during implementation and evaluation

Figure 3: Safety meeting presentation area

Figure 4: Safety meeting seating area

Figure 5: Safety meeting overall space

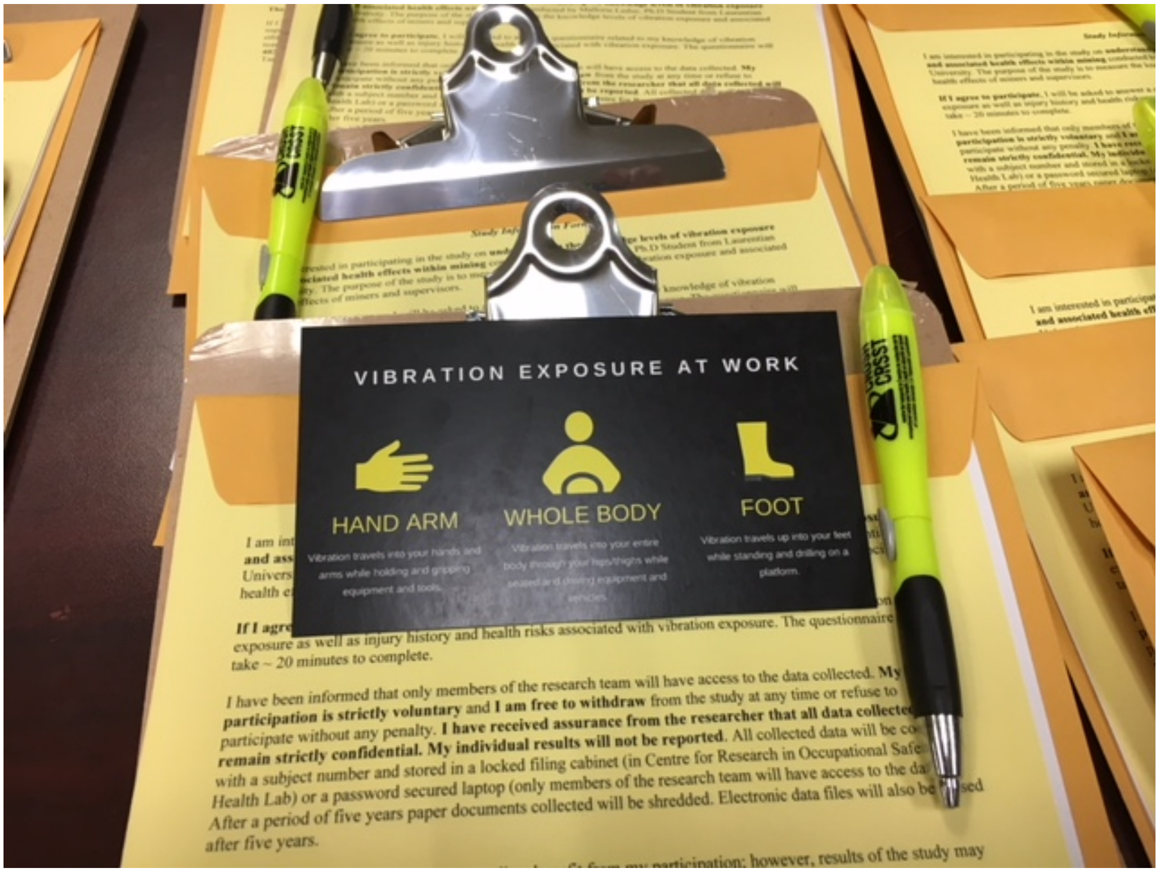


Figure 6: Participant packages and information cards

Figure 7: Participant survey packages and consent forms

Figure 8: Personal protective equipment set-up

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